Recurrent Communities of Practice (RCoPs) and Transient Core Members (TCMs)

Temporal Behaviour of Co-located and On-line Communities of Practice

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Abstract

Knowledge is a powerful tool, especially within companies and institutions. It has long been recognised that much of the knowledge of a company is embedded in the skills and practices of individuals and groups of individuals that share common interests. In some cases, these groupings can cross traditional organizational boundaries. These communities, known as *Communities of Practice (CoPs)*, have a significant potential for companies and institutions.

Although studied for years now, Communities of Practice are still poorly understood. Specifically, there has been little research into the dynamic, temporal aspects of how communities form, their patterns of activity and how they cease to exist. Such understanding is crucial for the successful use of CoPs within companies and institutions. Therefore, this thesis looks at the temporal aspects of Communities of Practice (CoPs). This is carried out by studying a co-located CoP, and four CoPs located within electronic networks.

The study led to a rediscovery of the already known concept of CoPs' *core members*, which refers to the members with strong participation in the community's life. This work also identified two completely novel aspects related to the temporal aspects of Communities of Practice.

The first one was called *Recurrent Communities of Practice (RCoPs)*. This refers to a new class of CoPs found inside the studied co-located Community of Practice (CoP). Recurrent CoPs are Communities of Practice that work over a specific period of time, ceasing their activity until a trigger starts a new period, repeating these two states over time. The Recurrent CoPs usually have the same participants in different periods of activity.

The second new concept was named *Transient Core Members (TCMs)*. This refers to a community's isolated members that do not engage in the community's activity constantly, but rather in "bursts" over time, similarly to RCoPs.

It is hoped that the procedures and methods explained in this work might help the development for new tools for researchers and professionals to detect and nurture Communities of Practice (CoPs) and Recurrent Communities of Practice (RCoPs). Specifically, the research expands our understanding of the temporal aspects of Communities of Practice, seldom discussed previously in the area.

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For Ricardo, my son

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Declaration

I declare that the work presented in this thesis is my own.

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1. Introduction

1.1. Motivation

In normal circumstances companies and institutions need to find efficient ways of working and producing services or products, but in times of financial downturn, similar to the one that the world is experiencing now, this aim becomes more difficult. One possible way to achieve this goal is to make use of the existing internal knowledge that every company or institution has. Successful companies and institutions are investing a significant amount of resources into mastering their internal knowledge. In some cases, even the concept of 'internal' has evolved to encompass frequent external partners and virtual communities.

Communities of Practice (CoPs) (Brown & Duguid, 1991; Lave & Wenger, 1991; Wenger, 1998b; Wenger et al., 2002) can help with the management of this knowledge, and/or with the groups that contains the knowledge. Wenger, who defined CoPs in 1991, summarises them as follows:

> "Communities of Practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis." (Wenger et al., 2002, p. 4)

This idea has been extensively studied over recent years, and it has already proved worthwhile, motivating investments of some of the most important companies in the world. Several cases can be found in the literature that attest to the value of CoPs for enterprises (Gongla & Rizzuto, 2001; Pemberton-Billing et al., 2003). A niche in the market was even created to help enterprises to make use of Communities of Practice (Vann & Bowker, 2001).

One interesting fact about the use of Communities of Practice is that as they are voluntary and driven by passion; it is not possible to force them upon employees or members of other groups. They only exist if they are nurtured gently enough not to disturb their own life. It is only possible to *help* the creation and functioning of them; it is not possible to *decide* for the creation of one (Roberts, 2006, p. 625).

This creates a fascinating scenario. When a Community of Practice is successfully established within a company and/or institution, it usually leads to a situation where both sides, the organisation and the employees, become satisfied with the arrangements. The company enjoys the benefits from a strong community working passionately on something the company needs, and the CoP's members enjoy the pleasure of doing something they really care about and within their workplace, as part of their workload.

However, some problems can appear in such arrangements. Sometimes a Community of Practice, similarly to a living being, changes and this can lead to its disappearance (Gongla & Rizzuto, 2004). Additionally, previous experiences have already demonstrated that attempts to control them can have negative effects in the communities, sometimes leading to their demise (Thompson, 2005).

Nevertheless, the benefits outnumber the risks, as internal knowledge is a powerful tool within organisations and it is through it that all successful outcomes are possible. Well-used knowledge can bring benefits not only to the organisations, but also to the workers, when it is used as a way of learning and motivation. Ultimately, employees will feel more valued and stimulated if they can see that they are contributing to the success of the enterprise.

Another advantage of the use of knowledge management in companies is to overcome the fear of the loss of expertise when an employee leaves the company, making the dissemination and management of such knowledge a crucial task.

Interestingly, the concept of Community of Practice has evolved to include the ubiquity of electronic networks (Kimble & Hildreth, 2005; Kimble et al., 2001). However, if the idea of finding CoPs in co-located workplaces is already complex, attempting to do so in modern environments with electronic networks available is even harder.

1.2. Research questions

Communities of Practice play an important role in the success of companies and institutions. However, knowing how to use their potential in a practical way is an arduous task, and before using such potential, it is necessary to understand how the communities function.

As will be discussed, several studies have already been carried out to try to reach this understanding. Much knowledge has been acquired, but much more is still hidden. There are still several unanswered questions. In particular, whilst companies are very interested in nurturing Communities of Practice, it is not clear what the temporal nature of these communities is. How do they come and how do they go? The research question asked here is, therefore, *what is the dynamic or temporal aspect of Communities of Practice?* In particular, *how do individuals dynamically engage with Communities of Practice? What is the sense of continuity throughout?* To date this approach has not been taken, and this thesis sets out to address this.

1.3. Research approach

The research looked at two different types of Communities of Practice: co-located Communities of Practice and electronic Communities of Practice (also known as *Virtual Communities of Practice* (*VCoPs*)). The aim was to study the different natures of engagement in these diverse settings. To address these two distinct forums, the research took a multi-method approach, using several case studies.

The first study (chapter 4) took place in the Higher Education Academy Psychology Network (*Psychology Network*, for short), using a questionnaire based on Wenger's work (Wenger, 1998b) to verify whether it could confirm the nature of a Community of Practice. The results confirmed the suspicions that the Psychology Network followed Wenger's definition of a Community of Practice. With this positive answer, the natural step was to carry out a deeper analysis in order to learn more about its functioning and behaviour. This was the objective of the next study.

The second study (chapter 5) was therefore interested in the dynamic nature of the CoP discovered in the Psychology Network. A series of interview studies was carried out to understand how the nature of engagement worked in the community. The data collected from the interviews was analysed using Grounded Theory (Corbin & Strauss, 2008; Strauss & Corbin, 1998). This study discovered what was named *Recurrent Communities of Practice (RCoPs)* within the Psychology Network. These are smaller CoPs that present a recurrence in their pattern of activities over time and were found within one or more larger Communities of Practice.

The last study had two main objectives: first, to understand the temporal aspects of Virtual Communities of Practice, and second to investigate the existence of Recurrent CoPs within Virtual CoPs. To achieve these the messages exchanged for a period of a year in four specialised newsgroups were analysed using matrices and Cluster Analysis (see chapters 6 and 7).

Using a combination of Social Network Analysis and sociomatrices (see chapter 8) it was possible not only to address the two objectives, but also to verify the existence of a different type of dynamic activity within the newsgroups, driven by specific members. These members were named *Transient Core Members (TCMs)*. They appeared to be crucial to the existence of the community.

1.4. Findings

At the end of this study it was possible to begin answering the main questions that were set out as the objectives for this work, and it was also possible to discover aspects never detected before in Communities of Practice. These aspects showed the existence of what was named *Recurrent Communities of Practice (RCoPs)* and *Transient Core Members (TCM)*.

The new type of Community of Practice discovered, named *Recurrent CoP*, or *RCoP* for short, was located through studies in a workplace. The initial studies showed first the existence of a Community of Practice, in the form of a Community described by Wenger (1998b). Later studies showed that in fact several smaller Communities of Practice existed in the same place. These CoPs were slightly different from the main Community discovered in the previous study. They were not present all the time, but rather they were only active when necessary. However, these CoPs always returned to activity in non-regular cycles. These special CoPs received the name 'Recurrent Communities of Practice' because of their cyclical behaviour. The natural step forward was to search for similar CoPs in an electronic environment.

For this an analysis of a year of exchange of communications in four CoPs was made, showing how the cycles of communication occur in a CoP, week by week. It was noticed that the communications occur in bursts, but are not regular among all community members, as some members are more active than others. Moreover, it was clear that two type of members are crucial for the existence of the community. These are the already known 'core members' (Gongla & Rizzuto, 2001; Wenger, 1998a,b; Wenger et al., 2002), who are the main powerhouse for the community's life, and the newly-discovered *Transient Core Members (TCMs)*. The latter act as a core member, but not on a regular basis like the common core members. Instead they support the community's activity, participating in discussions that are important for each TCM individually. However, when seen as a whole their importance is evident as they give the same level of support as the core members.

2. Literature Review

2.1. Introduction

Companies are aware of the importance that knowledge has for their functioning. This is seen not as an extra aspect that can improve their functioning, but rather it is seen as something crucial for their own survival.

Years ago experts started to sell the idea that this knowledge could be captured, kept and managed, in the same way as any object that a company possessed. Moreover, solutions of this sort were sold purely based on Information and Communications Technology (ICT) as a way to achieve that goal (Davenport & Prusak, 2000; Scarbrough, 2003). However, these solutions were rarely as effective as claimed.

Today it is understood that this important knowledge resides in the minds of the people working in the organisations, specifically it exists within informal social communities, which sometimes are not even visible. Moreover, these communities are seen nowadays as part of a complex system. The idea that they can be managed with technology alone is no longer acceptable (Scarbrough, 2003; Thompson & Walsham, 2004). Some authors already started to warn about this as long ago as 1999. For instance, Sarvary stated that "*[t]here is much more to knowledge management than technology alone. Knowledge management is a business process.*" (Sarvary, 1999). McDermott also expressed this view, stating that knowledge sharing is not achieved by "*building a large electronic library, but by connecting people, to allow them to think together*" (McDermott, 1999, p. 103).

This chapter introduces the main concepts necessary to analyse the research. The discussion begins with the work of Nonaka and his model of knowledge transfer, called the SECI model. From this point, a bridge is created between Nonaka's work and Wenger's concept of Communities of Practice, and this is followed by an introduction to the idea of Virtual Communities of Practice. Next, Wenger's indicators of the formation of a CoP are analysed, as these indicators were used in two case studies to help locate CoPs in a workplace. Finally, the issue of temporal aspects in Communities of Practice is discussed, as time seems important for the normal functioning of CoPs, but is not strongly represented in the research literature.

2.2. Tacit Knowledge and Explicit Knowledge

The knowledge that companies and institutions are interested in preserving and managing can be divided into two types: *explicit knowledge* and *tacit knowledge*. These were first presented by Polanyi (1958; 1961; 1962; 1966; 1967) and were introduced into Knowledge Management (KM) in the early 1990's by Nonaka (1991), who situated them in the work environment; however, it is easy to perceive that they exist everywhere, as these concepts are common to the human mind.

The first type, *explicit knowledge*, is the most widely known and refers to the knowledge that can be made available by a medium (writing, audio or video) and that can also be relatively easy to acquire, save and retrieve. Companies and institutions already have tools used to manage it. Examples of explicit knowledge are books, DVDs, manuals, tapes, CDs, etc.

The second type, *tacit knowledge*, refers to the knowledge that even if one wished to pass it on, it would be impossible. A good example of this is trying to teach a person how to ride a bicycle with the use of writing only[1]; one cannot learn balance through words, it must be experienced.

Researchers and professionals involved with KM have already analysed Polanyi's theory in detail, paying particular attention to the concept of tacit knowledge. This has been analysed and discussed in depth (Gourlay, 2002, 2003, 2004, 2006; Jorna, 1998; Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995), mainly in regard to its influence in innovation and Knowledge Management (Howells & Roberts, 2000; Howells, 2002). However, the subject also has its controversies. Gourlay (2002; 2004), for example, points out that some authors (von Krogh and Roos (1995); Nonaka (1995); Choo (1998); Aadne et al. (1996), among others) disagree about the extent of tacit knowledge (e.g., *does it exist only in individuals, in groups or in both*?). Similar arguments exist concerning the possibility of tacit knowledge being made explicit (Gourlay, 2002, 2003, 2006). Nevertheless, despite these debates, the concept of tacit knowledge is well-accepted in the scientific and KM communities, making it safe to assume that it can be learned from a person (at least partially), saved for future consultation and used afterwards (Gourlay, 2002). The benefits that the management of tacit knowledge might bring to organisations are enough to con-

[1] Polanyi has a very interesting discussion about riding a bicycle in (Polanyi, 1958).

vince companies around the world to invest substantial effort and resources into managing the knowledge available in their experts.

2.3. Knowledge transfer

Knowledge (explicit or tacit) is important for companies and institutions as it allows them to manage their expertise and improve themselves, creating new opportunities and enhancements in several areas. Moreover, this knowledge can lead to the development of new ideas, products and/or services (Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995; Nonaka et al., 1996). All this potential can be developed by the use of *Knowledge Transfer*.

It is possible to find several publications where knowledge transfer is analysed from various different points of view. Roberts (2000), for instance, discusses whether Information and Communication Technologies (ICTs) make the transfer of knowledge better, specifically in the case of the transference of tacit knowledge. The author corroborates what was commented on section 2.1 (Introduction), highlighting the inadequacies of ICTs for the transfer of tacit knowledge, and calling attention to the importance of human interaction for this task.

Another example is the work by Bechky (2003), who analysed the difficulties in communication that occur among different Communities of Practice (called "occupational communities" by the author), through the study of working groups in a company from Silicon Valley. The author discovered that despite those difficulties in communication, the CoPs found common ground to allow the effective transfer of knowledge.

The possibilities of addressing the issue of knowledge transfer are endless. However, in the case of this thesis, the scope of the literature review in relation to it will be restricted. Even without foreseeing all the possible implications of such a task (psychological, cognitive, social, etc.), this work assumes that knowledge transfer can be produced using the method explained by Nonaka (Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995; Nonaka et al., 1996), called the SECI model[2], and uses this as a foundation to explain how knowledge transfer occurs in social communities. The model is discussed in the following section.

[2]Nonaka's model was first called the SACI model, where the "A" stands for Articulation (Nonaka, 1991). The model's name changed to the SECI model in 1994, when the phase was renamed *Externalization* (Nonaka, 1994)

2.4. The SECI model

Nonaka first presented the SECI model in 1991 (Nonaka). It was based on the concept of apprenticeship, and explained how the tacit knowledge of an expert could be transferred to an apprentice through a process in four phases, with each one representing a unique type of movement between tacit and explicit knowledge. Nonaka called these phases *modes of Knowledge Conversion* and the model, the *Spiral of Knowledge* (Nonaka, 1994, p. 18) or *Knowledge Spiral* (Nonaka et al., 1996, p. 209).

The four phases are explained as follows.

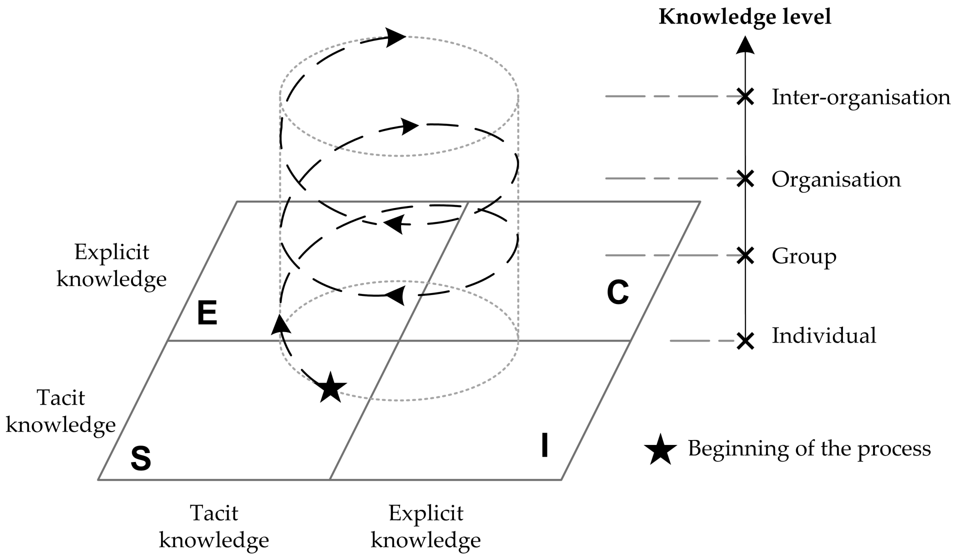


Figure 2.1.: The SECI model

[S]ocialisation This phase represents the transfer from tacit knowledge to tacit knowledge. Here the apprentice acquires the tacit knowledge that the expert has. Nonaka says that in this phase the person is “socialized” into the craft (Nonaka, 1991, p. 99). A subtle idea is included in this phase: that the complexity or variety found in different tasks and their different influences in the process of transfer is ignored.

[E]xternalisation This phase corresponds to the move from tacit knowledge to explicit knowledge. Here the new expert explicitly transfers the previous tacit knowledge to comprehensible forms that are easier to understand. The main characteristic of this phase is that the tacit knowledge is externalized, becoming available for others. This phase can be accomplished with the help of conventional media (writing, audio, video, programs, etc.) or through speech or dialogue. Again, there is a subtle assumption in this phase: that the knowledge involved in the move is sufficient to be classified as relevant and that all necessary tacit knowledge can be transferred and made explicit.

[C]ombination Here the move from one explicit knowledge to another explicit knowledge is represented. This phase corresponds to the moment when the tacit knowledge (now available as explicit) is combined with other explicit knowledge, individually (Nonaka, 1991, p. 99) or collectively (Nonaka, 1994, p. 19). Once again, an assumption is necessary in this phase: that what is studied is only explicit knowledge. This is relevant in the sense that the idea behind the SECI model was to transfer tacit knowledge, not explicit knowledge (Gourlay, 2006).

[I]nternalisation This phase corresponds to the move from explicit to tacit knowledge. Here the explicit knowledge available mainly through media is used to acquire tacit knowledge, although some explicit knowledge could be embodied in action and practice. Although Nonaka argues that internalization is similar to learning (Nonaka, 1994, p. 19; Nonaka et al., 1996, p. 208), there is a risk of this statement appearing to be an oversimplified approach to a much more complex concept. To be accurate one should consider all the ideas, concepts and discussions on learning, which is not feasible in this work.

The SECI model gives an account of how knowledge transfer happens in organisations at several different levels of grouping. Looking at figure 2.1 (on page 26) it is possible to notice that the process of knowledge transfer moves in a spiral ("the spiral of knowledge"), and that the four phases are repeated at different levels. First, it occurs as described above at an individual level, moving to a group level after the individual has shared the new ideas/concepts with a team or group. Later these ideas are divulged inside the company/institution, moving the knowledge to an organisational level. Next, the knowledge can be divulged between organisations in different places, reaching the inter-organisational level. The movement might even go further to different layers.

2.5. Knowledge Management (KM) and Communities of Practice (CoPs)

Due to the problems with the previous attempts at managing knowledge inside organisations using only ICT, experts were obliged to rethink their approaches. Several alternatives appeared, one of them being the use of the management of tacit knowledge, via models of the creation and distribution of knowledge based on practice (Roberts, 2009). In this scenario Communities of Practice (Brown & Duguid, 1991; Wenger, 1998b; Wenger et al., 2002) are recognised by their role as facilitators of knowledge creation and transfer (Roberts, 2009). This approach has great plausibility since authors like Nonaka (as discussed in the next section) and McDermott corroborate it; McDermott, for example, stated that "*Knowledge belongs to 'communities'*", and that knowledge circulates via communities of professionals (McDermott, 1999, p. 108). This shows how CoPs started to have their importance recognised by the experts in the field of KM; thus, it is necessary to understand how Knowledge Management and Communities of Practice can be linked. This is accomplished in the next section.

2.5.1. Communities of Interaction and Communities of Practice

In 1994, Nonaka defined an important concept in his work: *Communities of Interaction*. Although without outlining them precisely, he explained how important they are for accomplishing knowledge transfer successfully (Nonaka, 1994, p. 15). He also traced a relation between *Communities of Interaction* and *Communities of Practice* (Wenger, 1998b) via an analysis of the work of Brown and Duguid (1991) (Nonaka, 1994, p. 23).

Although Communities of Practice are only explained in the next section, it is possible to discuss the relation between CoPs and Communities of Interaction in Nonaka's work. To understand Nonaka's arguments better, it is important to see the parts of his work where these points appear:

> "Although ideas are formed in the minds of individuals, interaction between individuals typically plays a critical role in developing these ideas. That is to say, 'communities of interaction' contribute to the amplification and development of new knowledge. While these communities might span departmental or indeed organizational boundaries, the point to note is that they define a further dimension to organizational knowledge creation, which is associated with the extent of social

> interaction between individuals that share and develop knowledge." (Nonaka, 1994, p. 15)

> "The significance of links between individuals that span boundaries, both within and outside the organization, has been highlighted by Brown and Duguid's (1991) revealing insight into the operation of 'evolving communities of practice'. [...] The exchange and development of information within these evolving communities facilitate knowledge creation by linking the routine dimensions of day-to-day work to active learning and innovation." (Nonaka, 1994, pp. 23–24)

> "By contrast with conceptions of groups as bounded entities within an organization, evolving communities of practice are 'more fluid and interpenetrative than bounded, often crossing the restrictive boundaries of the organization to incorporate people from outside' (Brown & Duguid, 1991, p. 49). Moreover, these communities can provide important contributions to visions for future development. Thus these communities represent a key dimension to socialization and its input to the overall knowledge creation process." (Nonaka, 1994, p. 24)

Through an analysis of these three excerpts it is possible to draw some conclusions:

- Nonaka acknowledged the importance of social interaction in groups as a means of knowledge creation, and called these groups *Communities of Interaction*.
- He also acknowledged that these groups shared and developed knowledge (similar to the concept of *Shared Knowledge*, found in Communities of Practice, as explained in the next section).
- Nonaka demonstrated awareness of the existence of Communities of Practice, via the work of Brown and Duguid (1991).
- In addition, Nonaka stated that these communities (of Practice and of Interaction) are not limited by physical boundaries, including members from inside and outside organisations.
- He also argued that both Communities of Interaction and Communities of Practice span boundaries in the organisations.

- Finally, Nonaka acknowledged the crucial role that these social groups have in the creation of knowledge used within organisations.

In summary, Nonaka stated that Communities of Interaction amplify and develop new knowledge through social interaction, spanning boundaries. The same happens with Communities of Practice, as is discussed in the next section. Moreover, it is possible to notice that Nonaka acknowledged Communities of Practice as a way of sharing and developing knowledge. It is also possible to observe his emphasis on the characteristics of boundlessness and freedom that Communities (of Practice and Interaction) have. It is possible to argue that Nonaka was extending the concept of Knowledge Creation, via the SECI model, from the individual level to the level of community, as his model already demonstrated that this was possible in the upper layers of the model of knowledge transfer (see figure 2.1, on page 26).

2.6. Communities of Practice (CoPs)

In these days Communities of Practice are seen as an important tool for a Knowledge Management framework, but within a correct perspective, in which they are not another oversimplified solution for a complex problem, but instead they are seen as facilitators of knowledge creation and transfer (Roberts, 2009). However, to understand Communities of Practice it is necessary to know the history of the concept, thus the next section explains how the idea of CoPs was born and discusses the evolution of the term over time.

2.6.1. Historical development

The idea of Communities of Practice was first introduced by Etienne Wenger and Jean Lave in 1991, when they published *Situated Learning: Legitimate Peripheral Participation* (Lave & Wenger, 1991). Using five case studies related to apprenticeship (Yucatec midwives; Vai and Gola tailors; naval quartermasters; meat cutters and nondrinking alcoholics), the authors showed that newcomers learned through observation and social participation. Such learning is informal and occurs naturally when participating jointly with experts in daily activities. Moreover, the process of learning does not happen in a precise and delimited way; rather, it occurs throughout the whole process of (mutual) work. The book introduced the idea that learning is an informal social process, rather than a planned and individual one. In this new model the figure of the apprentice moves from a peripheral position to the centre, where the experts reside, and the learning comes as a consequence of social interaction and observation. For case studies a set of specific communities formed by people who shared common practical work (thus, sharing *practices*) was used. The publication revealed a new realm in education, in which social learning (constructivist) was used, in contrast to the behaviourism in vogue during that period.

Although innovative, the book lacked depth when discussing all the implications the new idea would bring. The main concern was with the learning process and not with the communities where this happened (Kimble, 2006), leaving several questions, such as the ones regarding the power forces within CoPs and the relationships between communities, without proper answers (Cox, 2005). Therefore, it seemed natural that the idea of Communities of Practice needed be explored further, giving an opportunity to Wenger to try to fill the gaps with a new book, released seven years later (Wenger, 1998b).

This first idea (Wenger and Lave's LPP model) is still in use by several experts (Campbell et al., 2009; Handley et al., 2007; Harris et al., 2004) and has been verified empirically in several cases. Harris et al., for instance, studied a case from the 1990s when the Australian police moved its training system from a centralised academy model to a professional development model (Harris et al., 2004). They analysed the consequences of this change upon probationary constables, regarding their acceptance and how they were seen. Another example is from Handley et al., who developed a conceptual framework, based on LPP, which was tested in an empirical study of how management consultants acquire the practices and identities suitable to client-consultant projects (Handley et al., 2007). Yet another example is from Campbell et al., who presented a case study of a newcomer to the practice of policing in Australia, as part of a larger study that examined the learning and development of a group of beginner police officers (Campbell et al., 2009).

One of the first authors to discuss the cognitive processes occurring within workplaces was Orr (1986; 1987; 1990; 1996), who published an ethnographic study of service technicians (reps) from Xerox. The company believed that the technicians had individual behaviour and if it supplied the reps with training and service manuals this would be enough to give them the necessary skills to repair a machine; however, Orr revealed that the technicians had developed an informal community which they relied upon (in addition to the repairing manuals and training). These technicians had informal meetings over breakfast, where they exchanged tips and personal experiences related to the fixing of machines, creating a great shared knowledge that helped them all. Moreover, Orr revealed that among the necessary skills needed to become a good technician it was necessary to learn how to tell good stories to become a member of the community (Murillo, 2011).

Two authors, Brown and Duguid, used the works of Orr (1986; 1987; 1990) as a foundation to argue that *canonical practice* (the practice officially accepted, kept and taught by a company) can put informal Communities of Practice in jeopardy, since these rely on *noncanonical practice* (the practice created, kept and taught by CoPs), forcing them to go further underground (Brown & Duguid, 1991, p. 53). Although their work is appreciated because it showed the importance of CoPs to leading companies, forcing them to rethink old approaches, it also received some criticisms. Cox (2005) argues that they represent an "internally egalitarian" community (Cox, 2005, p. 530), and that "*[t]he result is more than simply a picture of a harmonious collaborative group based on shared meanings which is too romantic.*" (Cox, 2005, p. 530). Contu and Willmott (2003) also criticise Brown and Duguid, arguing that they selected Lave and Wenger's thinking and ideologies, which were compatible with "dominant managerial values" (Contu & Willmott, 2003, p. 284).

Wenger, noticing that his previous book with Lave (Lave & Wenger, 1991) lacked explanation on several points, decided to release a new publication in 1998 to attack these problems (Wenger, 1998b). The book is considered today a milestone in the development of the concept of Communities of Practice. He created a vast and detailed conceptual framework based on a study conducted in an American insurance company, in which the daily work of a group of employees that processed medical claims was studied, leading to the conclusion that they formed of a strong Community of Practice. In the new publication Wenger spent more time and energy defining all the concepts that had only been explained briefly in the previous book, or were assumed not to be necessary (e.g., the concept of Communities of Practice). He perceived the great potential that Communities of Practice possessed and decided to provide the missing foundations. For this Wenger analysed the CoPs in depth, mainly in regard to their cognitive aspects, turning Communities of Practice more predictable, and facilitating their management within companies and institutions.

The main concepts This book introduced significant changes in critical definitions, such as *community*, which is now slightly different from the original concept, being related to a model more associated with companies and institutions, where the participants have focused objectives, in a search for the fulfilment of an enterprise. This change signalled a shift in approach towards companies, which is even more explicit in his book published in 2002. Other authors also noticed the changes in definitions and paradigms in Wenger's second book. Kimble, for example, highlighted how Wenger discarded some concepts (e.g., *LPP*), expanded some (e.g., *identity* and *participation*) and created new ones (e.g., *dualities*) (Kimble, 2006, p. 225). The concept of learning used in the book is defined as occurring through the interaction between four processes: *Practice*, *Community*, *Identity* and *Meaning*, which are fundamental to creating learning through social participation. The definition of Community of Practice is finally outlined with Wenger defining CoPs as "*[...] talking about practice as the source of coherence of a community*" (Wenger, 1998b, pp. 49). Communities of Practice are based on a model of the relationship with three dimensions between practice and community: *mutual engagement*, a *joint enterprise*, and a *shared repertoire* of experiences (Wenger, 1998b, pp. 49, 72–85):

Mutual engagement CoP's members engage in actions whose meaning is negotiated among themselves, which results in the community's practice. Moreover, mutual engagement defines the membership of a CoP and also the community.

Joint Enterprise This is the outcome of the negotiation among the members resulting from mutual engagement. Moreover, the members acquire a sense of shared accountability as a result of the process.

Shared repertoire With the passage of time members create shared resources for negotiating meaning. These resources include stories, words, phrases, tools and concepts, among others, which are produced during the shared quest for a joint enterprise.

The ideas are based on the assumption that, as social beings, we always engage in enterprises with people who share common interests, mutually learning and creating common knowledge as a consequence. To help understand his ideas, Wenger stated clearly that a Community of Practice is not just an aggregate of people that can be defined by a set of characteristics, and that CoPs are not the same as a group, team or network (Wenger, 1998b, p. 74). He also declared that a community's membership "*is not just a matter of social category*" (Wenger, 1998b, p. 74), allegiance, belonging to an organisation, title or personal relations with others, neither is "*geographical proximity sufficient to develop a practice*" (Wenger, 1998b, p. 74), and that a CoP is not defined simply by the flow of information in a network of interpersonal relations (Wenger, 1998b, p. 74). His arguments are valid as they are confirmed by other authors like Andriessen et al. (2001), who discussed in detail the differences between communities, teams and collections. However, his line of reasoning is not accept by all, as authors like Gourlay argues that Wenger "*[...] sees membership of groups as 'a matter of affiliation' in which 'identity is a matter of social categories', but provides neither authority, argument nor evidence to support his conclusion.*" (Gourlay, 1999, p. 7).

Wenger's work of 1998 is still much valued by the majority of the researchers in the area of Knowledge Management/Communities of Practice, being praised by several authors. Schwen and Hara (2003), for instance, considered Wenger's book a "*a rich theoretical description of a fully mature and constructive CoP.*" (Schwen & Hara, 2003, p. 262). Plakoff stated that Wenger's work "*is the most comprehensive theoretical foundation on the subject.*" (Plaskoff, 2003). However, Wenger also received several criticisms (Contu & Willmott, 2003; Cox, 2005; Roberts, 2006). Roberts (2006), for example, stated that "*[...] considerations of power are absent or relegated to footnotes in Wenger's (1998, 2000) later work.*". The statement is grounded on the works of Contu and Wilmott (2000; 2003), as they cite the work of Fox (1999), who states that "In Wenger (1998) 'wider issues of power and conflicts are safely tucked away in the footnotes', as Fox precisely pointed out (1999: 403)." (Contu & Willmott, 2000, p. 271). This criticism is supported not only by Count and Wilmott's publications, but also by the comparison of Wenger's works. He referred several times to the relations of power within CoPs in his work with Lave (Lave & Wenger, 1991), but omitted them in 1998's work and subsequent publications (Contu & Willmott, 2003).

Similarly, Cox (2005) stated that "*It almost becomes difficult to see why Wenger used the term 'community' at all since he denies most of our usual assumptions about it, save to express the strength and the voluntary, informal, authentic nature of the relationships identified.*" (Cox, 2005, p. 532). The argument is discussed in detail in Cox (2005) and it is grounded in the works of Cohen (2002), Brown and Duguid (2001), Contu and Willmott (2003), and others. His line of reasoning refers to the meaning of the term *community* in Wenger's works when compared with different aspects, like its use in different areas (such as sociology) or when seen throughout the history of its use. The rationale is sound and is summarised by a table with a list of the expected use for the term *community* and Wenger's usage for the word (Cox, 2005, p. 532). Cox's criticism is supported not only by the works by the authors listed in his paper, but also by the fact that it is only necessary to compare Wenger's works to verify that he modified several important concepts throughout his publications.

Wenger published another book in 2002 that was more pragmatic than the previous one, this time with McDermott and Snyder (Wenger et al., 2002), which is also considered a seminal work on Communities of Practice. Companies were very eager to learn how to apply the concept of CoP in the work environment, as they have important concerns with the administration of internal knowledge. Even though the term *Knowledge Management* was not clearly used in the book, *"Stewarding" Knowledge* was used instead. Although never explained, it gives the understanding that the CoPs now operate as stewards of the knowledge on behalf of their host organisation (Kimble, 2006). This book is different from the previous one in several respects, as it does not complement or add any new theory or model to the ones already presented in Wenger (1998b). Rather, sometimes a modification is made to the previous theory in order to adapt Communities of Practice to the book's main objective, which is to teach organisations how to employ CoPs to manage and use knowledge within their environments.

The change in the main concepts The change in focus that Communities of Practice went through caused a change in the structural model, Wenger having recovered the concept of learning from the second book (Wenger, 1998b), modified it and used it to explain CoPs. Wenger et al. stated that a CoP is a combination of *"a domain of knowledge, which defines a set of issues; a community of people who care about this domain; and the shared practice that they are developing to be effective in their domain."* (Wenger et al., 2002, p. 27). If this is compared with the definition of learning from 1998 (*"learning as interaction between Practice, Community, Identity and Meaning"*), it is clear that two components appear in both cases and are the same: *community* and *practice*. However, *domain* seems to be a combination of the previous *identity* and *meaning*. This can be demonstrated by the description of *domain* by Wenger, who states that it creates a sense of common identity, and that a well-defined domain legitimates the community through its purpose and value to the members (Wenger et al., 2002, p. 27), leading to the conclusion that the *domain* provides *identity* and *meaning*. The sense of common identity is created by the domain, and the *meaning* comes from the *domain*, as it reflects the community's purpose and values. These changes came to simplify the understanding of Communities of Practice, allowing easier acceptance and use inside organisations. Although not as praised as the book from 1998, this latest book from Wenger was well accepted by some experts and used as an important part of studies involving CoPs (Chen, 2010; Teigland, 2003).

However, the work also has critics. Murillo, for example, reprehends Wenger for causing some conceptual confusions in the literature due to, among other things, the introduction of a simplified model in that work (Murillo, 2011). This argument is well grounded because in addition to the confusion faced by researchers of the area, somebody beginning the studies of Communities of Practice who decides to follow Wenger's works will find himself/herself confused by the changes over time in the main points of the framework that defines CoPs. Similarly to what was previously discussed, it is possible to notice that this criticism is supported by a comparison of CoP's concepts defined by Wenger throughout his works.

Cox also criticised Wenger et al. due to *"a popularization and a simplification but also a commodification of the idea of community of practice"* (Cox, 2005, p. 533), which focuses *"[. . .] on the value of the community of practice as a management tool"* (Cox, 2005, p. 533). He also states that Wenger *"[. . .] abandons the early example of routine office work to refocus on 'innovation' and problem solving potential in large, blue chip, multinational corporations."* (Cox, 2005, p. 534). His arguments support what was previously commented on about the changes in the main concepts of CoPs by Wenger, but Cox also details how deep these changes are and why they have been made by Wenger. His argument is that Wenger deliberately modified those concepts to make CoPs more appealing to institutions and corporations, mainly the large ones. It is not difficult to agree with Cox's reasoning due to the clear modifications imposed by Wenger on CoP's theoretical framework.

Finally, Roberts discussed several problems with the new model proposed by Wenger (2002). For instance, she points out the problems created by the change in the size of what is still considered a (distributed) CoP (Roberts, 2006, p. 630). She argues that large distributed communities can be seen as a collection of communities of practice, and that *"Constellations of practice [. . .] help to incorporate spatially dispersed, virtual, or distributed communities and very large communities."* (Roberts, 2006, p. 631). Roberts also argues that Brown and Duguid (1991) state that only small organisations should be regarded as communities of communities of practice. The proper denomination would be *networks of practice*, a much looser definition. She concludes that *"There is a need to differentiate communities of practice in terms of size and spatial reach as it is not possible to expand all communities beyond certain limits."* (Roberts, 2006, p. 631). This is supported by the results of work by authors like Thompson (2005). Such an argument makes sense when the complexity involved in virtual CoPs, distributed CoPs and especially in virtual and distributed Communities of Practice is considered.

2.6.2. The definition and characteristics of CoPs

Having the history and development of Communities of Practice as a background, it is now possible to indicate which definition is to be used throughout this dissertation, although such a definition is not a definitive one and will be linked with others in this work.

First, it is necessary to explain the reason for such a choice. When they first emerged, Communities of Practice were only a consequence of 'Legitimate Peripheral Participation', but later their importance was perceived, leading to an expansion in several related concepts. Consequently, the third book by Wenger (2002) brought more emphasis on innovation and the creation of knowledge by the communities, although modifying some of the main ideas from the work of 1998, as noted previously; therefore, the definition of CoPs presented in the third book (reproduced below) is the most appropriate for the purpose of this work.

> "Communities of Practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis." (Wenger et al., 2002, p. 4).

This definition outlines which characteristics will be present in any community labelled a 'Community of Practice' in this dissertation. Its components are described as follows (Wenger et al., 2002, p. 27):

- "The *domain* creates common ground and a sense of common identity. A well-defined domain legitimizes the community by affirming its purpose and value to members and other stakeholders. The domain inspires members to contribute and participate, guides their learning, and gives meaning to their actions."

- "The *community* creates the social fabric of learning. A strong community fosters interactions and relationships based on mutual respect and trust. It encourages a willingness to share ideas, expose one's ignorance, ask difficult questions, and listen carefully."

- "The *practice* is a set of frameworks, ideas, tools, information, styles, language, stories, and documents that community members share. Whereas the domain denotes the topic the community focuses on, the practice is the specific knowledge the community develops, shares, and maintains."

It is important to highlight relevant issues regarding the components listed above. The commitment of a community to a 'domain', for example, is critical to the existence of a Community of Practice, otherwise it is just a group of friends (Wenger et al., 2002, p. 30). Since the domain gives identity and meaning (as discussed previously), it creates a sense of responsibility and participation in the community. The domain defines what the community is, making its members always take it into account when interacting among themselves, and also attracting newcomers that identify themselves with it. Moreover, the domain creates the common identity used to interact with the external world. The domain is not static and immutable, as it evolves with the community and always reflects the members' identity. Through the interaction, members are always validating and developing the community's domain, as it reflects its meaning and values.

Similarly, 'community' is critical to the learning that happens in Communities of Practice. One significant aspect of Communities of Practice that Wenger et al. (2002) describe is related to membership: they make it clear that for a Community of Practice to succeed, individual enthusiasm is essential. Regarding this component, it is important to stress that the term *community* here is used as synonymous with 'Social Community'.

Finally, 'practice' defines the core by which a Community of Practice is known, and also defines the common foundation that allows members to work together. Similarly to the other components, 'practice' evolves over time and carries the past (i.e., the knowledge acquired over time), the present (the current knowledge) and the future of the community. The future knowledge will come from the resources available today, which will allow members to deal with new situations, generating new knowledge as a consequence (Wenger et al., 2002, p. 38). Practice is a set of common approaches and standards that creates the foundation for all actions, communications, decisions and responsibilities a community has, i.e., it is a set of socially agreed ways of working on things together. All knowledge (tacit and explicit) that a community has defines its practice (Wenger et al., 2002, p. 38).

In this research the interaction of these three components creates and defines a Community of Practice. Nuances can happen in this model, allowing variations in such communities, but the three elements will always be present to outline a Community of Practice. It is accepted that this model cannot describe a Community of Practice completely and uniquely, because a structure as complex as a CoP has several other important facets, as discussed by Roberts (2006), which cannot be studied here due to limitations in scope and time. Issues such as power, trust, predisposition, size, spatial reach, socio-cultural differences and speed of development are also important to define a Community of Practice precisely. However, for the purposes of this work, the basic three components defined by Wenger suffice to define what can be considered as a CoP.

2.6.3. Important aspects in the concept adopted for CoP

Now that the concepts adopted for Communities of Practice in this work have been stated, it is necessary to clarify some important aspects.

The first one regards the relations between the practical aspects of the case studies and the concept adopted for Communities of Practice. In summary, the question is *how the CoP concept is defined in the thesis in the context of both the co-located and distributed communities studied.* The case studies are described succinctly in chapter 3, and in detail in chapters 4, 5, 6, 7 and 8. The preliminary and second case study (described in chapters 4 and 5, respectively) were conducted in a co-located community (The Higher Education Academy Psychology Network, U.K.). In these cases, the adopted concept (discussed in section 2.6.2, on page 36) was based on the second book of Wenger (1998b) due to the fact that it creates the foundation for a well-studied and accepted concept of Community of Practice. Such a framework represented the studied community correctly, as it was verified later on by the aspects found in the Psychology Network, which reflected the model of CoP described by Wenger.

Regarding the concept of CoP used for the study of the distributed community in chapters 6, 7 and 8, the notion of Community of Practice found in Wenger's second (1998b) and third books (Wenger et al., 2002) was used. This is justified on similar grounds to the previous case: the second book is a well-respected and accepted in-depth analysis of Communities of Practice, and the third book, with McDermott and Snyder (Wenger et al., 2002), presents a broader concept of Community of Practice, considering even cases of distributed CoPs, which can be verified by the inclusion of a specific chapter where distributed CoPs are discussed in detail (Wenger et al., 2002, p. 113). This inclusion was highlighted by such authors as Kimble (2006, p. 230), among others. However, Cox (2005, p. 534) and Roberts (2006, p. 630) doubt that this extension of the concept of CoP can be easily applied to any circumstance. Roberts's questions are mainly related to the influence of the community's size on the concept of (distributed) CoPs, as already discussed in the section entitled "The change in the main concepts", on page 35. In the case of Cox, he argues that "*Increasingly such communities are seen as necessarily virtual*" (Cox, 2005, p. 534) and that "*This and the potential vagueness of the term 'practice' invites one almost to define any workplace virtual group as a community of practice, leading to the term being bleached of meaning.*" (Cox, 2005, p. 534). He also lists the work by Schwen and Hara (2003) that doubt the possibility of a CoP being distributed. Such criticism is not only supported by the works of Schwen and Hara (2003) but also by the knowledge that a great number of publications in the area of CoPs/

KM classify on-line groups as Virtual CoPs, even without testing them against any form of definition.

The second aspect that needs clarification regards the differences between the adopted model of CoP and project teams. Lindkvist calls CoPs "tightly knit" groups that, due to the fact that they have been practising together for a long time, begin to develop a cohesive community with mutual relations and shared understandings (Lindkvist, 2005, p. 1189). This definition is based on the work of Brown and Duguid (1991), who used the definition of Community of Practice from the work of Lave and Wenger (1991). The adopted definition of CoP is based on the work of Wenger et al. (2002), which is an expanded (and slightly modified) version of the previous work by Wenger (1998a). Wenger's publication of 1998 is a detailed account of the initial work with Lave (1991), as previously explained. Therefore, the CoP referred to by Lindkvist can be considered the same as that referred to by Wenger (2002). Lindkvist also calls transient groups a "collectivity-of-practice" (CIP), and defines them as follows:

> "[...] temporary organizations or project groups within firms consist of people, most of whom have not met before, who have to engage in swift socialization and carry out a pre-specified task within set limits as to time and costs. Moreover, they comprise a mix of individuals with highly specialized competences, making it difficult to establish shared understandings or a common knowledge base." (Lindkvist, 2005, p. 1190).

Roberts (2006) uses Lindvist's definition of CIP to refer to temporary groups or project teams that are concerned with knowledge creation and exchange. She states that:

> "While communities of practice depend on shared enterprise, mutual engagement and shared repertoire, collectivities of practice rely on individual knowledge, agency and goal-directed interaction." (Roberts, 2006, p. 633)

Therefore, *project teams* and *Communities of Practice* are fundamentally different. Project teams are temporary and lack the main concepts CoPs have (shared enterprise, mutual engagement and shared repertoire), while Communities of Practice are strong in their identity and domain, with relationships that are meant to be long and durable. Although having members that are recognised as experts (the core of the community), CoPs know that the common knowledge does not rely only on individual expertise, as the community is always learning and evolving.

2.7. Virtual Communities (VCs)

It is essential to be certain that a Virtual Community can be a Community of Practice, as this will help with analysing whether VCoPs can transfer knowledge.

2.7.1. The definition of Virtual Communities

Several different definitions of virtual communities can be found in the literature, sometimes highlighting one approach or area at the expense of others.

It is appropriate to begin with the first definition available, made by Rheingold (1993), as it is believed that he was the first person to coin the term. He defines a virtual community through the union of technology with the human aspect, stating that the virtual community appears when enough people carry on public discussions long enough to form webs of personal relationships (Rheingold, 1993).

Another definition available is the one made by Igbaria (1999), who defines virtual communities through the combination of improvement in telecommunications, which leads to advances in Computer-Mediated Communication (CMC), without forgetting the social and human side. In this scenario virtual communities are similar to face-to-face meetings, but with the help of computers to overcome space and time (Igbaria, 1999).

Yet another definition comes from Roberts (1998). She prefers to base her definition on a more conservative approach: the analogy to geographic communities, using a list of dimensions to define a community, extending the concept to virtual communities afterwards (Roberts, 1998, p. 361):

> The working definition of 'community' [...] contains the following dimensions:
>
> - Cohesion: the sense of there being a group identity and that the respondent belongs to the group.
> - Effectiveness: the impact that the group has on the members' lives and on the outside world.
> - Help: the perceived ability of members to ask for and receive various kinds of help.
> - Relationships: the likelihood of group members interacting individually, including forming friendships.

- Language: the prevalence of specialized language.
- Self-regulation: the ability of the group to police itself.

Even though this last definition is more specific to the functioning of the community, it is still similar in its core to the previous two. It can also be noticed that some elements are common to all these definitions, and that such elements define common aspects of a Virtual Community, as noted by the authors. Considering all this, the working definition of a Virtual Community based on the same common aspects is:

> *A Virtual Community is a type of social community that keeps its participants in contact through the use of Computer-Mediated Communication (CMC).*

Common characteristics of VCoPs

The common parts in all definitions of VCs presented above can be summarised as:

The individual part Words such as *people*, *members* and *human* appear to represent the core of a community: the *participants*. By the use of the word 'participants', it is meant that the person engaged in such a community does not just read messages, or observe conversations, but rather, it means that the person is participating in the community through the exchange of ideas, contribution, and continuous involvement. This does not imply that a person cannot interrupt his or her participation occasionally, but it is assumed that the person will be in regular contact with the community and will contribute to the maintenance and good state of his/her community.

The community part Words such as *communities*, *friendships*, *social aggregation*, *personal relationships*, and *groups* emerge to represent the group of human beings that interact socially, sharing thoughts, opinions, advice, and feelings in a similar way to the real world. This implies the same feelings and attitudes of a community based on face-to-face relationships. It is important, though, to notice that such characteristics are only relevant if the limitations imposed by the medium used for communication are not considered. For example, sometimes one has only text to judge the feelings and intentions in a textual conversation (e.g., e-mail messages), sometimes one only has the audio and/ or video (e.g., VOIP or Video conference).

The communication part Words such as *Net*, *webs*, *telecommunications network*, *computer-mediated communication*, represent the means by which the community can be in contact with the members. This happens on a regular basis through the available communication system, which is not only based on CMC and Internet, but can be expanded by the use of mobile phones and/or other future means of communication. This dissertation, however, is very much centred on the CMC and Internet communication systems. It is accepted, though, that sometimes the participants use more media to keep in contact with the other members.

2.8. Virtual Communities of Practice (VCoPs)

After addressing the issue of common characteristics found in Virtual Communities, it is necessary to define the relationship between the Communities of Practice and Virtual Communities; after all, they are both communities, but what more can be said?

The definition of Virtual Communities of Practice (VCoPs) Due to the historical development, the definition of Virtual Communities of Practice used throughout the text is the same as Distributed Communities of Practice, i.e.:

> The term *Virtual Communities of Practice (VCoPs)* represents not-co-located Communities of Practice that communicate via Computer-Mediated Communication (CMC).

Wenger and Lave (1991) explicitly stated that for learning to happen in Communities of Practice, it is not necessary for the community to be co-located (Lave & Wenger, 1991, p. 98).

In 1998, Wenger did not discuss Communities of Practice in a distributed scenario. However, at the same time, neither did he affirm that CoPs only could take place in co-located situations.

In 2002, however, Wenger et al. explicitly discussed Distributed Communities of Practice, dedicating a full chapter ('The Challenge of Distributed Communities') to this issue (Wenger et al., 2002, p. 113). The authors discussed characteristics and challenges when helping the development of a Distributed CoP, using a case study of the Shell Oil Company as an example. As a result, they listed important points that should be considered when initiating such an enterprise, examining possible difficulties related to the process.

These points illustrate the fact that from the beginning, CoPs were defined as flexible enough to accept not-co-located communities, which implies that the idea of Distributed Communities of Practice is not a change in context, but rather a natural evolution. Distributed communities have a geographical meaning, thus the term *Distributed Communities of Practice* implies that CoPs can be geographically distributed (Daniel et al., 2003).

This issue was examined by Hildreth, Kimble and Wright (1998), in a paper that discussed several aspects of the use of CoP and CMC; by Daniel et al. (2003), who analysed the issues concerning DCoPs; and by Hung and Nichani, who examined the idea of CoPs existing in on-line environments (Hung & Nichani, 2002).

Lueg, however, raised controversial issues regarding the existence of DCoPs (Lueg, 2000, p. 3), stating that Distributed and Virtual are two different concepts when used in the context of CoPs. He argues that although the Community of Practice can be physically distributed, and the communication can be done through electronic media, the learning process still happens in the real world, as the participants are still interacting with it. Such an argument is not very precise, as it refers specifically to the case where practitioners use the DCoP only to share knowledge or to communicate and it does not consider the case where the learning and doing is related to the virtual world (e.g., specific programming languages used to build distributed environments). Maybe this could be explained by the fact that Lueg was referring to the specific case study in Hildreth and Kimble (2000).

Similarly, Hung and Nichani discussed interesting points regarding CoPs that exist on-line, arguing that "*on-line communities should be seen as quasi-communities and not full-fledged CoPs*" (Hung & Nichani, 2002, p. 23). Their point is that "*Communities of Practice (or CoPs) are characterised by tight-knit groups of people who know each other well. They have been working together for some time, and they are bound together by their shared practice and identity*", whereas quasi-communities "*are loose groups of people brought together, and participation is based on specific needs and demands.*" (Hung & Nichani, 2002, p. 25). Again, this argument is built up taking into account specific cases where the community is based on loose connections. Maybe if virtual communities with stronger bonds and goals were analysed, the conclusions might be different.

Considering this discussion on VCoP and DCoP, in this dissertation it is assumed that the arguments are sufficient to justify the existence of CoPs in virtual environments.

2.9. Wenger's indicators that a CoP has formed

In his work of 1998 Wenger listed 14 indicators of the formation of a Community of Practice (Wenger, 1998b, pp. 125–126). This list signals the existence of the three main components of a CoP: *mutual engagement*, a *joint enterprise* and a *shared repertoire* (Wenger, 1998b, p. 126). Murillo reinforces this characteristic, stating that Wenger's empirical indicators can be classified as manifestations of defining dimensions (Murillo, 2011).

1) Sustained mutual relationship – harmonious or conflictual
2) Shared ways of engaging in doing things together
3) Rapid flow of information and propagation of innovation
4) Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process
5) Very quick setup of a problem to be discussed
6) Substantial overlap in participants' descriptions of who belongs
7) Knowing what others know, what they can do, and how they can contribute to an enterprise
8) Mutually defining identities
9) The ability to assess the appropriateness of actions and products
10) Specific tools, representations, and others artifacts
11) Local lore, shared stories, inside jokes, knowing laughter
12) Jargon and shortcuts to communication as well as the ease of producing new ones
13) Certain styles recognised as displaying membership
14) A shared discourse reflecting a certain perspective on the world

Table 2.1.: Indicators that a of community of practice has formed (original) (Wenger, 1998b, pp. 125-126)

At this point some specific points need to be highlighted.

Necessary conditions for the search of CoPs In his work of 2011, Murillo highlighted two important aspects regarding Wenger's list. The first aspect is the argument that the use of Wenger's indicators to verify the existence of the three dimensions of a CoP (mutual engagement, joint enterprise and shared repertoire) and consequently of the existence of CoPs is acceptable, thus allowing the technique to be used in this work (Murillo, 2011). The second aspect is the argument that these three dimensions can be used to operationalise Wenger's model of a Community of Practice (Murillo, 2011).

Interpretation of Wenger's indicators Another important point is that Wenger did not explain the list thoroughly, only describing it via his concept of *Reification* (Wenger, 1998b, p. 125). Therefore, there is no exact definition of what he meant by the choice of terms and wording, nor which component of a CoP the item refers to. Additionally, Wenger did not discard the possibility of a single indicator being linked to more than one dimension, opening up the list to different interpretations, like the one from Boud and Middleton (2003), who used Wenger's list in a case study to analyse how learning happens in workplaces, and who is involved in it. They used Wenger's 14 indicators together with qualitative analysis to check if the examined groups could be considered Communities of Practice under Wenger's definitions (Wenger, 1998b). The paper gave no explanations of how the indicators were interpreted, though, reinforcing the argument that interpretations for Wenger's list in the literature might be based purely in personal choices.

Cox (2005) also analysed some aspects that can be learned from Wenger's list, and stated that Wenger's focus was on identity, and that he particularly "*stresses the importance of trajectories through different levels of participation in a community and the tensions of multi-membership of different communities as a key dilemma for the individual.*" (Cox, 2005, pp. 531–532). Additionally, Cox commented that Wenger's list explored the nature of boundaries between communities, although power was not the central concern (Cox, 2005, p. 532). Interestingly he expressed a set of characteristics of the list that helps to understand the extension of Wenger's list capacity of verification: "*Other likely but not necessary, features are that all participants will interact intensely [with] each other, that they are held accountable by all other members of group, and that much of the repertoire has been invented locally*" (Cox, 2005, p. 532).

Li et al. (2009) also proposed an interpretation for the indicators, and their choice for the links between the dimensions of a CoP and the respective indicators can be seen in table 2.2, on page 47. It can be noticed that several indicators are linked to more than one dimension, as some indicators fit different dimensions. This corroborates what was previously said about the possibility of single indicators being linked to more than one dimension. The authors believed that most of the indicators refer to mutual engagement and shared repertoire, with only two indicators (#2 and #7) that seem to link to joint enterprise (Li et al., 2009). A few indicators are linked to dimensions in similar way to the ones made in this work (as shown in table 2.4), however because the lack of explanation for their choices it is not possible to analyse or compare the reasons for such choices.

Murillo (2011) too proposed his interpretation for the link between Wenger's list and the three main dimensions as shown in table 2.3, on page 48. Similarly to Wenger, he also did not explain the reasons for his choices, which removes any

Dimension	Indicators of a community of practice
Mutual Engagement	1) Sustained mutual relationship – harmonious or conflictual.
Mutual Engagement, Joint Enterprise	2) Shared ways of engaging in doing things together.
Mutual Engagement	3) The rapid flow of information and propagation of innovation.
Mutual Engagement, Shared Repertoire	4) Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process.
Mutual Engagement, Shared Repertoire	5) Very quick setup of a problem to be discussed.
Mutual Engagement	6) Substantial overlap in participants' descriptions of who belongs.
Mutual Engagement, Joint Enterprise, Shared Repertoire	7) Knowing what others know, what they can do, and how they can contribute to an enterprise.
Mutual Engagement	8) Mutually defining identities.
Shared Repertoire	9) The ability to assess the appropriateness of actions and products.
Shared Repertoire	10) Specific tools, representations, and others artifacts.
Shared Repertoire	11) Local lore, shared stories, inside jokes, knowing laughter.
Shared Repertoire, Mutual Engagement	12) Jargon and shortcuts to communication as well as the ease of producing new ones.
Mutual Engagement	13) Certain styles recognised as displaying membership.
Mutual Engagement	14) A shared discourse reflecting a certain perspective on the world.

Table 2.2.: Indicators that a of community of practice has formed (Li et al. interpretation) (Li et al., 2009)

possibility of analysis and discussion about his rationale.

Although these works presented their interpretations regarding Wenger's list of indicators, none of them discussed each item and the reasons for their selections completely and individually. This makes them too incomplete to be used in this research. Using a predefined list of interpretation without knowing the reasons for their creation could mislead the questionnaire, interviews and ultimately the research, therefore it was necessary to define our own list of interpretations based on our personal experience. The list was divided into subgroups corresponding to the three dimensions of a community (mutual engagement, joint enterprise and shared repertoire), similarly to Murillo's and Li et al.'s works (the list is shown in

Dimension	**Indicators of a community of practice**
Mutual Engagement	1) Sustained mutual relationship – harmonious or conflictual.
	2) Shared ways of engaging in doing things together.
	3) The rapid flow of information and propagation of innovation.
	4) Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process.
	5) Very quick setup of a problem to be discussed.
Joint enterprise	6) Substantial overlap in participants' descriptions of who belongs.
	7) Knowing what others know, what they can do, and how they can contribute to an enterprise.
	8) Mutually defining identities.
	9) The ability to assess the appropriateness of actions and products.
Shared repertoire	10) Specific tools, representations, and others artifacts.
	11) Local lore, shared stories, inside jokes, knowing laughter.
	12) Jargon and shortcuts to communication as well as the ease of producing new ones.
	13) Certain styles recognised as displaying membership.
	14) A shared discourse reflecting a certain perspective on the world.

Table 2.3.: Indicators that a of community of practice has formed (Murillo's interpretation) (Murillo, 2011)

table 2.4, on page 49). Although the choices are based on a personal opinion, it must be made clear, though, that all possible caution to avoid misinterpretation was used. The definitions for the three dimensions of a Community of Practice, shown on page 33, were used as a basis for the decisions to link dimensions and indicators. The rationale used to build table 2.4 is as follows.

(1) Sustained mutual relationship – harmonious or conflictual: Mutual Engagement This item is clearly related to mutual engagement, as it is not possible for relationships (harmonious or conflictual) to exist without engagement.

(2) Shared ways of engaging in doing things together: Shared Repertoire Wenger defined repertoire of a community of practice as "*[...] routines, words,*

Dimension	Indicators of a community of practice
Mutual Engagement	1) Sustained mutual relationship – harmonious or conflictual.
Shared Repertoire	2) Shared ways of engaging in doing things together.
Shared Repertoire	3) The rapid flow of information and propagation of innovation.
Joint Enterprise	4) Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process.
Joint Enterprise	5) Very quick setup of a problem to be discussed.
Mutual Engagement	6) Substantial overlap in participants' descriptions of who belongs.
Mutual Engagement	7) Knowing what others know, what they can do, and how they can contribute to an enterprise.
Mutual Engagement	8) Mutually defining identities.
Mutual Engagement	9) The ability to assess the appropriateness of actions and products.
Shared Repertoire	10) Specific tools, representations, and others artifacts.
Shared Repertoire	11) Local lore, shared stories, inside jokes, knowing laughter.
Shared Repertoire	12) Jargon and shortcuts to communication as well as the ease of producing new ones.
Mutual Engagement	13) Certain styles recognised as displaying membership.
Mutual Engagement	14) A shared discourse reflecting a certain perspective on the world.

Table 2.4.: Indicators that a of community of practice has formed (interpretation in this work) (Wenger, 1998b, pp. 125-126)

tools, ways of doing things, stories, gestures, symbols, actions, or concepts that the community has produced or adapted in the course of its existence, and which have become part of its practices." (Wenger, 1998b, p. 83). Therefore, this item is understood as referring to the shared repertoire of a community.

(3) Rapid flow of information and propagation of innovation: Shared Repertoire In this case the rationale was that for information to flow quickly and innovation to be capable of propagation, it is necessary to have both embedded in the shared repertoire. However, one could argue that the flow of information can only happen if there is mutual engagement, or a joint enterprise, what are valid arguments. Due to the fact that only Wenger could give a definitive answer for this question and to the need to run the analysis, it was necessary to assume a position, thus in this work it is assumed that this indicator checks for a shared repertoire based on the argument outlined in the beginning of this item.

(4) Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process: Joint Enterprise When explaining joint enterprise, Wenger stated that "*It is the result of a collective process of negotiation that reflect the full complexity of mutual engagement*" (Wenger, 1998b, p. 77). This helps to select mutual engagement as a linked dimension, which is a reasonable choice, although another dimension can be considered in the same indicator: joint enterprise. This comes from the fact that if members share a joint enterprise they are constantly negotiating actions that reflect that enterprise, thus all conversation involved is just part of an ongoing process. Due to this argument joint enterprise was the dimension chosen for this item.

(5) Very quick setup of a problem to be discussed: Joint Enterprise Once again this indicator can have two interpretations depending of the opinion of the person involved in the choice. At first sight it could be apparent that the only possible dimension is mutual engagement; however, for reasons similar to the ones discussed in indicator (4), it is possible to argue that joint enterprise can also be linked to this indicator, justifying the choice for this item.

(6) Substantial overlap in participants' descriptions of who belongs: Mutual Engagement This indicator also has the possibility of being linked to more than one dimension. It can represent the consequence of a joint enterprise, where members share the same view of their community, hence sharing the same view of the participant's description of who belongs. However, the same can be said of a community that has a mutual engagement, as it would produce the same shared view and opinion, thus making difficult to link this indicator to only one dimension. In this work, however, mutual engagement was chosen as the appropriate dimension.

(7) Knowing what others know, what they can do, and how they can contribute to an enterprise: Mutual Engagement This is yet another case of close similarity between two possible linked dimensions, because either mutual engagement or joint enterprise can be selected as the linked dimension. This is the result of an analysis similar to the ones carried out in some of the previous items, since to be familiar with somebody to a point of knowing what they know, what they can do and how can they contribute to an enterprise requires mutual engagement and/or a joint enterprise, and this can only be reached as consequence of a community that is tightly coherent. In this work, however, the dimension believed to be most suitable for the indicator is the mutual engagement.

(8) Mutually defining identities: Mutual Engagement This indicator is very similar to the previous one, because if somebody is so familiar with a person to the point of being capable of listing all the characteristics named in the previous indicator, certainly they will be capable of defining the other person's identity. Moreover, if this knowledge is reciprocal, one can say that the two persons have (had) a strong mutual engagement and/or a long joint enterprise, and if this rationale is extended to a community, the indicator of being a Community of Practice becomes very strong. For this research the dimension that links better the item is mutual engagement.

(9) The ability to assess the appropriateness of actions and products: Mutual Engagement This indicator requires a familiarity with the community, which is only possible if the member has an inner knowledge of his/her community, which is likely to come from a mutual engagement and/or joint enterprise, including all the complexity inherent in both dimensions. Thus, this item could refer to two dimensions: mutual engagement or joint enterprise. In this work mutual engagement was chosen as the most appropriate linked dimension.

(10) Specific tools, representations, and others artifacts: Shared Repertoire As explained in indicator (2), the shared repertoire includes tools, representations and other artefacts ("*[...] routines, words, tools, ways of doing things, stories, gestures, symbols, actions, or concepts that the community has produced or adapted in the course of its existence, and which have become part of its practices.*" (Wenger, 1998b, p. 83)); therefore, this indicator clearly links to the shared repertoire dimension.

(11) Local lore, shared stories, inside jokes, knowing laughter: Shared Repertoire Again this indicator includes parts of what was described as shared repertoire by Wenger (1998b). One only needs to read the description of a repertoire (see previous indicator) for the relation between this indicator and the dimension of shared repertoire to be clear.

(12) Jargon and shortcuts to communication as well as the ease of producing new ones: Shared Repertoire Perhaps not as clear as the previous two indicators, this item still carries the same characteristics of the previous two: being part of a shared repertoire of stories, words, concepts, symbols, and artefacts of a Community of Practice. Although one could argue that this indicator can be a consequence of a mutual engagement or a joint enterprise, in this work it is believed that shared repertoire better represents its description.

(13) Certain styles recognised as displaying membership: Mutual Engagement Although styles can be included in the content of shared repertoire, in this work it is understood that for recognising these styles as displaying membership it is necessary to have a mutual engagement strong enough, and this can only happen within a Community of Practice, as defined by Wenger (1998b).

(14) A shared discourse reflecting a certain perspective on the world: Mutual Engagement This indicator is yet another that can be linked to two dimensions: mutual engagement and shared repertoire. This is possible because in both cases the members share a common ground that is the result of actions that negotiate meaning in a long term enterprise; thus, it is natural that the members share a perspective on the world, which is reflected by a common discourse.

Although the three dimensions of a CoP are tightly related, *mutual engagement* and *joint enterprise* are even more closely connected; consequently, it is not easy to distinguish when an indicator can be linked to one or to another. In fact, perhaps due to the fact that the processes involved in a CoP are very complex and inter-related, as described by Wenger (1998b), it is not possible to make a clear and undoubted relation between all 14 indicators and one or more of the three dimensions. Therefore, the lack of explanation by Wenger (1998b) might be a natural consequence of the inherent complexity of a Community of Practice. Overall, this means that although Murillo's work (2011) and this thesis try to show a rationale to link the indicators and the dimensions, the result might be no more than a personal interpretation of this issue. However, for the objectives drawn for this research, it suffices to say that Wenger's 14 indicators (1998b) are so well-established and thoroughly analysed to be used in this work as a way of searching and detecting CoPs, as long as this search uses the indicators only as guidance, and the focus is kept on detecting the three dimensions of a Community of Practice. Wenger's indicators were used as foundation for two case studies in this work (see chapter 4 and chapter 5).

2.10. Murillo's research

One of the main objectives in this research was to understand Communities of Practice within electronic networks, and for this it was necessary to use data from communities that were truly CoPs. Although understanding that it is not possible to certify beyond doubt that a community is a CoP, it is possible to test it against the main principles that define a Community of Practice (Wenger, 1998b), and tell if the community has these characteristics. The main problem was that this could require extra time not available in this research, but fortunately, there is a previous study performed by Murillo (Murillo, 2002, 2006, 2008; Murillo-Othon & Spicer, 2007) that did exactly this.

Murillo began his studies of CoPs during his master's degree (Murillo, 2002), in which he ran two Social Network Analyses in messages from a 30-week observation period of five specialised newsgroups (i.e., professional or practitioner-oriented newsgroups) to find Virtual Communities of Practice (VCoPs) analysing member stability and frequency of interaction. The first Social Network Analysis searched for the most *cohesive cliques*[3] and *2-plexes*[4] among the groups. The second SNA determined whether the interaction data observed followed a core-periphery pattern, and found 4 newsgroups among the five studied that fitted the searched behaviour.

Murillo used the experience acquired in his Master's degree to expand and refine the search for VCoPs during his PhD, using the same SNA methods. Still using Wenger's definition of CoPs as the foundation, he searched for Internet-based CoPs in 52 weeks of data from several newsgroups (Murillo, 2006), and was able to find only four communities that could be classified as (Virtual) Communities of Practice, following Wenger's definition. The time component was part of his research, but only as an intrinsic characteristic of the CoP, i.e., time was seen was a single snapshot of the complete studied period. This created an opportunity to use Murillo's data to study the VCoPs regarding their time component, what could be reach by the study of their communication. For this, time was studied as a single snapshot for the whole period, and also as a discrete factor separated in slices, what would help to understand the communities' members' engagement and roles.

2.11. Time component in Communities of Practice

As described previously, one of the main aspects looked at in this research is the time component in CoPs. Unfortunately, this subject is very little discussed in the known literature. The classic literature assumes time as an intrinsic component of Communities of Practice, and only recently have publications started to discuss time in a more detailed way. Some examples of the existing literature discussing time in Communities of Practice to date are summarised in table 2.5, on page 54.

[3] "A *clique* is a subgroup, with at least three members, in which each actor has a tie to every other actor, and the subgroup is not contained within a larger clique (Scott, 2000); i.e., it is a subgroup in which every member is in direct contact with every other member." (Murillo, 2002, p. 34)

[4] "The *k-plex* is an alternative model, patterned on the clique, that relaxes the requirement that every actor be tied to every other actor. In a 2-plex [. . .] one of those ties may be missing (in a 3-plex, 2 ties may be missing, and so on)." (Murillo, 2002, p. 34)

Publication	How time is analysed
Lave and Wenger (1991)	Time is an intrinsic component of a CoP.
Brown and Duguid (1991)	Time is an intrinsic component of a CoP.
Wenger (1998b)	Time is an important component of a CoP, responsible for learning.
Wenger et al. (2002)	Time is an important component of a CoP. If companies want to nurture CoPs, they need to provide this.
Zhou et al. (2007)	Mathematical model to discover CoPs using communication documents created over a period of time.
Gloor (Gloor et al., 2003, 2004; Gloor & Zhao, 2006; Kidane & Gloor, 2007)	Use of tools (mainly SNA) to discover CoPs via analysis of exchanged email messages.
Lervik et al. (2010)	How external temporalities influence learning in CoPs.
Moody et al. (2005)	How to represent time in CoPs. It discusses currently available methods and proposes a new one.

Table 2.5.: Summary of known publications discussing time in Communities of Practice

These publications are discussed in the following sections.

2.11.1. Classic publications discussing time in CoPs

Although accepted as part of the foundations of Communities of Practice, time is rarely found in the literature of CoPs, and when this happens it appears as an embedded component. When Lave and Wenger (1991) first discussed Communities of Practice this idea of time as intrinsic, although non-influential, component was already included (Lave & Wenger, 1991, p. 56). The same idea can be found in the works of Brown and Duguid (1991), as can be noticed by their analysis of Orr's work (1996). They referred to the time involved in acquiring the *noncanonical practice* in a subtle way, explaining that to construct a coherent account of the technical problems, the technicians needed to embark on a long story-telling procedure, which was passed on months later (Brown & Duguid, 1991, pp. 43–44). Throughout the paper it is possible to notice this recurring, but always as part of the creation of a shared repertoire among the employees.

Wenger altered this view slightly making the time component in the community's life clearer in his work of 1998, when talking about learning. He explained that the negotiation of meaning was a temporal process and that one needed to understand practice in its temporal dimension (Wenger, 1998b, p. 86). In 2002 Wenger et al. took this idea to a different audience, targeting the managerial level (Wenger et al., 2002). They stated that to create opportunities to nurture CoPs, organisations needed to create environments in which a set of approaches needed to be applied, and among these approaches time needed to be available for the communities (Wenger et al., 2002, p. 13). Moreover, they affirmed that the community's practice was built over time and this added value to the community (Wenger et al., 2002, p. 156).

These are just a few examples in the classic literature of Communities of Practice. It is natural that later authors followed the same rationale, as they built upon what was already defined by Wenger.

2.11.2. Recent publications discussing time in CoPs

Few recent works have a similar approach to this research regarding time within Communities of Practice. Some are very different in their objectives, but at least they treat time as a more complex component of CoPs, discussing possibilities and omissions not discussed until now.

A paper that addresses the time component in communities is by Zhou et al. (2007) that it is interesting not only by the fact it discusses time within CoPs, but also because it has certain similarities with the studies presented here. The authors searched for communities examining communication documents created over a period of time, which meant examining information about authors, document content, location where the documents were published and the time period involved on these. They addressed the problem using what was called a '*tripartite graph partitioning problem with prior knowledge available of entity covariances*', which implies that they formulated a solution to the problem using mathematical models (graph theory) and graphical representations (Social Network Analysis) of the relation between authors, words and publication venues to represent static and dynamic social networks. Using these models they searched for communities partitioning the previously created graphs in different time periods via consecutive runs of threads in the graphs; the knowledge of the previous run was used as input for the next one. They called the found communities 'temporal communities'. The paper used social networks of researchers and their related published work as data. What it defines as *community* is not clear, but probably is close to a

'Community of Practice' as defined by Wenger (1998b), although no references to Wenger's works appears in the paper. Interestingly, they used the same approach adopted in this research of including artificial data (they called it 'synthetic data') to test their methods, moving to real data afterwards. The paper does not refer to Knowledge Management or Knowledge Transfer, seeming only intended to discuss the methodology and its mathematical precision, not the practical use of it. Although accurate and well-explained, the implementation and pragmatic use of the method requires additional analysis and discussion, making its use in a managerial role doubtful.

A researcher who has spent several years working with the discovery of communities using the time component is Gloor (Gloor et al., 2003, 2004; Gloor & Zhao, 2006; Kidane & Gloor, 2007), beginning his quest with Gloor et al. (2003), in which the authors created a tool to search for what they named '*Collaborative Innovation Networks (COINs)*' (that have a definition close to Communities of Practice). The authors used email exchanges from W3C[5] working groups to visualise the communication within the groups over time. In the work the authors followed a sequence very similar to the one adopted in this research, i.e., the email messages were first transformed from plain text to database records, using a query to select specific messages from a time period, and finally representing the communication using a Social Network Analysis tool, such as Pajek (Batagelj et al., 2003), UCINET (Borgatti et al., 2002) or their own program, to discover, among other things, which nodes were the core members.

The work, although similar to this one, sets itself apart in a few ways. First, even though it searched for the COINs within the exchange of communications of a group using the time component for this, it did not look for recurrence in the pattern of the groups' activity, instead they searched only for the confirmation that the members were communicating over time, selecting the communities based on metrics used in Social Network Analysis: *Density*, *Group Degree Centrality* and *Group Betweenness Centrality* (Gloor et al., 2003, p. 4). Second, what was discovered in this thesis is different from what was discovered in the work by Gloor et al., as this thesis looked for recurrence in already confirmed (Virtual) CoPs to detect Recurrent CoPs, which led to the discovery of the Transient Core Members. Third, this thesis has its arguments and hypothesis grounded in Wenger's work, while Gloor et al. used the works by Wasserman and Faust (1994), meaning that this

[5] "The World Wide Web Consortium (W3C) is the main international standards organization for the World Wide Web (abbreviated WWW or W3). Founded and headed by Tim Berners-Lee, the consortium is made up of member organizations which maintain full-time staff for the purpose of working together in the development of standards for the World Wide Web." (Source: Wikipedia)

work has its foundation in the concept of Communities of Practice, while Gloor et al. based their research on Social Network Analysis. In addition, Gloor et al. searched for the communities without considering the consequences of the exposure of the 'COINs', while this research discussed this aspect for considering the consequences as too serious to be ignored, as demonstrated by previous works (Gongla & Rizzuto, 2004; Thompson, 2005).

In 2004 Gloor et al. published a paper presenting the *TeCFlow – A Temporal Communication Flow Visualizer for Social Network Analysis* (Gloor et al., 2004), a work similar to their previous paper, but with the inclusion of an animated visualisation of dynamic networks and plot of the betweenness, centrality and density of the networks over time. TeCFlow was used afterwards to analyse different types of social groups, with the results being published in various papers. For instance, Kidane and Gloor (2007) discussed an example of the use of TeCFlow to analyse an online community of developer and users of the open source Eclipse Java development environment. An interesting aspect found in TeCFlow was the option to define network members with more than an email address, which in these days seems to be a common aspect in electronic networks. A similar step was taken in this thesis during the analysis of the third case study, where communities' members were labelled with node numbers, despite the use of multiple email addresses. This allowed the same data consistency found in TeCFlow, ensuring that the messages' senders were correctly identified on all occasions (details of this step can be found in section 6.3.3, on page 132).

In 2006 Gloor et al. published a paper introducing a new tool called *iQuest* (Gloor & Zhao, 2006). This was an extended version of the TeCFlow, allowing input from archives of emails, phone records, blogs, web links and chat sessions, and providing additional options of analysis, such as textual context analysis. iQuest is now a product commercialised by iQuest Analytics Inc[6], making it impossible to verify the similarities and differences in analysis from the analyses done in the studies presented here.

Other researchers who also studied time within Communities of Practice are Lervik, Fahy and Easterby-Smith (Lervik et al., 2010). Interestingly, their approach was completely different from the previously discussed works and from this research. Their paper analysed important and neglected aspects of time in Communities of Practice, giving emphasis on the processes related to learning, specifically in relation to how external temporalities affect situated learning. Using Lave and Wenger's ideas (Lave & Wenger, 1991; Orr, 1996; Wenger, 1998b) as a foundation,

[6]`http://www.iquestglobal.com`

they conducted two case studies in companies providing technical after-sales services and concluded that aspects related to external temporalities have (good or bad) influences on the learning processes of the community's members, and that these aspects are related to technology, customer operations and work activities. Lervik et al. helped to shed some light on the influence of time in the functioning of Communities of Practice, however, differently from this research, their study was more concerned with the learning process within CoPs, whereas in this work, the concern is more related to the functioning of the community and how time influences this. They stated that "*[t]he temporal aspects of 'social and physical circumstances' have received little attention in situated learning theory.*" (Lervik et al., 2010, p. 286), which shows that the influence of time in Communities of Practice and/or Situated Learning was overlooked by the Literature. Their opinion corroborates what is affirmed in this research, that additional studies on the temporal aspects related to Communities of Practice are still very much needed.

Another study relating time and CoPs is the one by Moody et al. (2005) that analyses the dynamic representation of social networks with the aim of studying behaviour and structure. It discusses what is known as *longitudinal social networks*, i.e., social networks that have the time component embedded. In general, the main concern of their work is about a better way to represent time (in slices or as a film) in CoPs, however the aspects related to how time influences participation or how it acts upon the life of the community are not discussed. The paper discusses the issues involved in the representation of dynamic networks, and analyses several different techniques and programs used to represent time in CoPs, including Social Network Analysis programs, such as SoNIA, discussed later in this thesis (see section 8.3.2, on page 183). It classifies the types of time representation available when the paper was released, and proposes a new type of dynamic network visualisation, having several examples to illustrate the advantages of the new method. However, for this research the proposed solution could not be applied, as it would require extensive study and adaptation for the dataset available, which was not worthwhile, instead, it was decided to use already available tools that deal with time in an easier and faster way.

Although these publications have already started discussing time in depth, more still needs to be done, thus some of these aspects are discussed in the next section.

2.11.3. What is still missing

Although new publications have appeared treating time in a more elaborate way, some points are still not clear or still lack more analysis.

Time in the functioning of CoPs Due to Wenger's pioneering work in this area, time was studied in the same manner for a long time, time was treated as an essential component in the development of a CoP, related to aspects such as the creation of an identity and of a shared repertoire, and also for describing the life cycle of a Community of Practice (Wenger et al., 2002, p. 69). However, he never discussed the implications of time in the normal life of a Community of Practice, leaving questions unanswered like: *How important is the time response in Virtual Communities of Practice*? *Is the notion of time the same in different CoPs*? *Do delays in responses or engagements affect the interaction in CoPs (co-located or virtual)*? More detailed studies are still necessary to answer these questions and others.

'Time as single snapshot' versus 'time as a set of snapshots' This point address situations where Social Network Analysis is used to study Communities of Practice. In Social Network Analysis it is common to use a single snapshot in time as a way of discovering the members' connectivity, betweenness, core members and other aspects of a CoP. Still, it is unusual to find publications that use several snapshots of the community's activity to study members' participation or importance (the only known exceptions are Gloor et al. (Gloor et al., 2003, 2004; Gloor & Zhao, 2006; Kidane & Gloor, 2007) and Moody et al.(Moody et al., 2005)). In fact, it is rare to find computer programs that can analyse a sequence of snapshots. During this research several attempts were necessary to find the few programs capable of this type of analysis (see section 8.3, on page 181), and they were usually at the initial level of development.

How time is used to identify a community's members Another issue never discussed is if and how the community uses time to detect patterns of participation among members. One example of this refers to the situations where members could be lurking, waiting to get some benefit from the community, without truly engaging in participation. It is always assumed that a Community of Practice has members with equal intentions and that all participate for the sake of the community, not for personal reasons. The understanding and perception of members' variations in the pattern of activity can give important information about members' intention. As demonstrated in chapter 8 and in appendix B (on pages 179 and 241, respectively) members sometimes can have occasional bursts of activity that cannot be seen as intense participation. Likewise, sometimes a community member can begin participating with low levels of activity, increasing them with the time, becoming an important member, but due to the size of the time slice chosen, this is not evident in the case of a single time snapshot. Another point in this item refers to the cases when a community member is decreasing his/her participation, which can only be noticed via the analysis of the level of activity in time, as this drop is usually not observable if a single time snapshot is used.

The information about members' level of activity can be used to detect problems or to discover new aspects of Communities of Practice. In the first case, this can be used to deal with problems well before they can damage the community's life. In the second case, it can help to detect novelties, similar to the *Transient Core Members (TCMs)* (see chapter 8, on page 179), discovered in this research. In addition, analysis of the level of activities can also be used to help detect members with the potential to become a core member.

Time as a way of locating different types of CoPs Time might hide a few surprises regarding Communities of Practice. In this work, a new type of Community was discovered: the *Recurrent Communities of Practice (RCoPs)* (see chapter 5, on page 99). This special type of CoP is very similar to the typical Community of Practice, but with a very different characteristic: it is recurrent in its pattern of activities. This implies that it is only possible to notice it when the time in the studied CoP is seen in a manner that allows to notice the recurrence happening. A time slice too short and the recurrence disappears among the normal activity that occurs in CoPs; too wide a slice and the recurrence disappears again along with spikes of activities throughout the community's life span. One might wonder how many other different types of behaviour time might show, if used properly to study Communities of Practice.

This research did not attack all the issues listed in this section, but some were intentionally studied and some were found during the period of data analysis.

2.12. Conclusions

This chapter had a twofold objective: to list and discuss the available literature relevant for this thesis, and to create the foundation for the following chapters by discussing the implications of the discussed material with the subject studied in the work.

Due to the success of the idea of Communities of Practice, much material was published in several different areas, from learning to social science, leading to the creation of an broad spectrum of possible scenarios where CoPs are discussed. Hence, it is important to contextualise the listed material in relation to this research.

The discussion originated in Nonaka's work (Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995; Nonaka et al., 1996), where the main concern of this research was introduced: the management of *tacit knowledge*. Although introduced by Polanyi (1958; 1961; 1962; 1966; 1967), the concept of *tacit knowledge* became popular in the areas of Knowledge Management and Communities of Practice thanks to Nonaka (Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995; Nonaka et al., 1996), who popularised the idea that not only it was possible to transfer and manage the tacit knowledge from experts, but it could be used to improve companies and institutions. His ideas have been extensively analysed and debated throughout the years, and still stand scrutiny, keeping however, its appeal, having been verified empirically several times in the past. However, the whole idea of the existence of tacit knowledge and the possibility of transferring it or even managing it is challenged by some authors, Gourlay (2002; 2003; 2004; 2006) being the most widely cited among them. Nevertheless, Nonaka's theory has great plausibility, as demonstrated by the number of publications available in the area of KM/CoP discussing his concepts. This framework is the foundation for this research as provide the fundamental presumption necessary to drive the study, i.e.; that the tacit knowledge can be transferred/managed from a person (or community) to another person (or community). Additionally, it is assumed that Nonaka's model (SECI) is accurate even in electronic networks. This point was discussed in sections 2.4 and 2.5 (on pages 26 and 28, respectively), and it was concluded that it is secure to assume that the SECI model works in the same way in different levels on participation (individual, group, organisational, and so on) within an organisation (see figure 2.1, on page 26), even in the case of electronic networks.

Assuming that knowledge could be transferred in and among communities, the following step was to discover if that knowledge was the same found in Communities of Practice, as defined by Wenger (1998b; 2002). This was accomplished through a work from Nonaka that established the necessary relation between KM and CoPs (Nonaka, 1994), as discussed in section 2.5.1, on page 28.

Assured that the relation between CoPs and KM was real, it was decided to study Wenger's works related to Communities of Practice to understand them better, and verify if it was possible to seek these communities in electronic networks. Therefore, section 2.6, on page 30 discussed the history, changes in concepts, and listed the important aspects related to CoPs, as way to comprehend the evolution and the current understanding of what Communities of Practice represent, consequently allowing to relate them with this research in a clear way. As planned, the following step was to study the concepts of Virtual Community and Virtual Communities of Practice (VCoPs), as described in sections 2.7 and 2.8, on pages 41 and 43, respectively. This allowed to attest through several publications that although sometimes named differently, CoPs do exist in electronic networks, as demonstrated by the works of authors like Murillo (Murillo, 2002, 2006, 2008, 2010, 2011; Murillo-Othon & Spicer, 2007) and Allen et al. (2003); these on-line CoPs are called in this research Virtual CoPs, or VCoPs, for short. They represent an idea that although challenged by some authors like Hung et al. (2002) and Lueg (2000), is still a robust and meaningful concept as demonstrated by Murillo.

Having created the foundations to assume that tacit knowledge in VCoPs can be transferred/managed, it was necessary to try these assumptions, and for this the first necessary step was to find a way to check for CoPs/VCoPs in electronic networks. A solution for this was to use Wenger's list of indicators that a CoP has formed (Wenger, 1998b, pp. 125–126). The list was chosen for two reasons: first, because is the only known checklist developed by Wenger that can be used to test whether a community is a CoP; and second, because this list was also used by Murillo in his research.

Wenger's list is remarkably understudied, but it is a very practical form of testing if a community can be considered a CoP. Wenger's book of 1998, where the list first appeared, contains only a quick explanation of it, without further discussion regarding the reasons for choosing each of its 14 indicators. Additionally, there are no suggestions of how to relate each indicator with the three main components of a CoP (mutual engagement, joint enterprise and shared repertoire). Only a few publications that discuss Wenger's list were found, and even fewer that propose a relation between indicators and CoP's components. Boud and Middleton (2003), for example, used the list in a case study, but they did not discuss their interpretations nor their use of it, while Cox (2005) discussed his interpretation of the list and included some insights that helped to understand Wenger's probable purposes when creating the list. However, neither Boud and Middleton, nor Cox discussed or proposed a link between the indicators and the main components of a CoP. This was present in Li et al. (2009), who analysed all main publications from Wenger, and proposed an interpretation for the list of indicators, linking them to one or more CoP's components, although not detailing or explaining their choices. Murillo (2011) also proposed a link between the indicators and the components, however, similarly to Li et al. he did not explained his choices or discussed why the indicators were allocated to the specific components. Using the information available in the literature about Wenger's list this work proposed an interpretation for the 14 indicators and linked each one with a CoP's component; moreover, the rationale for the decisions was explained and can be seen in section 2.9, on page 45.

The plan was to use the list of indicators to help in the seek for CoPs/VCoPs. However, an important point was missing in the creation of the basis for the search: the time component of Communities of Practice. Wenger's list does not include time in any of its items, or at least it does not do it explicitly. Instead, time is included in a subtle way, following the approach adopted in his book of 1998 (Wenger). Therefore, a search was started to find literature that could help in this matter, however it was noticed that the majority of the publications in the area of CoP/KM only take account of time as an inherent and non-influential component of Communities of Practice, or in the best of the cases time is used to represent the life cycle of a CoP, being used to produce a snapshot of the community's life in a specific instant or to show the whole life of a CoP. Table 2.5, on page 54 summarises all known publications that discuss time in Communities of Practice to date. It is possible to divide these publications in two sets, one encompassing the works considered "classic" that represent the beginning of the studies in Communities of Practice (discussed in section 2.11.1, on page 54), and the other grouping the most recent works that deal with time in CoPs (analysed in section 2.11.2, on page 55).

In the first group (section "Classic publications discussing time in CoPs") appears the works from Lave and Wenger (1991), Brown and Duguid (1991), Orr (1986; 1987; 1990; 1996), Wenger (1998b), and Wenger, McDermott and Snyder (Wenger et al., 2002). They deal with time as an inherent component of the CoP's life, embedded in its daily activities, and present naturally in the three main components of a CoP: mutual engagement, joint enterprise and shared repertoire. This is noticeable and accepted as correct as these three components only exist if considered the CoP's activities throughout time, as they are formed, reinforced and kept with the passing of the time. Although with some variations the authors in this group usually refer to time only when discussing the community's development, its life cycle, the relations among members or between them and the community, or in situations in which time appears as part of the scenario where the community functions, evolves and connect with other communities. No discussions are made regarding the points listed in section 2.11.3, on page 58, lacking for example debates about the implications of time in the normal life of a Community of Practice.

The second group (section "Recent publications discussing time in CoPs") discusses the latest literature available in which the temporal aspects of CoPs is examined. The first authors found, Zhou et al. (2007), used time as a way to detect members of what was called *temporal communities* via the use of Social Network Analysis and mathematical models. They used time as a way of detecting these communities, although without a clear definition of what was considered a community; additionally, the concept of time was restrict to the exchange of communication between members. Another author who searched for CoPs using time component was Gloor (Gloor et al., 2003, 2004; Gloor & Zhao, 2006; Kidane & Gloor, 2007), who together with other authors, searched for the *COINs* (*Collaborative Innovation Networks*) that have a very close definition to Communities of Practice, and although showing some similarities to this work (such as the representation of the communication of these entities over time), he did not search for patterns of recurrences in their communities. Other authors who studied time in Communities of Practice were Lervik, Fahy and Easterby-Smith (2010) that analysed the influence of time in the situated learning that happen within CoPs. Their study was concerned with the influences of external temporalities on the learning processes of the CoP's members, and not with the influence of time in the inner functioning of CoPs, as this research. Yet another study in time related to CoPs is from Moody, McFarland and Bender-DeMoll(2005), who analysed what was called *longitudinal social networks*, i.e., social networks that have the time component embedded. Their study analysed the best way to represent time in CoPs (slices or films), proposing a new system for this purpose. As can be noticed by this summary, the amount of works that deal with time in CoPs is very small, and among them the ones that analyse time as structural component is even smaller. It was found only one author that proposed to use time to help in the search for communities (assuming that they are similar to CoPs): Gloor, and in this case the approach was restricted to the use of SNA tools and avoided several important issues, discussed in section 2.11.3, on page 58. The same section discusses all different approaches that have been ignored in the study of time in CoPs, to date.

After the step of the studying the available works dealing with time in Communities of Practice, it became clear that to search for (V)CoPs in electronic networks, and taking in account their temporal component, a new approach needed to be created, as the existent literature was scarce and too diversified to be used as guide.

3. Methodology

3.1. Introduction

Having explained the objectives (in chapter 1), and following a discussion of the literature (in chapter 2), it is time to explain how the methodologies were chosen for this research.

Bearing in mind that the research aim was to study the dynamic of the life of Communities of Practice, in such a way that time could be analysed as a continuous and non-static component, which would have an effect on the inner functioning of the communities, the research methodology needed to be carefully chosen.

It was necessary to select methods that could embrace time in a flexible way and from the start it was clear that a single approach would not accomplish this objective. Therefore, the methods used needed to be adapted in several steps of the research in order to verify (or study) certain aspects necessary in that phase. Additionally, a specific method needed to be replaced due to a lack of results when used of the search for the Recurrent CoPs (see chapter 7 for more details).

3.2. Research Design

Research Design has different definitions by different authors. Yin, for instance, uses logic to define it, saying that Research Design is the logic that links the data, the conclusions from the analysis and the initial questions (Yin, Robert K., 2003). Nachmias and Nachmias, on other hand, use the concept of guiding plan to explain research design. They state that this plan will guide the researcher throughout all the phases of the research, from the data collection until the conclusions. Moreover, such a plan can help the researcher to test relations between the studied variables (Nachmias & Nachmias, 1992).

In the case of this study, the research design was used as a framework to help the planning of all necessary actions at each step of the case studies. This is shown in figure 3.1, on page 66.

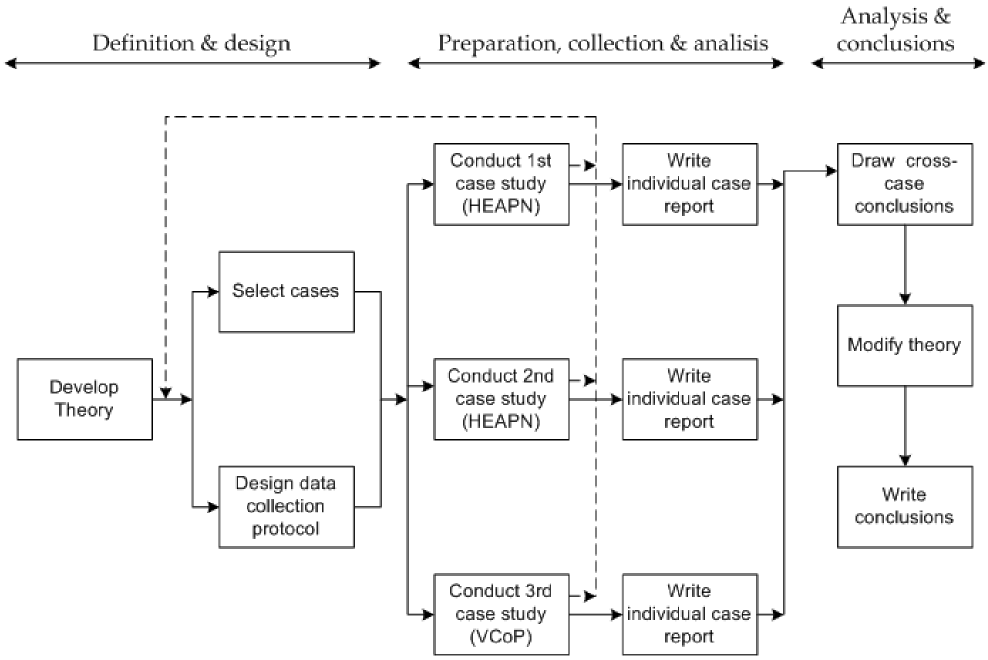


Figure 3.1.: Research design (based on Yin, Robert K. (2003, p. 50)).

Notice in the figure that after each case study feedback was used to amend the developing theory, making it possible to refine the theory to reflect the results from the data analysis.

The *definition & design* section in figure 3.1 illustrates the creation of a theory that reflects the temporal aspect of Communities of Practice. The plan was to study a known CoP to create the necessary theory, thereafter running case studies on it and on a new CoP, as a way to corroborate the theory.

The *preparation, collection & analysis* section in the figure shows the aspects related to the case studies. The easiest and fastest way to complete this step was to analyse a known and accessible CoP and to run case studies in it. The best approach to accomplish this was to study the researcher's workplace due to the familiarity with the work environment and to the likelihood of obtaining permission to run the cases, if compared with other workplaces. Therefore, after acquiring the necessary permission, the Higher Education Academy Psychology Network was used as a test bed to learn about the inner functioning of a CoP. After that and with the results of the data analysis in hand, the theory would be refined and tested in a different Community of Practice. Additionally, it was decided that the new CoP needed to exist within an electronic network.

Finally, the *Analysis & Conclusions* section in figure 3.1 shows how the results would confirm if the theory worked similarly in co-located and on-line Communities of Practice. In case of different results from what was expected, the theory would be modified to reflect that.

3.3. Research Strategy

The main point of the research strategy used in this work was to have access to an existing Community of Practice to guarantee that the steps explained in the previous section could be achieved. An approach to ensure this would be to study a community in which the researcher was already participating. Fortunately this was the case, as the researcher worked as an employee of the *Higher Education Academy Psychology Network* (*Psychology Network*, for short) during the period of this research. As explained in chapter 5, the Psychology Network had several internal and external communities and it would be very helpful if it was possible to study a few of the existing CoPs (see chapter 5 for a detailed explanation of the work environment and the existing communities).

The strategy was to use these CoPs to gather experience in designing and running experiments, and also in running data analysis. With this knowledge having been acquired the next step would be to use the newly developed set of procedures in an external Community of Practice, preferably a Virtual Community of Practice (VCoP), to check the resulting theory in virtual environments.

To gain the necessary experience and in order to maximise the knowledge acquired from the studied CoPs, a method based on interviews was chosen for the first case study, and one based on interviews and Grounded Theory (Corbin & Strauss, 2008; Glaser & Strauss, 1967; Strauss & Corbin, 1998, 1990) was used in the second case study. This allowed the creation of a theory describing temporal behaviour found in a co-located CoP. Such theory was later checked against a VCoP by a mixture of content analysis, statistical analysis and visual analysis (third case study).

As far as the interview process is concerned, a particular publication discusses in depth the use of interviews in Information Systems in depth: Myers & Newman (2007). The authors examined the commonality and importance of interviews for qualitative research, although highlighting how understudied the topic is within Information Systems. They examined the research method of 22 qualitative studies from four Information System research journals (*MIS Quarterly*, *Information Systems Research*, *Journal of AIS* and *Infomation and Organization*) between 2001 and 2005. Several aspects were studied in the papers concerning the quality of the methods used, such as the number of subjects/interviews, period of interviews, interview model, description of the process used for the interview (regarding its details), type of interview (structured, semi-structured or in group), recording technique, thick/thin description (quantity/quality of used quotes), anonymous/revealed (anonymity of the interviewees) and feedback offered to the companies/subjects. Using the problems and/or omissions found in the analysed papers, the authors proposed a new model for qualitative interviews in Information Systems called the *dramaturgical* model, based upon the ideas of Erving Goffman (1959; 1961), who created a theory of face-to-face interactions that uses the metaphor of the theatre to describe social life. The authors proposed a model that has seven guidelines to be used in qualitative interviewing, seeing it as a drama, and the people involved as actors or audience. Although exposing various problems and difficulties found in existing models for interviews, the new proposal only offers a superficial solution for the problems, suggesting researchers have a better understanding of their roles (and of the participants). However, it still serves as a good reminder that the interview process is complex and full of important overlooked aspects.

Regarding the third case study, the related methodological aspects are discussed in section 3.6, on page 80.

3.4. Preliminary Study

Upon request, the Psychology Network director agreed to the study of the available communities. However, before starting the main studies it was decided to run a test case with the Psychology Network employees. For this, *Wenger's indicators that a CoP has formed* was used as a foundation for the case study (see section 2.9, on page 45 for a discussion about Wenger's list). The complete discussion of this preliminary study is available in chapter 4.

This first study was primarily intended as a test bed for the creation of a questionnaire that could be used later in one of the existing communities of the Psychology Network. However, the outcome provided more than just questionnaires and experience, since it was shown by the data analysis that the small community formed by the employees presented strong signals that it was a well-formed Community of Practice.

3.4.1. Method used

To apply Wenger's indicators to the Psychology Network it was decided to use *Structured Interviews* due to the fact that this is a well-known methodology and it is well-accepted throughout different areas, with several publications discussing its use and principles (e.g., in social science (Nachmias & Nachmias, 1992) or in Human Computer Interaction (Cairns & Cox, 2008)). Additionally, its simplicity allowed a quick implementation, since a structured interview only needs a researcher asking a list of questions of a participant, and the repetition of the same process with each interviewee.

The questions used in the interview process needed to be the same for all respondents, thus normally requiring the use of a fixed questionnaire. In this work such a questionnaire was created having Wenger's indicators as the main driving force for its creation. The complete questionnaire is available in Appendix A, section A.1.1, on page 229. Also, during the interview the researcher can clarify any doubt regarding the questionnaire; however, he or she needs to do this without influencing the participant and at the same time keeping the sequence of questions and consistency of help throughout the interviews.

Perhaps another method could be as effective as the structured interview, but the nature of Wenger's indicators, as a simple list with 14 items, made the creation of a questionnaire straightforward, consequently making it easier to run structured interviews, with it only being necessary to create a question for each indicator. Obviously some precautions were necessary during the creation of the questions. For example, a direct question using the wording used by Wenger was avoided. Instead it was necessary to create questions that contained the same verification, but different in the writing, to avoid the interviewee grasping what the question was trying to discover. Additionally, because the interviewees were work colleagues there was sometimes an attempt to "help", guessing what must be the "correct answer". However, in these few cases it was explained that there were no correct answers. Upon this explanation the interviewee relaxed and started to answer the questionnaire without the pressure of "doing something wrong".

Strengths and limitations

Naturally every research method has advantages and disadvantages. However, in this specific case, the strengths and limitations that this methodology presents can vary slightly from common cases. This is due to the proximity between the researcher and the interviewees, as they worked together. Nevertheless, all possible caution was used to avoid the problems caused by this.

As far as its strengths are concerned, a structured interview:

- guarantees that all participants are asked the same questions;
- allows the researcher to explain a question more clearly in case of doubts from the participant;

- allows the researcher to verify if a different method could/should be used in the next case study and why;
- provides a reliable source of quantitative data;
- is easy to design, implement and analyse;
- makes it easier to avoid problems with the responses, for instance with incomplete questionnaires, biased answers, etc.

Considering the fact that the researcher worked in the same place as the interviewees, it is possible to add to the list:

- The proximity between researcher and interviewees helped to make the interview less formal.
- It was easier to set a convenient date and time for both interviewer and interviewee to have a meeting.
- The answers could be checked against facts that were known by the researcher, making a biased or imprecise answer less likely.

However, the methodology also has drawbacks. For instance:

- In this specific case it was restrictive, because it was noticed in the middle of the interview process that there was a great opportunity to discover more about CoPs, but it was necessary to complete the case study before this opportunity could be used in another case study.
- The answers were limited in their scope and richness, causing a certain amount of additional information to be lost because it was not in the questionnaire.
- Again, the close relationship between the researcher and the participants might have influenced the responses.
- It was very limited by the requirement to use Wenger's indicators.
- It delivered a narrow data analysis due to the number of participants.

Once again, due to fact that the researcher was part of the studied community, it is possible to add to the previous list:

- The wish of some participants to "help", trying to guess what must be the "correct" answer.

- The possibility of restraint in making statements/complaints by the participants, as they were aware that the interviewer was somebody from their own workplace.
- The possible difference that an external interviewer would have made in gathering information without any influence from internal knowledge from the workplace.

Considering their advantages and disadvantages, structured interviews were judged safe enough and worthwhile to be applied in the case study.

3.5. Second Study

With the discovery of a Community of Practice formed by the employees of the Psychology Network in the first case study it was crucial to learn as much as possible from it. It was necessary to put together all available information gathered in the first study and introduce a new methodology that allowed an analysis in depth of the discovered community. It was learned, for instance, that the newly discovered Community of Practice was:

Apparently not geographically distributed The initial study led to this conclusion, as all participants were from the same workplace, but the second study showed that this was not the case.

Strongly connected All the participants used all available means to interact and work together: face-to-face meetings, exchange of emails, telephone calls, exchange of documents stored in a file server, etc.

Presenting signs of intense use of CMC Even when staying in the same workplace, the employees used the resources available via Computer Mediated Communication (CMC) intensively. This characteristic became more evident when they worked from home.

All these aspects led to the conclusion that a deeper study was necessary to discover more about the functioning, formation and characteristics of the discovered CoP. Therefore, *Grounded Theory* (Corbin & Strauss, 2008; Glaser & Strauss, 1967; Strauss & Corbin, 1998, 1990) was chosen as the ideal methodology to be used in the case study.

3.5.1. Grounded Theory

Grounded Theory does not have a separation between data collection and data analysis, as they are both integrated in the research process to work together and recurrently until a theory is developed. Furthermore, a researcher does not start the research with a preconceived theory in mind unless his/her objective is to discuss and/or extend it. Instead, the researcher starts with an open mind and allows the theory to emerge from the data (Strauss & Corbin, 1998, p. 12).

Another important issue is related to the researcher's previous knowledge at the beginning of the GT studies. Glaser and Strauss made their position on this very clear from the beginning, stating that it is impossible to erase from the researcher's mind all theory already acquired before the start of the GT studies, and that the emergent theory can be produced by the researcher's mind, based on his/her reading, life experiences, research and scholarship (Glaser & Strauss, 1967, p. 253).

With this point made clear it is now possible to explain how Grounded Theory works.

3.5.2. The functioning of Grounded Theory

Grounded Theory helps to create a theory with very few pre-conceptions, since during the development of the study the feedback collected in each interview generates learning that is applied in the next interview, i.e., on each iteration the theory is checked against the new data, consequently resulting in a better understanding of the data. At the end of the recursive process, the method provides categories and concepts inherent to the analysed data. The process of analysis is done with the use of open coding, which identifies concepts and their properties and dimensions, classifying these into *codes*.

The role of the literature review As far as the literature review is concerned, there are two opposite approaches adopted in Grounded Theory. One comes from Glaser, who was against the idea of a researcher reviewing the relevant literature before the beginning of the GT studies (Glaser, 1992, p. 31). He was concerned that seeing any material related to the study beforehand would contaminate, inhibit or even block the researcher's capacity to analyse the data found in the study (Glaser, 1992). The second approach comes from Strauss and Corbin, who believed that the literature review has an important role in GT studies, as long as it is used as a complementary tool (Mills et al., 2006). They believed that the literature could help the researcher to develop the theory if used in parallel with the collection and analysis of data.

This last approach seems more coherent and realistic, as it accepts the fact that it is not possible for a person to forget selected items from the memory in order to run a case study. Therefore, in this thesis the adopted approach was the one from Strauss and Corbin, where the literature acts as an additional tool, being used carefully when necessary, together with the processes of collection and analysis of the data.

Data collection, data analysis & constant comparison The processes of data collection and analysis are repeated recursively, with the results always being analysed after each step to detect patterns, changes or important signs that could indicate the need for extra analysis or modifications in the process of data collection. Results, categories and ideas are always compared in every step of the study for a better understanding of the studied environment and a more accurate creation of the theory.

Strauss and Corbin highlighted the importance of the process of comparison, stating that this was an essential feature in their methodology, not only when used among the detected incidents, but also when used in what they called *theoretical comparison*, as a way to induce thinking about properties and dimensions (Strauss & Corbin, 1998, p. 78).

Coding The concept of *Coding* is very much related to data collection and analysis. It is through the recurrent work with the data that it is possible to create the codes that reflect the studied environment. For this, Strauss and Corbin created three important concepts: *Open Coding*, *Axial Coding* and *Selective Coding*.

Open Coding was defined as by Corbin and Strauss as "*[t]he analytic process through which concepts are identified and their properties and dimensions are discovered in data*." (Strauss & Corbin, 1998, p. 101). They explained that Open Coding could be implemented using line-by-line analysis, having the data examined in a very close way, phrase by phrase or word by word (Strauss & Corbin, 1998, p. 119).

The second important concept is *Axial Coding*, which was defined as "*[t]he process of relating categories to their subcategories, termed 'axial' because coding occurs around the axis of a category, linking categories at the level of properties and dimensions*." (Strauss & Corbin, 1998, p. 123). The process associates the categories with subcategories in order to explain the studied case in more detail (Strauss & Corbin, 1998, p. 124)

The last concept defined by Strauss and Corbin is *Selective Coding*, which is defined as "*[t]he process of integrating and refining the theory*." (Strauss & Corbin, 1998, p. 143). Although apparently over-simplified, what Strauss and Corbin meant with this definition was an integration of categories, making them organised around a central and explanatory concept (Strauss & Corbin, 1998, p. 161). The process is carried out recursively and through *Theoretical Saturation* (explained in a later section) the theory is refined, improving poorly developed categories (Strauss & Corbin, 1998, p. 161).

Theoretical Sampling Another concept is *Theoretical Sampling*, created by Glaser and Strauss (1967) and later defined by Strauss and Corbin as "*sampling on the basis of emerging concepts, with the aim being to explore the dimensional range or varied conditions along which the properties of concepts vary.* "(Strauss & Corbin, 1998, p. 73).

Theoretical Sampling looks at how the concepts change in regard to their dimensions, and to achieve this the researcher needs to think carefully about the concepts already discovered and what to do next to look for variations in or confirmations of the data (Strauss & Corbin, 1998, p. 233).

Writing memos Strauss and Corbin defined memos as "*written records of analysis that may vary in type and form.*" (Strauss & Corbin, 1998, p. 217). However, this definition is not enough to guide somebody in using memos, thus they explained the use of the term further, making it clear that "memo" refers to the written record which contains the product of analysis or directions for the researcher (Strauss & Corbin, 1998, p. 217). As Strauss and Corbin highlighted, memos vary in presentation and form, but not in function. They are meant to allow the researcher to put together the thoughts and insights about the analysed data until that point. These ideas will be sorted, ordered and retrieved, to allow a constant re-evaluation of the building theory.

Theoretical Sensitivity The concept of *Theoretical Sensitivity* was created by Glaser (1978). Later, Strauss and Corbin (1990) explained it as "*the attribute of having insight, the ability to give meaning to data, the capacity to understand, and capability to separate the pertinent from that which isn't.*" (Strauss & Corbin, 1990, p. 42). This set of skills evolves with the data collection and analysis, and consequent theory creation. Theoretical Sensitivity is a sum of all the researcher's experience (previous and that related with the current case study). It is necessary that the researcher see the patterns and differences present in the data, and understand its behaviour and its relationship with the aspects involved in the study; therefore it is crucial that he/she immerse him/herself in the study to make it possible to comprehend the meaning of the data within the context of the study, and represent it through the creation of categories and concepts.

Development of the core categories During the process of Grounded Theory, the recurrent analysis and collection of data will lead to the creation of a set of categories, via memo writing and constant comparison. Among these categories some (or all) of them will develop in a core category, which appears as a consequence of the focused search in the data for answers to the research questions. Further interviews and analysis are carried out to discover as much as possible about the nascent categories, which can lead to the discovery of additional ones, and/or improvement/disclosure of details from existing ones. After some cycles of analysis, a set of categories should reach theoretical saturation (explained in the next section).

Theoretical Saturation Another important concept in Grounded Theory is *Theoretical Saturation* (Glaser & Strauss, 1967). Theoretical Saturation indicates when it is possible to stop the data collection and the data analysis. This happens because no new concepts appear upon sampling and analysis of new data, thus there is no need for additional cycles of collection and analysis of data. Corbin and Strauss identified three signs to detect that Theoretical Saturation had been achieved (Corbin & Strauss, 2008, p. 212): no new data appears from the data analysis that is relevant and related to a category; the categories and their respective properties and dimensions are developed enough, showing good variation; and the relationships between categories are securely established and validated.

Generating Theory Strauss and Corbin defined *Theory* as a set of related concepts that together creates the framework used to describe and predict phenomena (Strauss & Corbin, 1998, p. 15). To understand what generating a theory implies it is important to understand what the authors call *Theorizing*: this is the process of conceiving/intuiting ideas or concepts, which are formulated in a logical, systematic and explanatory way (Strauss & Corbin, 1998, p. 21). As soon as the researcher starts the recurrent processes of data collection and data analysis, he/she begins the creation of categories that are constantly compared and refined throughout the whole study. These categories evolve and some (or maybe all) of them reach theoretical saturation. At the same time the researcher orders and analyses the written memos, making comparisons, relations and critiques of these memos. This constant process helps to develop the theory that will explain and characterise the studied case.

3.5.3. The choice of Grounded Theory

Grounded Theory was chosen due to the conclusions from the previous case study showing strong signals that the Psychology Network had a Community of Practice formed by its employees. Their answers indicated that there was much more to be studied, but the technique used in the first case study (structured interviews) was not designed for this. Therefore, it was necessary to find an alternative tool that made it possible to gather this extra and rich information.

The first objective was to discover everything that was possible about the Community of Practice, mainly how it was formed, how it worked, how it functioned and how time was related to it. However, due to the fact that the researcher was working in the Psychology Network, it was necessary to find a method that could avoid any problem of biased analysis or results as much as possible. Grounded Theory is the perfect choice for these cases because all analysis and conclusions solely originate in the data.

It was also necessary to gather ideas, concepts and characteristics from the detected Community of Practice. For this it was necessary to use a methodology that could explore unseen patterns and show all aspects from the community. Once again Grounded Theory was the perfect tool because it would construct all definitions based on the mind model described by the participants.

The use of Grounded Theory within the context of CoPs conceptual framework

Communities of Practice in this work are based on Wenger's definitions and conceptualisations (Wenger, 1998b). Although Wenger's concepts have varied over the years (see section 2.6.1, on page 30, for a discussion about this), the fundamental definitions of what a CoP is, how it is created and how it behaves, can be considered stable and coherent enough to be used in this work (the complete conceptual framework for Communities of Practice can be found in chapter 2, section 2.6). This conceptual framework is well-studied and accepted in several areas of knowledge, having been used in research for a number of years.

Grounded Theory has gained similar respect and acceptance among researchers in different fields. Moreover, GT is not new for Communities of Practice, as it has already been used in some studies in the area. Agrawal and Joshi (2011), who reviewed the literature of the past two decades on empirical studies related to Communities of Practice, found several papers that used Grounded Theory in their study.

Some examples of the use of Grounded Theory in the studies of Communities of Practice can be given. For instance, Rothaermel and Sugiyama (2001) presented a theory grounded in the study of *TimeZone.com*, a virtual Internet community devoted to wristwatch hobbyists and enthusiasts. Another example is the work of Geiger and Turley (2005), who used GT to investigate the knowledge sharing about customers' preferences and their requirements in the CoPs of sales personnel. Yet another example can be seen in the work of Akhavan et al. (2006), which used GT to collect data from case studies in organisations that had successfully adopted Knowledge Management.

These examples show that Grounded Theory is a well-known methodology in the field of the studies of Communities of Practices, justifying its use in the search for a better understanding of the previously discovered CoP. However, Grounded Theory is not perfect, having advantages and disadvantages, like any other methodology. These aspects are discussed bellow.

3.5.4. Strengths and limitations

It is important to discuss the benefits of using Grounded Theory in this thesis, without forgetting that drawbacks also exist.

Regarding its advantages we can say that Grounded Theory:

- provides an opportunity for "*a systematic and rigorous procedure*" (Offredy & Vickers, 2010);
- permits the creation of "*rich data, which arise from the experiences of individuals who are taking part in the research study*" (Offredy & Vickers, 2010);
- has a very close relationship between data and analysis;
- creates an opportunity for the researcher to have a limited influence from preconceptions;
- has an open approach to the discovery of new ideas and concepts;
- when properly used, is very accurate in its findings;
- does not allow the steering of the results towards a specific aspect or area; they naturally originate in what the data shows.

Considering the study of the Psychology Network, Grounded Theory also had the advantages of:

- allowing a better understanding of aspects and relationships that were informally discussed during the first case study;

- creating an environment that could reduce the bias caused by the fact that the researcher was part of the studied community;
- allowing the discovery of concepts not previously thought of (e.g., the Recurrent CoPs, discussed in chapter 5).

However, Grounded Theory has also its drawbacks. For instance:

- "*The subjectivity of the data leads to difficulties in establishing reliability and validity of approaches and information*" (Offredy & Vickers, 2010).
- "*It is difficult to detect or prevent researcher-induced bias*" (Offredy & Vickers, 2010).
- It is a slow and time consuming process.
- It requires attention to detail and great concentration.
- It does not allow the steering of the results towards a specific aspect or area; they naturally originate in what the data shows.

Once again, the fact that the researcher worked in the studied workplace created additional disadvantages:

- making it very hard to ensure that any result or noticed aspect was not a biased result due to the researcher's personal involvement;
- creating an extra layer of work during the interviews, in a way that could isolate the fact that the interviewer and the participants were working in the same workplace that was being discussed during the interview.

It is important to highlight one aspect from the previous lists: the same item "*Does not allow the steering of the results towards a specific aspect or area; they naturally originate in what the data shows*" appears in the lists of advantages and of disadvantages at the same time. This is peculiar to Grounded Theory and it is a consequence of the results being created based solely on data, i.e., at the same time that GT allows the data to be free of any influence or bias (ideally speaking), it causes a lack of control in the focus of the results. Moreover, even if one tries to direct the study's focus through modifications in the interview process (via questions and orientations), the answers and the resulting theory will be independent of such influence.

3.5.5. How Grounded Theory was employed

The use of Grounded Theory in this research was detailed in section 5.5, on page 107. This current section only lists a few important details in the actions adopted when GT was applied to the study of the CoP within the Psychology Network.

The role of the literature review

As described in section 3.5.2, on page 72, the literature review was used only as a helpful tool to accomplish the main objective. However, the knowledge of CoP acquired before the start of the study was present in the whole study, and helped to identify concepts and aspects that appeared during the analysis. This knowledge came mainly from Wenger's work and was helpful in identifying common aspects present in Communities of Practice.

Additionally, Wenger's work was used in the creation of the questionnaire used in the interviews, having as a starting point the list of 14 indicators that a CoP has formed, from Wenger (1998b, pp. 125–126). A detailed discussion about the indicators can be found in section 2.9, on page 45. The first questionnaire used is available in Appendix A.2.3, on page 233. The second questionnaire used is shown in Appendix A.2.4, on page 236. Finally, the last version of the questionnaire is available in section A.2.5, on page 239. The questionnaires tried to use the 14 indicators as a guide as much as possible; however, some items could not be used due to the particularity of the studied environment. A discussion about them can be found in section 5.5.3, on page 110.

Following Grounded Theory guidance, after each interview an analysis was carried out, followed by a comparison with the previously collected data. This allowed the discovery of all the concepts described in section 5.6, on page 111.

The coding

Microanalysis was used for coding, as described in section 5.5, on page 107. This was necessary because, after the first interview and later analysis, there was great difficulty locating patterns and creating concepts. Consequently it was decided to use Open Coding (Strauss & Corbin, 1998, p. 119), via line-by-line analysis, on the transcript from the interview.

As expected, it took a great amount of time to analyse the interviews; however, the rewards that this detailed analysis brought are priceless. Thanks to this, all the main concepts were discovered and it was possible to detect the existence of what was called Recurrent Communities of Practices. All codes passed through several recurrent analyses, and through the use of Selective Coding (explained in section 3.5.2, on page 73) the final theory was created.

Theoretical sampling

Upon the discovery of the new concepts during the interviews, Theoretical Sampling (Strauss & Corbin, 1998, p. 73) was used to verify the existence of these new concepts. The technique confirmed the concepts in different interviews and helped bring about theoretical saturation.

Development of the core categories

During the case study several categories and their properties were developed. After passing the phase of theoretical saturation these categories and their relationships were defined. The final step was the development of the core categories following the recommendations of Glaser and Holton (Glaser & Holton, 2004, p. 15), cited previously in section 3.5.2, on page 75. The results with all the categories, properties and relationships discovered are presented in section 5.6, on page 111.

3.6. Third Study

After the discovery of the Recurrent Communities of Practice in the second study and consequent analysis, a question appeared as a direct result of the study: *do RCoPs exist in electronic networks?* The question is relevant considering that the RCoPs made intense use of CMC and that electronic networks are a ubiquitous technology these days. Consequently a search for a case study that could help to answer that question was initiated.

After searching for possible scenarios that could be used in a study, a set of works by Murillo (Murillo, 2002, 2006, 2008; Murillo-Othon & Spicer, 2007) was found. In these works Murillo used a dataset in which he searched for and found Communities of Practice (Murillo's research is summarised in section 2.10, on page 52). The dataset is formed by messages delivered between 2002 and 2003 in several Usenet newsgroups. He used qualitative and quantitative analysis to search for CoPs and found four groups that fitted Wenger's definition of a Community of Practice. Chapters 6, 7 and 8 describe the case study using Murillo's dataset in detail through three different methods (one chapter for each method).

This section describes only the aspects related to the effectiveness and functioning of the methodologies used in the case study.

3.6.1. Objective

The main objective of this new case study was to learn more about the behaviour inside the community formed by the participants of newsgroups, as a way of learning how to search for Recurrent CoPs inside electronic networks. For this, an analysis needed to be carried out on the exchanged messages in the four newsgroups detected as CoPs by Murillo. As this type of analysis was new, it was necessary to try different methodologies until the most suitable could be found.

3.6.2. Quantitative Analysis

The first attempt to study Murillo's dataset was using *Quantitative Analysis*. This section summarises the analysis that is described in detail in chapter 6.

Reasons for choosing Quantitative Analysis

Quantitative Analysis has the advantage of allowing *ad hoc* exploratory qualitative analysis, which helped to deal with the size of the dataset to be analysed.

Murillo's data needed to be converted into large matrices (as is detailed in the following section). This required several different attempts to find patterns within these matrices. These attempts were made through the use of intuition while looking closely at parts and at the complete matrices, as a way of discovering spot patterns. These patterns could indicate the presence of Recurrent CoPs, as also explained in the next section.

The use of Quantitative Analysis

Quantitative analysis was used in matrices with all messages sent by each node (i.e., by each participant[1]) from a specific newsgroup. This type of matrix is called a *sociomatrix* (Wasserman & Faust, 1994).

One matrix for each of the 52 weeks of the studied period was created, each matrix being of the type square adjacency with a size of 755 (the number of participants). Each generated matrix had column headings and row headings with the node's number (for anonymity purposes), and inner cells with the number of messages sent from a node in the row to a node in the column.

In addition to the sociomatrices for each week, it was also necessary to create a matrix with the total number of messages sent by each node per week. This last

[1]Throughout this work the words *nodes*, *participants* and *members* are used in an interchangeable way when referring to a community. This is due to the fact that every community's member is a node in a graph representing their relationships. This is better visualised in chapter 8, where Social Network Analysis is discussed.

matrix would make it possible to detect *core nodes* (i.e., members with with strong participation in the community's activities) looking for those with a high number of messages sent, and also would make it possible to locate potential *recurrent nodes* (i.e., members with the possibility of being part of a Recurrent CoP).

Before trying any method it was decided to look in the matrices, as a way of detecting patterns that could show an indication of recurrence. It was also decided to read a few selected messages to understand participants' behaviour.

For the first part (seeking recurrences), an initial search was undertaken in the matrices for nodes with high levels of activity, but with gaps of a few weeks in the participation, creating the same effect described in figure 5.3, on page 113, when a pattern appeared showing cycles of activity and inactivity. However, this alone was not enough to classify any potential node as recurrent. A deeper analysis was necessary to check if the node was not leaving the community after a period of activity, or if it was just a momentary activity (not participating any more after that period), or even if it was at the beginning of a process of becoming a core node, having constant participation after the verified period.

For the second part (understanding of participants' behaviour) a group of selected messages was analysed to find out if the community was dealing with projects or other triggers that could imply a recurrence. The aspects of trust (on selected nodes), real participation (not only lurking, spamming or other different types of activity), and relation between content and message's subject were also analysed.

Due to the size and number of matrices involved in the process, it was decided to run some tests in an excerpt from the main matrix (containing the levels of activity of each node). For this a matrix with the first 12 weeks of the analysed period, from a specific newsgroup, was created.

The realisation that the same type of deep analysis would not be possible in the complete dataset of the four CoPs (each one with 52 weeks of participation) led to the search for a better method to be applied. The chosen method was Cluster Analysis, discussed in section 3.6.3, on page 83.

Strengths and limitations of Quantitative Analysis

Because the use of a specific quantitative method only occurred after the initial analysis, what can be said about the advantages and disadvantages of using the current methodology is limited, but relevant.

It is important to highlight that the third study was moving from a study in a co-located CoP (the second study) to a study in a Virtual CoP, therefore, some preliminary examination was necessary, justifying the tests carried out on the sample of the dataset.

The methodology applied showed its strengths, allowing:

- Better understanding of participants' behaviour. The conclusions were not only based on number of messages sent, but also on whether these messages were relevant or not.

- Better understanding of the number of messages represented in the matrices. It was learned that the existence of gaps in the activity was not enough to tell if a node was part of a Recurrent CoP, thus making it necessary to study other aspects of its behaviour. For instance, some nodes had a burst of activity in the studied period, followed or preceded by a period of inactivity. However, it was necessary to study the complete node's activities in the period to understand that the burst was only an isolated event and not a proof of recurrence.

- To the discovery that the dataset needed preparation before any analysis could be carried out. For example, there were different types of participants that needed to be excluded from the matrices before the analysis started: "sink" nodes, "source" nodes, core nodes, etc., as they were not relevant to the search for Recurrent CoPs (see section 'Removal of self-loops, "sources" and "sinks"' on page 134).

However, the methodology also has its limitations:

- It is inefficient for a large amount of data. As described previously, it is only possible to carry out deep analysis on messages' contents and study participants' behaviour if the dataset is small. For the original data given by Murillo this analysis is not possible.

- As a consequence of the previous item, all conclusions that derived from the analysis were restricted to the sample used for the analysis. It was not possible to generalise these conclusions to the rest of the dataset.

- Potential recurrent nodes could not be confirmed. Once again as a consequence of the first limitation it was not possible to study the nodes that were potentially recurrent in more detail.

3.6.3. Cluster Analysis

This section discusses the methodological aspects of Cluster Analysis (CA) without giving details of its characteristics and use. A complete description of what

Cluster Analysis is and how it was used in this case study can be found in chapter 7.

Reasons for choosing Cluster Analysis

After using Quantitative Analysis it became clear that a visual search in the sociomatrices could not be used to find any potential Recurrent Community of Practice within the Virtual CoPs. A detailed explanation of the problems that might occur if this methodology was used in the complete dataset is available in chapter 7, section 7.1 (Introduction), on page 151.

Due to this limitation it was necessary to find a more reliable methodology capable of dealing with a large amount of data without problems. In addition, the technique needed to be mathematically strong, well-tested and capable of detecting patterns in large datasets. Cluster Analysis (Burns & Burns, 2008; Chatfield & Collins, 1980) was seen as the ideal tool for these cases, as it is well-known and used in several different areas where pattern detection is necessary (e.g., for studies of market behaviour in business).

The main objective of this attempt was to use Cluster Analysis to detect the patterns typical of Recurrent CoPs, as shown in figure 5.3, on page 113, in the model of activities generated by the four newsgroups's communities already detected as CoPs by Murillo.

The use of Cluster Analysis

The details of the use of Cluster Analysis can be found in chapter 7, but it is possible to give a brief summary of the use of this technique.

SPSS (2010) was used to run Cluster Analysis on the data, and once again an initial test was carried out on a sample of 12 weeks of the complete dataset. The objective was the same as the previous methodology, i.e., to check if the results could indicate that the method was suitable for finding Recurrent CoPs within the 4 chosen newsgroups (VCoPs). This initial test is described in section 7.7, on page 155, and the result is shown in figure 7.3, on page 158.

The test showed that is was necessary to remove core nodes and *noise nodes* (nodes with a low level of activity) because the resulting dendrogram was too crowded with groups, making it difficult to reach any conclusion.

New tests were run with variations of the dataset, resulting in different conclusions in each case:

- One test without core nodes and noise nodes: the result lacked meaning due to the small size of the dataset (see section 7.8, on page 160).

- Four tests with artificial recurrent nodes: the artificial nodes were detected up to the limit of four inclusions (see section 7.9, on page 161).
- Two tests running a deep analysis of the original matrix, but without core nodes and noise nodes (see section 7.10, on page 170): a few nodes from different clusters were talking, which excluded the possibility of a tight subgroup within the main CoP. Additionally, the second test showed a high level of communication among some specific nodes (not core nodes).
- Two tests with the complete data from 52 weeks of a specific newsgroup (see section 7.11, on page 173): the resultant dendrograms were too crowded with clusters to lead to any conclusion.

Although Cluster Analysis could not help to verify the existence or not of Recurrent CoPs within the newsgroups, it showed that it has some strong points that helped in this research. In the following section these points are listed, together with its weaknesses.

Strengths and limitations of Cluster Analysis

Some Cluster Analysis characteristics have already been discussed previously or are presented in chapter 7; however, a summary of them can be produced. Its strengths can be listed as:

- Tests using different techniques are easy and cheap to be carried out, the only requirement being that the data be adequately prepared to be used by the CA program.
- The visual results make it easier to find patterns, as the clusters are easily noticeable
- It can used with data that has a large number of independent variables.

Cluster Analysis limitations can be listed as:

- The requirements to process a large amount of data can be machine and time demanding.
- The resultant dendrogram depends of the nature of the data used, thus sometimes the result might not be easy to read, or might lack meaning (as occurred with the test in the sample).

- The preparation of the data to be used in the Cluster Analysis program can be time consuming and complex, depending on how the collected data is presented.

3.6.4. Social Network Analysis

Social Network Analysis (SNA) (Scott, 2000; Wasserman & Faust, 1994) is another well-known method, commonly found in the social science area. SNA represents the social ties among individuals that belong to groups through graphs called *sociograms* (see figure 8.1, on page 180). A more detailed explanation about what Social Network Analysis is and how it works can be found in chapter 8, section 8.2 (SNA and RCoPs), on page 179.

Reasons for choosing Social Network Analysis

After several tests it became clear that it would not be possible to find any Recurrent CoP, or even a group with similar behaviour (i.e., with the same pattern of activity/inactivity) in the newsgroups through the use of Cluster Analysis. Detailed information about the tests and outcomes can be found in sections 7.7 (on page 157), 7.8 (on page 159), 7.9 (on page 161), 7.10 (on page 170) and 7.11 (on page 173).

The problem was not related to the methodology or to the tool used, but rather to the inherent characteristics of the four VCoPs studied. Thus, it was necessary to try a different approach, preferably one that has already been tested in newsgroups and CoPs. The most adequate option was to apply the visual tool successfully used by Murillo, which is also commonly found in studies of groups and communities: *Social Network Analysis (SNA)* (Scott, 2000; Wasserman & Faust, 1994).

Social Network Analysis was an efficient tool for this case study as it showed the social ties among groups' participants via graphs called *sociograms*. In these graphs the connections between nodes (the social ties) can represent preferences, friendship, or any type of relationship between persons, and in this study they represented the messages exchanged between the participants.

Because Social Network Analysis uses graphs as the foundation for the analysis, it allows the use of the metrics found in graph theory (betweenness, centrality, density, etc.). However, in the specific case of this research, a much simpler approach for the SNA was adopted. A combination of the visual aspect of the Social Network Analysis and the Quantitative Analysis of the socialmatrices was used to detect the presence of Recurrent CoPs.

The use of Social Network Analysis

Although available in SNA, metrics from graph theory cannot be used to search for Recurrent CoPs, as such a search is based on the pattern of the communities' activities over time, and in these metrics time is usually considered a fixed component, making them inadequate for this case study.

Another issue when using SNA in newsgroups is that the available programs that run Social Network Analysis only started considering time as a variable component in their latest versions, and in the majority of the cases, only in alpha or beta versions. A deeper discussion of the time issue in SNA programs can be found in section 8.3, on page 181.

Due to these two factors it was decided to use only the visual part of the SNA programs, which shows the changes in the nodes' connections over time. This part was available in the selected programs used in this study and it is also described in section 8.3, on page 181.

This simple approach made it possible to select only the sociograms and their changes over time, as a way of study. This means that looking at how the edges in the graph changed with time was enough to tell if a recurrence was present in the studied period. This technique is presented in more detail in section 8.5, on page 196. Also, sociomatrices were used as a way of analysing the dataset, learning about the behaviour of the VCoPs and preparing the data for the SNA programs (see section 8.4, on page 189 for more details on the steps used during these processes).

The combination of SNA and analysis of sociomatrices proved crucial for the discovery of the *Transient Core Members (TCMs)*. The members that were classified as part of TCMs presented a very peculiar behaviour, acting as core members for a specific and short period of time, but contributing immensely as a whole to the community's life. The discussion about the results of using SNA can be found in section 8.5, on page 196.

Although a crucial tool for this research, Social Network Analysis has its drawbacks, thus it is important to present the benefits and problems found when using it. This is accomplished in the following section.

Strengths and limitations

Social Network Analysis was chosen to solve the problem of verifying the existence of Recurrent CoPs within electronic networks due a series of factors, such as:

- Similarly to Cluster Analysis, Social Network Analysis is appropriate to study groups of people, even when the amount of available data is very large.
- Its strong visual component was the perfect tool for the search for RCoPs.
- Its flexibility made it possible to run several tests with few modifications in the dataset, allowing a thorough analysis of the VCoPs.

Naturally, Social Network Analysis is not perfect and presented some limitations that needed to be overcome. Examples of these are:

- All programs used were in the beta or alpha stage of development because the SNA programs only started using time as a variable component recently, releasing only unstable versions of these programs. Perhaps this limitation will disappear with the popularisation of this feature.
- There was not a single SNA program (or version of it) with all the needed features, thus it was necessary to run several tests in different versions of the programs to find a combination that could accomplish the necessary steps for the analysis. The solution was to use two different programs to combine the analysis and reach a conclusion.
- The lack of software documentation due to the fact that alpha and beta versions of the SNA programs were used, making it very time-demanding and only feasible through a trial and error approach.

All things considered, despite the difficulties of using SNA, the problem of searching for RCoPs within electronic networks was finally solved.

3.7. Combining methods

This chapter described a series of different methodologies that were used to help accomplish the research objectives. They are listed in table 3.1, where a summary of the type of community studied, the research methodologies used and the findings of each case study are shown.

However, it is important to explain the rationale for the choices and combinations of the research methods used. As demonstrated by table 3.1 each new case study increased in complexity, requiring different methodologies and/or a combination of them to complete each study successfully.

Case study	Community studied	Research method	Findings
1st study	Co-located	Structured interview	CoP detected
2nd study	Co-located	Grounded Theory Semi-structured interview	Recurrent CoPs
3rd study	Virtual CoP	Quantitative Analysis Cluster Analysis Social Network Analysis	Transient Core Members

Table 3.1.: Summary of the methodologies used in each case study and their findings

The first case study needed only a single method (structured interview) to confirm the existence of a Community of Practice within a co-located community. However, the study showed that there was a great amount of information about the community that was not addressed by the methodology employed, thus requiring another case study with a different approach capable of capturing and understanding this information.

The second case study was designed to deal with this issue and required a methodology capable of building a theory that explained the CoP's functioning, but that was solely based on the collected data. Grounded Theory is the ideal tool for these cases, but to provide the necessary data for GT it was necessary to use a type of interview that allowed the participants to speak freely. Semi-structured interviews allow this type of development, and were consequently chosen for the case study. At the end of the study it became clear that the combination of these two methods was successful and did not only result in the creation of a theory that described the main aspects of the CoP discovered in the first case study, but also revealed a new type of Community of Practice: the *Recurrent CoPs*.

This discovery led to consideration of the question of whether or not RcoPs existed in other communities or even in other environments, therefore a third case study was organised to try to answer some of these questions. It was decided to run a test in a completely different environment, but with one aspect in common with the workplace analysed in the first and second studies: the use of Computer-Mediated Communication (CMC). As the employees of the Psychology Network used CMC heavily, it was decided to investigate whether Recurrent CoPs could be found in an environment completely based on CMC. In order to have such an environment a large dataset containing the communication of four certified (virtual) CoPs was acquired (see section 6.3.2, on page 130, for more details about the dataset and the steps taken for its preparation for analyses).

At this point it is important to highlight that Grounded Theory could not be used in the dataset, despite its great success in the second case study. This is because, although the dataset contained all messages exchanged in the newsgroups, such messages did not discuss the participants' membership in the forum, nor did they explain how the participants relate to each other. Instead, the messages, as might be expected, contained the usual discussion about the themes of concern to the newsgroup. It was therefore necessary to use the community's activity, represented by the flow of messages, to study those relationships. This meant tracking the sender and the receiver of each message in the newsgroup's activity. The messages' content was only relevant to study the behaviour of specific participants (e.g., core nodes) and to guarantee that the message was not *spam*[2]. This tracking resulted in a visual description of the community's functioning, providing a picture of how the group worked as a CoP, and allowing analyses to be carried out, which ultimately made possible the search for Recurrent CoPs.

During the initial analysis of the dataset it was decided to verify if a RCoP could be located by a visual inspection of the socialmatrices that described the four CoPs, thus Quantitative Analysis of a few samples of the dataset was used. This analysis showed that a visual inspection would not be enough to detect RCoPs in the analysed newsgroups. It was necessary to use a method that could detect patterns created by groups spread in a large dataset, thus Cluster Analysis was chosen as an ideal solution for the problem. However, after several months of unsuccessful attempts it became clear that another tool had to be found to replace Cluster Analysis. After long deliberation Social Network Analysis was selected to detect the RCoPs, but unfortunately this did not happen. However, with the combination of the SNA and the Quantitative Analysis of the dataset, it was possible to detect a previously unseen behaviour in some participants of the studied VCoPs: some of them acting individually were responsible for a great part of the activities of the community, but this could only be noticed if all participants with the same behaviour were seen as a whole.

At the end of the research it was noticed how valuable the methods applied were individually, but that sometimes only a combination of them could solve a problem, and that without such an arrangement it would be very hard, if not impossible, to reach the same outcomes in this research. It is very unlikely that a single method used in each case study separately could have discovered the Recurrent CoPs and the TCMs.

[2]Unwanted e-mail (usually of a commercial nature sent out in bulk).

3.8. Conclusions

In the introduction of this chapter it was explained that it was necessary to choose methodologies that could help to study the dynamic of a CoP's life. The capacity to deal with time was one of the main aspects searched for in the methodologies, as it was necessary to understand how time influenced the inner functioning of CoPs. Through a careful search this objective was addressed and it was possible to discover several new aspects regarding Communities of Practice and the influence of time on them.

Each case study required a careful selection of methodologies, and in some cases only a combination of them could deliver a coherent result. The simplicity of the preliminary study allowed a straight result with the help of a simple structured interview. It is no surprise that this is the most common method for qualitative research (Myers & Newman, 2007), and it proved itself very efficient. However, this does not belittle the achievement of using Wenger's list of indicators that a CoP had been formed to detect a CoP in a co-located workplace. Very few similar studies were found in the literature.

Nevertheless, this first study was the trigger for something more challenging: the quest to discover how a CoP worked. This objective drove the researcher to tests and studies to try to find the best methodology to know more about the CoP discovered in the first case study. In this second study two methodologies helped to uncover the secrets hidden inside the discovered CoPs: semi-structured interviews and Grounded Theory (GT) (Corbin & Strauss, 2008; Glaser & Strauss, 1967; Strauss & Corbin, 1998, 1990). Once again the study raised more questions about the nature and existence of the RCoPs, thus inducing the creation of a new case study.

In the third case study the search for RCoPs within electronic networks led to a set of attempts to achieve an answer for the question. After successive tests two methods were chosen to help in the search: Social Network Analysis (Scott, 2000; Wasserman & Faust, 1994) and semi-structured interviews. This new study, although not successful in finding the RCoPs in electronic networks, was able to discover a novel characteristic found in Virtual CoPs: the Transient Core Members. The TCMs represent a great potential for the creation and maintenance of a VCoP's life.

All this would be impossible if not with the help of these carefully chosen methodologies.

In the following chapters the studies using the methods described here will be discussed in detail.

4. Preliminary Analysis of the Psychology Network

4.1. Introduction

This thesis initially set out to find nascent Communities of Practice, or 'hidden' CoPs. The intention was to find potential CoPs and study the possibility of helping to move them to fully developed CoPs, and for this aim, time was important. It was necessary to understand their development in time, from emergent to actual CoPs. Different communities, co-located and virtual, were briefly and informally analysed.

Firstly, it was noticed that in some environments even this division was blurred. This is mainly due to the ubiquity of electronic networks these days. The same happened with the concepts of distributed and virtual, where distributed became as normal as co-located, and virtual began to be part of co-located communities, even among local members (Roberts has already discussed these issues (Roberts, 2006, p. 631)).

After looking elsewhere, it was decided to study the researcher's workplace. As an employee of the Higher Education Academy Psychology Network (*Psychology Network*, for short), the researcher began to pay attention to the environment.

It was noticed that the Psychology Network had several communities, perhaps due its nature[1]. Moreover, it was also noticed that even the workplace formed a community. Therefore there was a possibility that among all these communities, some of them could be considered a Community of Practice. However, it was needed to be sure that this was the case, thus it was decided to study this possibility further.

This chapter describes a study carried out in the Psychology Network to confirm that its employees formed a Community of Practice. This was done through a structured interview study performed with a questionnaire based on Wenger's indicators that a CoP has formed. (Wenger, 1998b, pp. 125–126).

[1] A detailed description of the Psychology Network and its communities is presented in chapter 5.

4.2. The study

As explained previously, this study aimed to confirm that the employees formed a Community of Practice. They showed cues that they had formed several communities, internally and externally, but a formal confirmation was necessary for at least one, and the internal community seemed to be the more promising for this.

The environment

The Higher Education Academy Psychology Network (also known as the *Psychology Network*) supported the teaching and learning of psychology across the U.K. A core team, based at the University of York, worked with students, staff, departments, professional bodies and overseas organisations to develop supportive networks and to improve the learning experience of psychology students in Higher Education. The choice to undertake studies in this workplace came for two reasons.

The first is that the Psychology Network naturally supported and nurtured several different thematic communities within the area of Psychology throughout the U.K., being because this, a source for potential CoPs.

The second reason is that the researcher was an employee of the Psychology Network until its close in October 2011. This allowed to have the support of the director and the employees, which provide invaluable opportunities to freely study the internal communities maintained by the institution. In addition, this freedom even made it possible to study the workplace shared by the employees.

Two studies were implemented in the Psychology Network involving the employees and their workplace. However, only the first one is discussed in this section. The second study is explained in chapter 5.

The Objectives

The study was targeted to confirm the existence of each indicator in Wenger's list from his work of 1998 (Wenger, 1998b, pp. 125–126). For this, a series of structured interviews with each employee was performed. During these interviews each item was approached in an indirect way, although there was an attempt to keep the interview as close as possible to the issue discussed in each item. The intention was mainly to find out whether Wenger's list could confirm the existence of a Community of Practice within the Psychology Network. If successfully confirmed as a CoP, a deeper analysis could be carried out later on in the CoP to discover more about it.

The complete material (questionnaires and indicators of existence of CoP) used in the study can be found in appendix A.1.

The Method

Wenger, using the concept of *reification* (Wenger, 1998b, p. 57), created a list of indicators that a CoP had been formed. The list consisted of the following:

1. Sustained mutual relationships – harmonious or conflictual
2. Shared ways of engaging in doing things together
3. The rapid flow of information and propagation of innovation
4. Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process
5. Very quick setup of a problem to be discussed
6. Substantial overlap in participants' descriptions of who belongs
7. Knowing what others know, what they can do, and how they can contribute to an enterprise
8. Mutually defining identities
9. The ability to assess the appropriateness of actions and products
10. Specific tools, representations, and other artefacts
11. Local lore, shared stories, inside jokes, knowing laughter
12. Jargon and shortcuts to communication as well as the ease of producing new ones
13. Certain styles recognized as displaying membership
14. A shared discourse reflecting a certain perspective on the world

These items verify the existence of the three main components of a CoP: *mutual engagement*, a *joint enterprise* and a *shared repertoire*. Section 2.9 (on page 45) presents a detailed discussion of Wenger's 14 indicators. To confirm the existence of a CoP, qualitative research methods were used. A semi-structured interview was carried out in the workplace, to discover the existence of 11 of the 14 items. Items 6, 8 and 14 were excluded from the interview, as they were not applicable to the chosen environment. This is due to their nature. Indicator 6 ('Substantial overlap in participants' descriptions of who belongs'). These exclusions should not affect the overall research as the list is not rigid, and some items are used to verify the same characteristic. The interview was applied to the staff (seven participants, excluding the researcher) and the results are as follows.

The results

The answers received are listed in table 4.1.

Items	*Participants*						
	1	*2*	*3*	*4*	*5*	*6*	*7*
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Yes	Yes	Sometimes	Yes	Yes	Yes	Yes
4	No	No	No	Sometimes	Yes	No	No
5	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11	Yes	Yes	Yes	Yes	Yes	Yes	Yes
12	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 4.1.: Answers to the interview conducted during the first study

The first point to notice is that all of the answers are consistent, clearly showing an agreement with Wenger's indicators. The only item that shows some diversity is item 4 ('Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process'). The interpretation of this item can be a bit confusing and can lead to misunderstandings. The different answers might be the result of a lack of understanding or it might just represent a different opinion on the issue. It is not possible to reach any conclusion based only on the answers received.

Using only the indicators as a base, the results show that the participants have the beginning of a strong co-located CoP. Moreover, the three dimensions verified are apparent. Mutual engagement, represented by items 1, 6, 7, 8, 9, 13 and 14, is present for all participants. Joint enterprise, represented by items 4 and 5, is strongly represented in the community (the exception is question 4, discussed previously). Finally, a shared repertoire, represented by items 2, 3, 10, 11 and 12 is again very significant.

At the end, this study generated several questions. It was not clear that the list of indicators had been enough to confirm the existence of a Community of Practice. Maybe the important aspect present is the underlying existence of the three main components (*domain*, *community* and *enterprise*). Additionally, in some cases, a few items needed to be excluded, and in others, the understanding was not complete. These added extra doubts about the efficacy of the whole list. Wenger (1998b) did not detail the use of the indicators, resulting in a series of unanswered questions.

Although the indicators could be used to classify a community as a Community of Practice, considering its limitations and problems, they were not sufficient to be used as the only form of search for CoPs. A more detailed analysis was required.

4.3. Conclusions

This study has demonstrated that it was necessary to use more sophisticated techniques to search for Communities of Practice. Using Wenger's indicators alone was not enough to capture all the necessary information to discover CoPs. Although useful in situations where the community is already known, they cannot replace a more detailed study.

However, for what was expected, the methodology accomplished its objectives. It confirmed the existence of a Community of Practice not only because of the similarity in the answers to the listed items, but also because of the cues that appeared during the interviews, showing signs of the three main characteristics expected in CoPs.

This study was the main driver for the implementation of the second study in the Psychology Network.

5. Grounded Theory of Recurrent Communities of Practice

5.1. Preamble

All the studies on co-located CoPs in this research have been carried out in the Higher Education Academy Psychology Network, or Psychology Network for short. This was due to the fact that the researcher was a member of the organisation, where he worked as Computing Officer[1]. It was also due to the fact that the Psychology Network gave support to several different communities related to the area of Psychology. This represented a rich environment, where it was very likely that Communities of Practice could be found.

However, the major surprise was to discover the existence of a Community of Practice not among the supported communities, but rather among the staff. When the first case study (see chapter 4) was performed among the Psychology Network staff, it intended only to verify a suspicion that a CoP could exist among the employees. However, it turned out that the study detected strong signals of a fully developed Community of Practice.

It is very interesting that this Community of Practice existed despite the lack of awareness of its participants. Furthermore, the workplace held a combination of several different types of CoP. It was a co-located CoP, as most of its members worked at the same workplace. It was a VCoP, as they heavily used Computer-Mediated Communication (CMC) to keep the community working, and finally, it was a Distributed CoP, as they worked with members in different locations (even abroad). This made the situation very fortunate.

In addition to this, the employees and the organisation's managerial level readily agreed to help on all occasions when the studies were performed. This happened despite the fact that such studies could bring about, as they did, some disturbance to the normal work environment.

[1] All subject centres in the U.K. linked to the Higher Education Academy started the procedures leading to their official closure on the 31st of July, 2011. The Psychology Network closed on the 31st of October, 2011.

The rich environment allowed the pursue of two studies related to the search for understanding CoPs. In addition, the second study showed a completely unknown type of Community of Practice.

5.2. Introduction

This research aimed to understand CoPs' behaviour better, mainly in relation to the temporal aspects of their life.

The previous case study showed strong indicators that there was a Community of Practice inside the Psychology Network. This CoP was formed by the employees and had the characteristics commonly found in CoPs as defined by Wenger (Wenger, 1998b).

The following step was designed to create a theory that could explain the CoP's behaviour and motivations. The tool used for this was Grounded Theory (GT) (Corbin & Strauss, 2008; Strauss & Corbin, 1998). Once again the case study was implemented in the Higher Education Academy Psychology Network.

At the end of the study a new type of CoP was discovered. It was named *Recurrent Community of Practice (RCoP)* and it is detailed in this chapter.

5.3. Objectives

The main objective was to develop a set of hypotheses using Grounded Theory that could explain the main characteristics of the Community of Practice noticed in the previous study (chapter 4). It was expected that the theory could identify aspects of the forces behind the formation and behaviour of the CoP.

An extra objective, decided after the beginning of the data analysis of this study, was to develop the initial analysis of the *Recurrent Communities of Practice (RCoPs)*. These special CoPs have never been studied before and deserved a preliminary discussion.

5.4. Detail of the context

The case study was carried out in a specific context, so this might have influenced some of the results. The literature generally contains case studies in places where one single community is working towards one specific goal (Kimble & Hildreth, 2005; Lave & Wenger, 1991; Wenger, 1998b; Wenger et al., 2002), which usually does not result in the creation of other communities. However, the Psychology Network was different. Its objective was, among other things, to nurture Communities of Practice. Therefore, there was a tendency to work with and in communities.

However, this does not seem atypical in current workplaces, due to the common tendency of having several projects running at the same time, which in consequence leads to time allocation in slots and the formation of working groups or teams, which in some cases can lead to the formation of a CoP.

The venue was an academic environment which supplied resources for a wide range of activities for teachers, practitioners and students of Psychology in the U.K. The Psychology Network worked with several external communities, which in general had different working patterns. Sometimes they used Computer-Mediated Communication (CMC), and sometimes they held face-to-face meetings.

5.4.1. Structure of the organisation

The work environment for the Psychology Network was an open-plan office. It contained individual desks for each of its employees, who worked on individual computers. They had an Intranet and a shared file server. They communicated by email or face-to-face. They had regular staff meetings where common goals, individual issues and shared enterprises were discussed. All but two of the employees had a 'working at home' day, where they could perform the normal work load from home. The two exceptions to this procedure were the secretary and the researcher.

Within the Higher Education Academy, the Psychology Network had the structure represented in figure 5.1, on page 102. Its organisational structure was also simple. This structure is shown in figure 5.2 (also on page 102).

Two members of the Psychology Network worked in different locations. The first of them worked in Scotland. She was the representative of the Psychology Network in Scotland and worked with Scottish projects linked to the Psychology Network. The second one worked in Australia. She worked mainly on projects related to disabled psychology students, although sometimes she worked with the Psychology Learning and Teaching (PLAT) conference and with the PLAT journal, as a reviewer. Even though these two members were located in different venues from the Psychology Network, they worked in a similar way to the other employees, having communication based on CMC and face-to-face meetings, and also using the common resources, such as the Intranet.

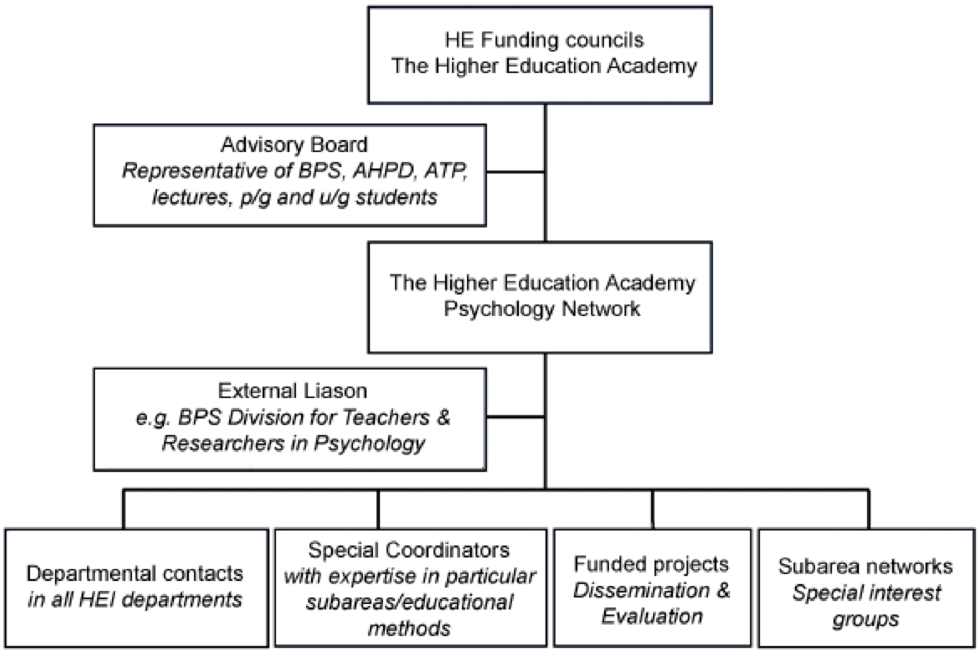


Figure 5.1.: Administrative structure of the Higher Education Academy Psychology Network

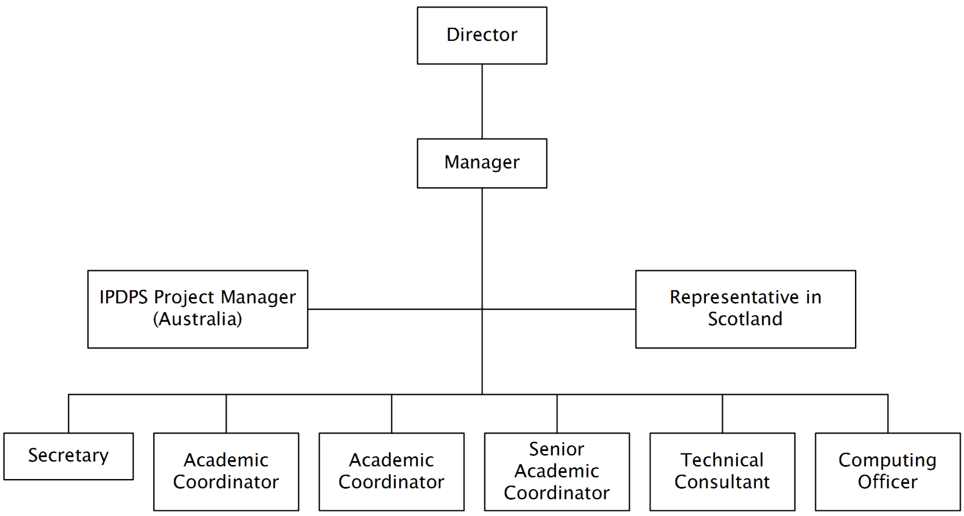


Figure 5.2.: Internal structure of the Higher Education Academy Psychology Network

5.4.2. Examples of normal activities within the organisation

The Psychology employees had a set of common activities that ran regularly. Examples of such activities are:

Psychology Student Employability Guide (an electronic and paper publication) This was a publication from the Psychology Network intended to help new graduates in Psychology to find a job after leaving University. This was created in two forms: a printed version that was sold and an electronic version, available free of charge. For the completion of the Guide, the Senior Academic Coordinator set up different communities to work on different parts of the project. A small work group was formed to create the content. This group was formed by the Senior Academic Coordinator and other experts in the field, from different Psychology departments (in different institutions). They communicated mainly by CMC. After completion of the separate parts, the Senior Academic Coordinator worked with an internal publisher to create the electronic version of the publication.

A tri-monthly newsletter sent to all registered institutions that run Psychology courses This was a regular publication intended for all psychology students and professionals related to the teaching and learning of psychology within Higher Education, and it was sent to all psychology departments in the U.K. that had requested it. The Newsletter was a three-monthly publication, which required a period of (approximately) two months to be produced. The initial phase began with an email notice from the Manager informing recipients that all material that was intended for the newsletter needed to be sent. The Manager organised the content, together with the Director and one of the Academic Coordinators. After completion of this part, the Manager worked with a publisher/designer who worked from abroad, and with the Computing Officer, to create the electronic version of the newsletter. In its final phase it was sent to an external professional printer and it was also available on the Psychology Network website. Everybody in the Psychology Network read the final version, proof checking it for errors or mistakes. Soon after the release, the whole process started again to create another issue of the publication. Approximately 4,000 copies of the newsletter were delivered after its completion.

Psychology Learning and Teaching journal (also known as 'PLAT journal') This publication aimed to inform people about and encourage good practice in the teaching and learning of Psychology within Higher Education. It circulated free to all lecturers in the U.K. who wished to receive a copy. It was primarily a publication for practitioners, aiming to encourage scholarly approaches to learning and teaching in psychology. This was a project led by one of the organisation's Academic Coordinators, who worked with the Director and a group of external experts. The journal was released twice a year and during the preparation involved experts in different areas of psychology to review its content. The Academic Coordinator also worked closely with an external professional publisher to create the electronic version of the journal, which when finished was sent to a professional printer. Later the electronic version was made available on the Psychology Network website.

Psychology Learning and Teaching (PLAT) conference Every two years, the Higher Education Academy Psychology Network organised a forum for the transfer and take-up of knowledge and practice within undergraduate and postgraduate psychology teaching, learning and assessment. Its major aim was to bring together: lecturers and postgraduates teaching psychology; support staff working with psychology departments; researchers in the teaching of psychology; organisations implementing policy related to teaching in Higher Education and developers and publishers of psychology resources. On average the conference had an attendance of 150 delegates. The conference was led by an Academic Coordinator, who worked with all the members of the Psychology Network. The activities involved were varied and required different groups and skills in the course of two years. Examples of such activities are:

- Website: The Academic Coordinator worked in conjunction with the Computing Officer to develop the website.
- Speakers, chairs and VIPs: The Academic Coordinator, working with the Manager, the Director and other Academic Coordinators, decided who were the best experts in psychology learning and teaching to invite as special guests for the conference.
- Programme: The Academic Coordinator worked with the Manager, Director and the other Academic Coordinators to develop an attractive programme that could fulfil the delegates' expectations.
- Paper reviewing: Academic Coordinators, Director, Manager and (external) experts in the field worked together to review and choose the best papers for the conference.

- Conference proceedings: The Manager, Academic Coordinators and Director, working together, created an electronic version of the proceedings, which was later sent to an external professional printer, who created the final paper version.

- Venue: The search for the best option of venue in the U.K. for the conference was divided among the Academic Coordinator, Manager and Director. Later the final choice was decided at a meeting with all the members of the Psychology Network. In the following months, activities related to the venue were divided among the employees (conference dinner, walking tour, etc.). These would consequently generate other activities, requiring different allocations of participants (internal and external to the organisation) and a different schedule.

Psychology related events – workshops, meetings, conferences One of the main activities of the Psychology Network was to organise events related to Psychology Learning and Teaching in the U.K., therefore several workshops, meetings and conferences were supported by the organisation. These events were mainly led by the Academic Coordinators, who created the programmes, allocated venues (usually in different institutions), contacted external experts in the areas, chaired the events, prepared the relevant material, and in conjunction with the Computing Officer created the web pages for the events. Some of the events were organised for special interest groups that evaluated the requirements, participated in the events and produced the final report, which was later published on the website, together with other materials related to the event.

Psychology special coordinators and networks The Higher Education Academy Psychology Network offered support for individuals (sometimes called 'special coordinators') and self-sustaining networks that were aligned with the aims of the Psychology Network. These groups were formed by communities that needed support to develop their activities. Examples are: *Teaching qualitative research methods at undergraduate level in psychology (TQRMUL)*; *Using e-learning in clinical psychology programmes*; *Primary care graduate mental health workers*; *Regional networks for postgraduates who teach (PGwT)*; *Psychology network mental health group*; *Teaching social psychology network*; *Supporting the teaching of health psychology and supporting the teaching of cognitive science*. These groups had different levels of activity and requirements depending on their size and area. Usually the Academic Coordinators liaised with them to provide support. They commonly had a mini-website related to their group within the Psychology Network's main website. They also organised regular events for their members. Sometimes they provided a set of common resources (shared repertoire) and information on their mini-websites. These special coordinators and networks also worked closely with the Manager, Director and the Computing Officer.

Psychology Postgraduates who teach (PGwT) The Postgraduates who Teach (PGwT) Network was intended for psychology postgraduate students with teaching-related responsibilities. Regional groups operated in seven parts of England, Wales, Scotland and Northern Ireland. The PGwT offered support through workshops, email discussion lists, web resources, bursaries and awards. This group was a special case of the 'psychology special coordinators and networks' described previously, and worked closely with the Senior Academic Coordinator, who managed the seven regional coordinators. They had individual schedules for each of the seven regions, having related events with similar requirements and activities to the 'psychology related events', discussed previously. In addition, the PGwT group had a mini-website with material for the students and for the regional coordinators in separate areas. Because of this, the Senior Academic Coordinator and the regional coordinators worked closely with the Computing Officer.

Psychology related website – updates, amendments and mini-websites The Psychology Network provided a significant number of resources related to the teaching and learning of psychology in several different forms. One of them was via its website. Owing to the constant development of learning practices, the website needed frequent updates. This task was undertaken by the Computing Officer, who worked together with each member of the Psychology Network, sometimes individually and sometimes in groups. Examples of the activities related to the website are: advertisements for new grants, updates to guidelines and inclusion of new material related to special coordinators and networks. Another activity related to the website was the maintenance of the mini-websites that were created and updated when requested by the leaders of special networks, Academic Coordinators, or by the Manager or Director. These functions involved working with several different communities.

The Psychology Network Repository of Student Practicals (RoSP) The Psychology Network Repository of Student Practicals (RoSP) provided access to an on-line database of materials and resources to support student practical work and the teaching of research methods within psychology at undergraduate and postgraduate levels. The person in charge of this resource (an Academic Coordinator) needed to update and improve it continually with the help of the other members of the Psychology Network and occasionally with external persons.

Projects funded by the Psychology Network Throughout the year several projects were funded by the organisation. Each project was related to an external person or community that was searching for funds to develop some project related to the teaching and learning of psychology in the U.K. Although all the projects were different in nature, they were all required to follow a set of procedures and to have a 'contact' in the Psychology Network. This contact could be any member of the organisation who had experience and/or interest in the project. These contacts worked closely with the person(s) responsible for the project, helping, guiding or giving advice that could help the completion of the project. In the end each project would generate one report describing the whole process and the outcomes of the enterprise. Sometimes a project could require the work of more than one member of the organisation to accomplish its goal. One example of this is when it was required that a mini-website be created for the purpose of delivering information or collecting data (e.g., on surveys). In this case the Computing Officer was asked to join the working group to develop such a website. In other cases a project required a paper publication as its outcome, therefore the publisher/designer (who worked from abroad) could be asked to participate.

5.5. Methodology

The methodology chosen for the study was Qualitative Research Methodology, specifically Grounded Theory (GT) (Corbin & Strauss, 2008; Strauss & Corbin, 1998). A detailed explanation of the GT method can be found in section 3.5.1, on page 72.

Grounded Theory allows the creation of a theory that is developed from the data, assembled and analysed via the process of research. Through this method the data is recursively analysed to identify embedded categories and concepts. This is done by the use of open coding, which identifies concepts and their properties and dimensions, classifying these in *codes*.

During the case study the start of the process of data analysis was difficult, as it was not possible to make relations between the codes, thus *Microanalysis* was used as a technique to help overcome this difficulty. This technique uses detailed analysis of each line of the transcription of the interview to outline the initial categories and their respective properties. With the help of microanalysis, the categories emerged and it was possible to carry out the complete analysis.

The case study involved informal semi-structured interviews with five of the seven Psychology employees. The exceptions were the Director and one Academic Coordinator. In the first case, this was due to the involved role in the structure of the organisation (as explained in section 5.5.1), and in the second case it was due to the lack of available time. The interviews were digitally recorded and later transcribed. Three initial interviews were transcribed by the researcher, in order to understand the whole process of analysis, and the two remaining ones were done by a professional transcriber.

During the analysis some issues required further questioning with some of the staff members in order to clarify some findings. This produced a better and clearer idea of the functioning of RCoPs.

Additional findings that could not be included in the listed categories are discussed afterwards, in order to give a better understanding of the overall behaviour and functioning of Recurrent Communities of Practice.

5.5.1. Time schedule

As far as the time schedule for interviews was concerned, there was a delay caused by the difficulty of scheduling time with the Psychology Network staff. The intention was to study the entire staff over a two month period; however, it was extremely difficult to schedule time, which resulted in the first interview happening in August 2008 and the last in February 2009. Also, it was not possible to interview two people. In one case this was because it was repeatedly impossible to schedule any time for the interview and in the other case, because the Director was intentionally excluded from the chosen group, owing to the managerial nature of the role, and also to the lack of time available for an interview. Although the Director worked in several RCoPs, the role was different in those, acting more at a managerial level. In contrast, the Manager was included owing to the important role he played in the community's daily activities, contributing and participating significantly. With the majority of the interviews already finished, it was decided to cancel the remaining ones in order to complete the case study.

There were, however, extraordinary cases that were not included in the list of participants.

In one case, the person left the organisation before the beginning of the interviews. That person could have contributed to the findings, but unfortunately it was not possible to carry out the interview in time. It is believed that this did not affect the overall results.

Three other cases that were not included relate to members who were not located in England (one lived in Scotland, one in Australia and one in Brazil). This happened because, during the interview period, the target community was co-located, and in the excluded cases the members worked in other institutions and only established contact when participating in a project. To carry out the interview with them, the circumstances would be different from the original community, thus the questionnaire would need to be updated and the interview would need to happen via CMC, preferably by teleconference. It is not clear how much these changes would have affected the current findings and if the mixture of co-located and virtual would be acceptable. If, on the one hand, the Psychology Network contained a diverse and flexible set of communities (co-located, VCoP and mixed), the internal members had face-to-face contact on a daily basis with the other members, whereas the excluded members did not.

5.5.2. Environment and preparations

Care was taken not to disturb the normal routine of work in the Psychology Network during the period of the interviews. The intention was not to interrupt the members' normal activities, nor to increase the burden of their normal workload. In all cases the time used in the interview was counted as time worked, which helped to reduce the stress related to the use of their working hours. The rooms used for the interviews were private and with good environmental conditions, to avoid any stress caused by discomfort.

On average each interview ran for 45 minutes, but in one case it took only 30 minutes and in another 1 hour and 10 minutes. All interviews were recorded with the authorisation of the interviewees and were transcribed for later study. Of these, three interviews were transcribed by the researcher and the other two by professional transcribers.

Special care was taken to guarantee that the interviewees received all necessary information regarding the case study, without compromising the collection of data. Standard ethical procedures were followed via an introduction script (available in appendix A.2.2). In addition, all participants signed a consent form before the beginning of the interview.

5.5.3. Questions used during the interviews

Having the main objective of to study in mind, a plan was traced to perform a detailed analysis in the newly discovered CoP. Using the questions applied in the first study as a foundation, Grounded Theory would be used to discover the inner aspects of the community.

Interview schedule

The list of questions used reflected the previous discovery in the Psychology Network. Once again the questions were built upon the list outlined by Wenger in his work of 1998. The list contains 14 indicators that a CoP has been formed. These items verify the existence of the three main components of a CoP: *mutual engagement*, a *joint enterprise* and a *shared repertoire* (Wenger, 1998b) (see detailed discussion of Wenger's indicators in section 2.9, on page 45).

As noted earlier, Wenger did not explain the list thoroughly, simply describing it via his concept of *Reification*. Therefore, there is no exact definition of what he meant by the choice of terms and wording, nor which component of a CoP the item was meant to refer to. Because of this, it was decided on the target of some items and their consequent intention. It must be made clear, though, that all possible caution to avoid misinterpretation was used. The list of relations used is shown in table 2.4, on page 49.

Additionally, items 8 and 13 of the list could not be translated into questions, therefore they were translated as signals to be alert to during the interviews. This was owing to the fact that these items are not easily spotted in a workplace like the Psychology Network; thus it was decided to "be alert" in case any sign of them appeared during the interviews.

These items are very common in self-created CoPs, where a common identity is formed. CoPs within workplaces are different. These characteristics might appear or not. Notice, however, that they are not essential to this type of CoP, they are just extra characteristics. To detect similar behaviour in a workplace-related CoP, it is necessary to pay attention to the signals.

Moreover, the definition of *Identity* of a CoP described by Wenger is a joint creation. It is complex and it is intrinsically based on the practice of the community. He lists identity as *negotiated experience*, *community membership*, *learning trajectory*, *nexus of multimembership* and as *a relation between the local and the global* (Wenger, 1998b, pp. 149-163). In summary, it is possible to find these two items (8 and 13 in the list) in a CoP, but it is not a certainty.

Initial interview schedule The intention was to discover how the members worked with each other, regarding frequency and working style.

With this objective in mind, a schedule based on these factors was drawn up. The main concern was to avoid putting in people's minds the concepts found in Wenger's list, thus finding what was expected. Therefore, during the interviews conscious care was taken to talk to the interviewees with a sensitive detour towards those aspects, although avoiding direct enquires about them.

Toward the same goal, the questionnaire was used as a starting point, and as a marker to remember the main objectives. During the interviews significant effort was taken to allow the participants to describe the perspective from which the community is seen, leading to changes in the order of some questions as well as the inclusion and deletion of others.

The questions were divided following approximately Wenger's list. The questionnaire for this phase (*first phase*) can be seen in appendix A.2.3, on page 233.

Later interview schedule Following the Grounded Theory guidance, each interview influenced the following one. After analysing the answers in an interview, the subsequent one had the questions adapted to improve the gathering of information and to detect the formation of patterns in the answers, consequently bringing new insights to the research. Therefore, the list of questions was used as guidance only. New questions were introduced and/or removed when necessary, reflecting the dynamic nature of the interviews.

After running the interviews and updating the main questions/points to be used, the questionnaire became slightly different. The main core concepts from a Community of Practice were added as a main driver for the interview, not because these were not included before, but they were only a reminder, as during the interviews it could be easy to be driven away from the main core concepts.

The questionnaires for the second phase and the final one can be seen in appendix A.2.4 (on page 236) and in appendix A.2.5 (on page 239), respectively.

At this point the concept of Recurrent Communities of Practice started to appear, but it was not possible to include specific questions about them. However, it was possible to find references to them from all the interviewees during the analysis.

5.6. Analysis

The study looked for the already known and existing Community of Practice within the Psychology Network. The initial plan was to carry out a deeper study in this CoP and create a theory based on the findings. However, an overarching idea emerged. During the interviews it was possible to notice that there was more than one CoP in the workplace. The analysis showed that these CoPs represented a novel type of community unknown to the current literature.

The following sections will discuss their characteristics in detail.

5.6.1. Recurrent Communities of Practice

It was clear that all members participated in the already detected CoP, but they also participated in several smaller CoPs. These were mainly related to projects with defined deadlines and had activities only during a specific period of time. These special CoPs have been named *Recurrent Communities of Practice (RCoPs)*, due to their periodic nature.

Moreover, for the employees the shift between the CoPs was natural and hardly noticed. For them it was just a question of allocation of time to do another activity related to the job. However, a careful analysis shows the creation of those RCoPs and their related activities during certain periods of time. It is also noticeable that those communities had periods of inactivity.

The term 'Recurrent CoP' describes a Community of Practice that is *constant*, *recurrent*, *active* and fits *Wenger's CoP model*. This means that the CoP is:

- *Constant* in the sense that its members are usually the same;
- *Recurrent* in the sense that it has non-regular frequency of activities;
- *Active* in the sense that during the periods of activity it produces outcomes;
- *A formal Community of Practice* in the sense that it follows Wenger's definition of Community of Practice (Wenger, 1998b).

This type of CoP has as a main characteristic the existence of non-regular periods of activities and inactivity. Its members can be internal and/or external and they are only convoked when it is necessary, usually owing to a project with a specific deadline. The existence of such special CoPs was noticed in all the interviews. Below are some examples:

> *Participant 1: "I also liaise with people in other institutions as well. We've got a regional coordinator who is kind of employed by the Network but also is based in a different institution."*
>
> *Participant 2: "If I'm doing SIG, it's you and [ ], from Academy, and lots of other people, from other universities."*

Participant 3: "[. . .] belonging is the eight staff who work here on a contracted basis. There are a number of other people who do work for us on a regular basis. Based in varied parts of the world. It would be just hard to say the extent to which they belong to our workplace."

Participant 5: "So for example, [ ] will come when she's around to do specific jobs, or she'll do editing jobs on the journal or the newsletter remotely."

Figure 5.3 (on page 113) better illustrates the behaviour of a Recurrent Community of Practice (RCoP).

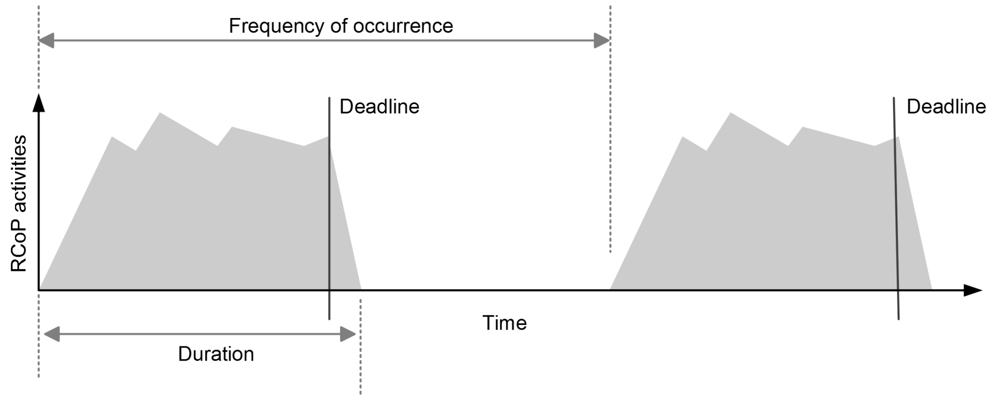


Figure 5.3.: Recurrent Communities of Practice (RCoPS) activity pattern

This type of CoP has never been defined before in the literature, consequently deeper analysis was carried out in the interviews to acquire more knowledge about its characteristics and behaviour.

Following Grounded Theory guidelines, several categories related to RCoPs and their respective properties were outlined and divided as follows.

5.6.2. Categories

Nature of the Community

Recurrent CoPs vary in the nature of their composition. It was noticed that their members could be from different places depending on the nature of the project involved. Sometimes they were internal, sometimes external and on other occasions there was a mix of the internal and external members. Therefore, the category *Nature of the Community* has three concepts: *Internal*, *External* and *Mixed*.

Internal Some of the members of the RCoP did not see themselves as a participant in a community, consequently they referred to the community as a "team", "group" or other similar term. However, it was verified previously, in the previous case study, that the Psychology Network was a CoP, independent of how its members referred to it or to themselves.

> *Participant 1: "[...] Because I'd have to liaise with a person within our office ... based in our office ... who is designing the workshop ... person who is responsible for making sure the bookings happen on-line and also there's those two people being in the office [...]."*
>
> *Participant 1: "[...] I think about PLAT [conference]. Yes, we all definitely had to work as a team there."*
>
> *Participant 2: "If I'm doing web based things, then I work with you. If I'm doing RoSP and data inputting, I work with [ ]. If I'm doing IPDPS, then I work with [ ]."*
>
> *Participant 3: "[...] the example of the newsletter I gave earlier, [...] there are three or four people involved quite heavily ... another example would be that we organise a conference every two years, which is a large conference and that involves [...] everybody in the run of that particular [...] conference ... and that will be a year or more work on a project where people will be involved to a greater or lesser extent for the entire year."*

External On other occasions a CoP needed to be convoked, having external and internal participants. In such cases sometimes some of the members were located in other institutions within the U.K. or abroad.

Occasionally the participants referred to this type of contact (and related action) as "liaising". At other times they used the term "work with", even implicitly.

> *Participant 1: "[...] but I also liaise with people in other institutions as well. We've got a regional coordinator who is kind of employed by the Network, but who is also based in a different institution."*

> *Researcher: And in your work with these activities, do you work mainly alone or do you work with others?*
>
> *Participant 2: "With others, [...] And also people outside of the Network. So people from [the] mother institution, people from Higher Education Academy."*

Mixed Another typical configuration of an RCoP is when its members are mixed, as internal and external at the same time. This happens when the community needs to deliver some outcome that requires expertise from members outside the CoP.

> *Participant 2: "If I'm SIG, it's you and [ ] (from the Academy) and lots of other people, from other universities."*
>
> *Participant 2: "[. . .] I'm taking [ ]'s work, editing it, updating it then I give to [ ], [ ] then edit it, she then gives it to me. Either, we work on it and then give it to [ ]. [. . .] Then eventually [ ] is happy with it. [ ] is happy with it. That's when I put it together as a document, then I come to you!"*
>
> *Participant 3: "[. . .] one of the things I mentioned we do is produce a Newsletter and it is the case that a number of people in the Network work together to do that. While notionally I am the editor of the newsletter and I am in control, [ ] helps with a lot of the pictures and images that go in there. [ ] actually uses the desktop publishing software to create the newsletter."*

Degree of participation in the RCoP

In our case study, during one interview an *in vivo* coding appeared and it was crucial for the analysis:

> *Participant 3: "[. . .] the degree to which they are part of the community will be the degree to which they do work for us? [. . .] Well, that is measured by the frequency, the work or the extent of the work and so on. So, somebody is a more integral part of the community if they do more work, produce more output, have more contact with other members of the centre. With people that work in this office."*

Based on this, it was possible to define a set of concepts for this category. These concepts outline the main characteristics found in this category:

- Frequency
- Duration of activities
- Extent of the work
- Contact with other members
- Constancy of participants

Frequency of activities The frequency of activities can help to identify if a Community of Practice is a Recurrent Community of Practice or not. If the community works mostly on a constant basis then it might be a common CoP; however, if they have periods of activity and inactivity, there is a good possibility that it might be an RCoP.

The case study has identified some subgroups of the main CoP as being RCoPs due to the periodic nature of their activities. The periods of activity have usually been triggered by the occurrence of projects with specific deadlines. To complete the project a smaller CoP was formed for this purpose. The members worked together sharing already acquired knowledge until the end of the project.

The "Frequency of activities" can be divided into Regular or Irregular, described as follows:

Regular This property refers to the cases where the RCoP has regular periods of activity. Its members are called and work together for a period of time, stopping their activities when the project finishes, and then remain inactive for a while. Later on, an event happens that triggers a new wave of activities. In the Psychology Network case, two examples of this type are the PLAT conference and the three-monthly newsletter:

> *Participant 3: "[. . .] another example would be that we organise a conference every two years [. . .] in fact it involves everybody in the run of that particular [. . .] conference [. . .] and that will be a year or more work on a project where people will be involved to a greater or lesser extent for the entire year."*
>
> *Participant 5: "So for example, [ ] will come when she's around to do specific jobs, or she'll do editing jobs on the journal or the newsletter remotely."*

Irregular Sometimes the Recurrent CoP has periods of activity that are triggered by a non-periodic event, for example the organisation of a workshop, or by the search for help to solve a problem.

> *Participant 4: "[. . .] I was asked to coordinate three workshops this spring on assessment, plagiarism and feedbacks and I don't really have backgrounds in those areas so I did some reading up on them and then I looked up who had written journal articles on those areas, who had done similar events and I got in touch with those people and said 'Would you be willing to let me pick your brains and find out what we should do at these events?', and so that's how I got some assistance in figuring out what to do. [. . .] They're already in the community, I'm just connecting with them more closely."*

Participant 3: [. . .] sometimes the people I need to ask would be people who do my job in other Subject Centres, so I would contact the Manager at another Subject Centre [. . .] there is an email list by which one can contact all the managers in Subject Centres, so you send around a general email that says 'Can anyone help with this?"

Duration of the activities (Extent of the work) Another interesting concept that RCoPs have is the length of the period of activities the community has. Such activities can be triggered by a project that might put the members together for a short period of time, stopping afterwards, and keeping the community 'dormant' until the next trigger. On the other hand, sometimes the project requires a period of activities spread over a long period of time. These two possibilities define the properties of this concept.

Long Two good examples of this characteristic are the RoSP project and the Newsletter. In these cases the people involved worked continuously over a long period of time in order to achieve some outcome. However, in the RoSP case, there was no specific deadline, as the project's aim was to always improve the material available.

Participant 2: "[. . .] with the RoSP it will be, continually updating it. Continually adding more things. I suppose it is going to end, but once it is launched, then it is out there. It will forever be improved upon."

Participant 3: "[. . .] we organise a conference every two years, which is a large conference and that involves [. . .] and that will be a year or more's work on a project where people will be involved to a greater or lesser extent for the entire year."

Short Sometimes the activities involved in an RCoP are short and unpredictable in time, thus there is a burst of activity over a short period of time, which might be followed by periods of inactivity. These activities are usually seen as normal work tasks on an average day in the job.

Participant 2: "When I needed to have new logos for my e-bulletins. . . there was a person that I turned to."

Participant 5: "So for example, we were looking for a virus thing this morning for example, he kind of identified the problem and then we both looked for a solution. [. . .] then we both worked together to find what the final solution was."

Contact with other members Recurrent CoPs, similar to any Community of Practice, keep contact among their members in order to exchange knowledge, or simply as a way of keeping the community alive. However, in cases where projects trigger the recurrent practice, this contact is crucial. Such contact can be intense and regular, but it can sometimes be sporadic or restricted to a specific period of time.

Constant This characteristic is mainly related to co-located CoPs. As a consequence of working in the same workplace the members of an RCoP usually have constant contact with the others. This does not imply, though, that if the contact is maintained via CMC the community cannot be a CoP or an RCoP. A good example of this is the VCoP and in particular, the case of the two members who lived abroad (the IPDPS[2] project manager and the publisher designer).

> *Participant 2: "If I'm doing web based things, then I work with you. If I'm doing RoSP and data inputting, I work with [ ]. If I'm doing IPDPS then I work with [ ]."*
>
> *Participant 5: "I think in day to day work [ ], who also does IT work on the day to day website, we'll generally help each other out."*

Triggered On some occasions the activities of an RCoP are triggered by a specific action from one of the members, for example if one of the members needs help. As this situation is not predictable or regular, it is not possible to determine when a new burst of activity will happen.

> *Participant 3: "[...] sometimes the people I need to ask would be people who do my job in other Subject Centres, so I would contact the manager at another Subject Centre, and say 'I need some help with this. Can you help?'. And [...] there is an email list by which one can contact all the managers in Subject Centres, so you send around a general email that says 'Can anyone help with this?"'*

Constancy of participants In addition to the properties already listed, another important one has been identified. Through the interviews it could be seen that the participants of RCoPs are generally constant.

[2] IPDPS stands for *Improving Provision for Disabled Psychology Students* and it was a project maintained within the Psychology Network with the aim of giving support for disabled students in Psychology at the U.K.

> *Participant 2: "[In] Most of the projects are the same people. Always. From the beginning to the end."*
>
> *Participant 4: "[...] for example sometimes [ ] will ask me to review a journal article, [...] I've done it [before] so she doesn't really have to give me more information other than giving me the article and the review, or she'll say 'Can you recommend somebody to review an article on this?', and I'll know what she means."*

Nature of Communication

Owing to the richness of resources available these days for any typical workplace, the range of possibilities for internal and external communication has increased quite substantially. Consequently it is not surprising that this is reflected in the way the CoP and RCoPs worked within the Psychology Network. However, without a clear definition of what can be seen as a property or what can be seen as a dimension, the characteristics listed as follows clearly describe an internal aspect of the communities involved in the workplace.

Face-to-face meetings Almost all interviewees described the importance of having face-to-face meetings. This seemed to have an influence on the exchange of ideas, hence making communication easier and more efficient. It seems that even in situations where CMC could be used for the exchange of information and ideas the face-to-face approach delivered a more personal aspect, making it the first choice for almost all staff members.

It seems that this was more highlighted in the case of group meetings, even though technologies for virtual meetings are freely available these days. In the case of the Psychology Network, this option was not necessary, due to the fact that almost all the members worked in the same place. On the other hand, the two members who worked from abroad (Australia and Scotland) usually communicated through email or telephone. However, for meetings with the Publisher Designer, the Manager usually used a free teleconference program (Skype[3]), as this made it possible to speak for free.

> *Participant 2: "[...] And it's only because she was here I met her. We talked about it, but we could probably have done it over the phone but it wouldn't have been the same. Having her here was the big thing."*

[3]Skype is an instant message (IM) program that allows conversations in text, audio and video. More information about it can be found at `www.skype.com`.

> *Participant 5: "[...] Then perhaps if we can't solve it [the problem] we'll bring it up at a staff meeting or offer it for discussion at a staff meeting, where other people can hopefully suggest good possible solutions, so you can pick from a range that are available."*

> *Participant 4: "[...] I try to talk with her because I think it's a small office, it's better to talk to people directly [...]."*

On some occasions the Manager and the Director have had virtual meetings using the same teleconference program. This may signal a tendency to choose CMC in specific cases where meeting face-to-face was not possible.

This raises several interesting issues related to Virtual CoPs: Are VCoPs affected by this tendency? How does this affect RCoPs? Additional studies are necessary to answer these questions.

Computer-Mediated Communication (CMC) Another conclusion from the analysis is that the use of CMC seems to influence RCoPs in CoPs. Computer-Mediated Communication, specifically email, was used so frequently that it became a natural form of communication within the CoPs. Sometimes it was even used as a way of queuing requests for the recipient, so he or she would deal with them when appropriate.

> *Participant 4: "[...] sometimes I will email her if it's something like [...] small that's just kind of [...] FYI or [...] sometimes I'll put information in her box [...]."*

This becomes more prominent in an environment such as the Psychology Network, which have a policy of allowing staff members to have a "working at home" day. Therefore email was the best option, leaving the choice of the best time to read it to the recipient.

> *Participant 4: "[...] if it's [ ] usually I just talk to her about it, sometimes I'll send her an email if she's busy or she's not there or working at home."*

However, it was not only email that was frequently used. Other forms of electronic communication and sharing of documents were also common:

> *Participant 3: "[...] is also done through email or telephone calls and we have a number of electronic mechanisms for actually transferring documents or data to other people."*

As one can see the whole working environment was based on the use of CMC for transmission of data and information. The members used all the technology available in a very integrated manner.

It would be interesting to investigate further how this characteristic affects Recurrent CoPs, as they use CMC in a similar manner, or even more than the co-located CoPs. One can estimate that CMC might have a significant importance to allow the quick establishment of connections needed by an RCoP.

Open plan Another common aspect among the interviews was the good effect that an open plan office layout had on community members' communication. It was noticed that open plan facilitated communication and created an aspect of "closeness" among the members.

> *Participant 2: "[. . .] When you are the new person, it is quite scary to them to have to go to different doors. When you are new and everyone talks, you get to know everybody [. . .]."*
>
> *Participant 3: "[. . .] because we are all in an open plan office, talking to people face-to-face is easy [. . .]."*

This characteristic is intrinsically related to co-located Communities of Practice, but it is advisable to study this more, as it might give new insights into aspects that can be reproduced in virtual environments or even in RCoPs, considering that these recurrent communities exist within co-located CoPs.

Questions about how to make an environment "comfortable" to a person deserve a careful study. This possibly requires some aspects related to Psychology and Social Science, which are beyond the aim of this research. However, the sense of "closeness" is ambiguous these days. The Internet and CMC have changed this sense to simply that of being able to have access to a person or to some information, therefore RCoPs seem to operate normally within the current environment, co-located or not.

5.6.3. Additional findings

After the analysis phase several well-defined categories and related properties were discovered. These have been described in section 5.6.2 (on page 113) in detail. However, several additional findings also appeared during the analysis, enriching the results. Nevertheless, this extra information cannot be listed as categories or properties. It helps to explain better the studied CoP (and related RCoPs), describing aspects that, in addition to local aspects of the Community of Practice, might also help to understand other CoPs and RCoPs (co-located or not).

The list of findings is as follows:

Problems of implementing new ideas in CoP

When it comes to the adoption of new ideas, CoPs, similar to other communities, tend only to accept new concepts if the advantages outnumber the disadvantages. This seems an obvious conclusion, as nobody would wish to make a change that did not clearly bring any advantage. However, this impression became very clear through the perception of two interviewees:

> *Participant 3: "[...] in general people seem responsive to things, but there are things which are rightly perceived to become tedious and time-consuming to do. So, people are less willing to do those but in general I think that if people see that there is some practice that is worthwhile, and it is easy to adopt then it seems to get adopted."*
>
> *Participant 5: "If they're already doing something in their day to day job and kind of you change the way that things might be done, they've got to see a big benefit to the change that they need to make, or it's got to have some instant pay off [...] otherwise you have to persuade them that it's a good idea."*

This seems so universal that one could argue that you can find the same idea in every community you could meet, co-located or not, Recurrent or normal CoP. Nevertheless, the issue of how the judgement is made by the community is still vague. It seems that it is a decision at an individual level that spreads throughout the community, but this is only a guess. Further studies are necessary to solve the questions of how an individual opinion spreads throughout the community and how one assesses the value of an idea. It seems likely that this is a psychological and Social Science matter, beyond the scope of this work.

Certainty of who belongs or not to the Community

One aspect that is very clear for the members of the CoP (and consequently of the RCoPs) is the sense of who belongs or not to their community. Such a sense is mainly based on what was previously described in the category "Degree of participation in the RCoP".

> *Researcher: Do you consider them [the temp workers] as members of your community?*

> *Participant 4: "Not if they just come in and out quite quickly, no, and she wasn't even a psychology student so I think she was just earning a buck."*

> *Researcher: Why was the temp not included [in the definition of community]?*
>
> *Participant 5: "Because she's doing specific project work, to do the one specific goal, so she just does that and nothing else."*

There is a clear sense of identity, participation and joint enterprise for the members of the community. They intrinsically recognise a member when they have contact with one. This is despite the fact that the temps are working on something that is related to the members' aim, or that the temp workers can return to do a similar job in the workplace. There is no confusion or doubt. They know who are really members of their community.

This highlights the already-discussed findings that the Psychology Network is a Community of Practice.

Sense of Community different from CoP or RCoP

Participant 4 held a set of particular views on communities. These really engage with the concept of community, but in doing so reveal a possibly different type of community that might underlie the main CoP. The concept is not entirely related to Recurrent CoPs, or to Communities of Practice; rather it shares some similarities with these, in addition to some aspects that are entirely different.

For instance, the following excerpt shows a sense of community that implies only the 'Share of Knowledge' and 'Participation' from Wenger (1998b). There is no 'Identity' or 'Joint Enterprise'.

> *Participant 4: "[...] also to engage people in other ways in the network through events by getting psychology academics to come and speak about teaching and share their knowledge with postgraduate students, trying to engage more postgraduate students in the network [...] basically what we're trying to do is raise the profile of teaching and so we do that [...] by engaging our community in what it is that we do, so I think that's really my job, community engagement."*

'Community Engagement' seemed to express a strong concept in this view. It is not very clear what participant 4 meant by the concept. However, it is possible to guess that the term implies a sense of increased participation in the community by increasing its visibility and the number of members. Thus, it seems that participant 4 believed that expert members can advertise the community, attracting newcomers, ultimately expanding participation through the sharing of knowledge. This sense is very common in Communities of Practice, although in this last one there are other aspects not described in the description of participant 4.

On the other hand, participant 4 seemed to understand that in some cases the advertisement and the sharing of knowledge alone are not enough to bring newcomers:

> *Participant 4: "[. . .] yes they should be in our community if they're teaching psychology but some of them are 'uninterested' in what we do and don't engage so [. . .] I still think [. . .] there's a role for us to try to get them to engage but I think with some of them [. . .] are not going to do it, so I really see our community as those people that are interested in what we do."*

This description highlights the sense of 'interest', resembling the sense of 'Identity' from Wenger. If someone identifies him(her)self with an idea or with someone, certainly they will be interested in that idea or person. Perhaps participant 4 had a fragmented idea of what a community can be, or maybe he/she was trying to describe a new concept with different nuances from the already-studied CoPs.

In this excerpt the sense of identity is strong. Participant 4 believed that the community did not require permanent or previous participation, only the wish to engage with the community and consequently with the shared knowledge:

> *Researcher: "It can be the case that the person who is a psychologist would like to know how to teach better but he's not keeping in contact with you, do you consider this person as a member of the community or not?"*
>
> *Participant 4: "Yes."*

This sense is similar to CoP, as defined by Wenger, but it simplifies all the requirements for being a newcomer. It is assumed that the identity and the wish to become an active member already put the individual in the position of an existing member. This conceptualisation requires more study. It may be a different definition from the ones already discussed in the literature, or it may be a new concept of identity related to the membership.

Another excerpt shows that participant 4 believed this newly-defined community had a different aspect from other communities, as it was built to give support to a bigger community, and that it was capable of doing so without having another community supporting it.

> *Participant 4: "[...] I think we're somewhat of a different kind of community. [...] We are a small group of people that's supporting a nationwide community but there's nobody that's really out there supporting us, I guess [...]"*

This implies a sense that the community is heavily focused on their aim, which in this case is to give support. This highlights the sense of joint enterprise, but it detaches identity and all the other inner concepts of CoPs; maybe it is only a fragment of a wider concept that values the joint enterprise above all. However, only a detailed study can clarify this.

This last excerpt shows that participant 4 gave major importance to the sense of being located in the same place.

> *Participant 4: "[...] I think we're a community because we all come to the same office and we sit at our desks in mostly the same room for varying periods of time but we're together for a period of time each week and so [...]"*

This sense shows that the newly-defined community is based on shared space and shared working time. This might be the result of habit, as participant 4 is within a co-located CoP, but it could also represent a strong sense of purpose, hence identity.

After seeing all the excerpts one can see clearly that only a detailed study with participant 4 could clarify whether these descriptions are only fragments of an image of a community, specifically a CoP, or if indeed participant 4 is trying to describe a new type of community with slight similarities to CoPs, but with different inner aspects of functioning and values.

5.7. Conclusions

After the discovery of a Community of Practice formed by the employees of the Psychology Network (chapter 4), a new goal was established: to discover more about it. Questions related to its formation and functioning were the main objective of a second study. For this, the new study was set up using a specific tool to discover concepts within data: Grounded Theory. The interesting characteristic of this methodology is that one learn more every time some data is collected, and this knowledge feeds back to the process of gathering data.

The expected knowledge regarding the community's behaviour and functioning did appear in the analysis. However, what was surprising was to discover something completely new related to CoPs. A new type of community, named *Recurrent Community of Practice*, or *RCoP*, was detected. This community was hidden inside the main CoP detected in the first study.

Due to its main characteristic of being recurrent, the RCoPs could easily pass unnoticed. However, if time is taken into account when analysing the level of activity in the CoP, the recurrence is noticeable (see figure 5.3, on page 113). Moreover, usually the trigger for the periods of activity is a recurrent project with a short or medium period for its accomplishment.

The existence of several RCoPs within the main CoP was noticed. However, the most evident one was related to the creation of the Psychology Network trimonthly newsletter. All aspects that define a CoP were present: the 'domain', the 'community' and the 'practice', and also a clear sense of identity and meaning. In addition to these characteristics, the community only worked on the newsletter for a specific period of time, ceasing any activity for almost two months. This clearly showed the existence of a recurrence.

Considering the intrinsic relation between RCoPs and IT, it is natural to wonder if they exist in purely virtual environments. Therefore, the next step in the study was to try to locate Recurrent CoPs within electronic networks. This is discussed in chapter 6.

6. Quantitative Analysis

6.1. Introduction

The previous chapters have built the necessary hypotheses for this study. Those can be summarised as *co-located Communities of Practice (CoPs) can produce Recurrent CoPs (RCoPs) as spin off groups*. Such groups are subgroups of the main CoP(s) and have all the characteristics of CoPs, but they also have a time component which makes them recurrent.

One important aspect to be considered is that the original study which detected the RCoPs showed that these were subsets of a main Community of Practice (CoP). Although there is always the possibility of the existence of RCoPs separated from a larger CoP, searching for them within an already known CoP will increase the chances of success. Therefore, an environment which contains already detected and well-known CoPs has been chosen. A consequence of that choice is that the search concentrated on finding smaller RCoPs inside CoPs. The environment is described on the following sections.

Another aspect to be considered is the necessity of keeping control of the studied communities over time. That is necessary because Recurrent CoPs have a burst of activities that stays for some time, returning to a passive state afterwards, repeating this periodically.

The choice was for the Newsgroups (also known as *Usenet groups*). This was due to the findings of Murillo (Murillo, 2002, 2008; Murillo-Othon & Spicer, 2007) who searched for CoPs within Newsgroups. Upon contact, Murillo kindly agreed to transfer the original data used in his research. The whole data encompassed several newsgroup messages spread across distinct areas of interest, from programming languages to taxes. Murillo's research concentrated on the activities of the groups over the studied period as a single "snapshot". In this research, it is necessary to include an additional component in the analysis: *time*. The current study examines the patterns of activities over a period of 52 weeks, and considers their development with time.

6.2. Differences between Murillo's research and the current study

Murillo searched in newsgroups for CoPs using Wenger's theory (1998b) of Communities of Practice (CoPs) as the foundation for a definition of a Virtual Community of Practice (VCoP). He found four newsgroups that could be considered a Community of Practice, under Wenger's conceptual framework (see section 2.10 for more details of his research).

As the second case study of this work detected the Recurrent CoPs as subgroups of a main CoP, the search for RCoPs within electronic networks needed to look in similar configuration, i.e., one or more CoP that could contain RCoPs. Therefore, Murillo's research showed to be very appropriate to this research, as it has already detected the existence of four (Virtual) CoPs within an electronic network, being only necessary to search for RCoPs in the same data.

The current research, however, uses different techniques to search for Recurrent CoPs. The main reason for these changes is that, unlike Murillo's studies, the temporal component in the communities' activities is crucial. While for Murillo the only concerns with time involved the communities' life span (ensuring stability) and the frequency of interaction (ensuring continuity), in this study time is used to verify the frequency of activities in a cyclical manner. For Murillo, time could be seen as a component that was examined as a whole throughout the study. For this study, however, time needed to be analysed in a manner that showed the frequency of engagement (ensuring recurrent burst of activities) of the participants over the period studied.

In order to accomplish this objective a series of steps was necessary.

First, it was necessary to acquire the original data used by Murillo. This would guarantee that the analysis would be carried out in four already certified CoPs. This step was achieved thanks to Murillo's agreement to pass on the data. It is important to highlight that although the data is public, collecting daily newsgroup messages from 2002 and 2003 would be a quite difficult task. Some time was spent searching for those messages. The results showed that it is very hard to locate archives with those old messages. It is possible, however, to locate individual messages, but collecting them one by one and creating a single file is very time-consuming.

The second step was the conversion of the original plain text file to a form of data more suitable for the analysis. This required a series of tests and programming. The processes involved are described in detail in the following sections.

The third step was to analyse the data via the creation of several programs to extract the necessary information. Again, the details involved on this step are detailed in the following sections.

At the end of the analysis we found what was named *Transient Core Members (TCMs)*. These are members that have strong participation in the community's life, but do not form a cohesive subgroup, as Recurrent CoPs do. They resemble the core members, but their individual participation is not constant as is that of the core members.

6.3. Initial Analysis

Due to the nature of the work involved (intensive and time consuming) it was decided to implement an initial analysis on a sample of Murillo's data, which contained messages from the 4 newsgroups. The sample was created using 12 weeks of the initial messages from the newsgroup *cplus* (a community of C++ programmers from the whole world). This group was chosen due to its characteristics, which define it as a strongly connected community, with a high volume of messages exchanged in the 12 week period (4,338 messages).

6.3.1. Goals

The objectives of the initial analysis can be summarised as:

1. In the technical side of the analysis:
   To develop the programs necessary to implement and automate data preparation steps for the analysis. The reason for this is that it was necessary to carry out a number of repetitive tasks that could be simplified with the use of programming languages (for instance, to split all messages from the single file into individual messages containing all the content from the original ones).

2. In the search for RCoPs:
   To test and learn how to discern the temporal nature of the conversation and learn how a typical CoP behaves regarding time and bursts of activities. That skill is necessary before addressing the complete groups, where the number of messages is undoubtedly greater.

The initial analysis proved very fruitful, achieving both objectives.

6.3.2. Materials

The data used came from Murillo's material used for his study. This data is formed by a collection of four large files in plain text with all the messages exchanged during the year-long period used for his analysis. Each file corresponds to one of the four detected CoPs.

Those messages follow a well-defined standard (Horton & Adams, 1987). Messages sent to the group to initiate a new topic (known as a *thread*), are called *thread heads*. Messages sent as a reply to other messages are called *directed messages*, consequently *undirected messages* are messages that are not a follow-up of previous ones (e.g. *thread heads*). Threads can have several follow-ups and some of these can start new threads (Murillo, 2002).

6.3.3. Steps

In order to fulfil the objectives, a sequence of steps was followed. They can be summarised as:

- Transposition of data from plain text to database and to spreadsheet afterwards;
- Division of the whole period into slots of 7 days;
- Listing of all users (senders/receivers) and correction of problems with duplication of emails/users;
- Creation of one matrix for each week of data;
- Creation of one matrix for the complete period of analysis;
- Removal of self-loops[1], *sources* and *sinks*;
- Test of analysis in data sample.

These steps are detailed as follow:

Transposition of data from plain text to database and to spreadsheet afterwards

Due to the fact that all messages were available in plain text only, the first step to allow the data analysis was to transfer them to a database. Afterwards, the

[1] *Self-loops* are different from *loops* in the sense that a *loop* might involve several nodes in a circular structure, while a *self-loop* only involves a single node: the node that is sending a message to itself.

data was converted and included in a spreadsheet to allow a quick analysis of it. Several programs have been developed to work with the spreadsheet and with the database, in order to manipulate the data. This manipulation helped to understand the group's behaviour and helped to draw conclusions about the existence of RCoPs.

To fill in the database it was necessary to create a set of programs in PHP language (Lerdorf et al., 2006) to separate the individual messages from the long text file and to place them as records in the database. To help with the task, the Usenet standard provided by document RFC 1036 (Horton & Adams, 1987) was used. It details the format of headings and content in Usenet messages. Each record in the database corresponds to a message with information about date, sender, conversation thread, subject and message body, among others.

The next step was to convert the database, which was in Microsoft Access 2007 format, to spreadsheet format (Microsoft Excel 2007). Such conversion was necessary to allow a better visualisation and analysis of the data, by way of seeing the exchange of messages as matrices, with the cells representing the number of messages exchanged between the participants (represented by the rows and columns).

The choice of a spreadsheet (Microsoft Excel in particular) was due to its flexibility and ability to manipulate data. However, for the final analysis with the complete set of messages, the decision was for the use of a database due its robustness and its capacity to deal with large amounts of data. In addition, spreadsheets have limitations in the size of the matrix that can be manipulated (for Microsoft Excel 2003 the limit is 256 columns, and for MS Excel 2007 it is 16,384 columns). Although the 2007 version could manipulate the generated matrix for the complete data, the creation of programs for spreadsheets is not easy and requires a significant amount of testing. Therefore for the matrix size of 755 (number of participants in the sample) used in the initial analysis, Microsoft Excel 2007 was more than adequate.

Division of the whole period into slots of 7 days

In order to capture the temporal characteristics of the activities inside of the CoP, it was decided to divide the data into periods. The difficult part was to decide the size of that period; thus, several tests were carried out in the sample to find out which one was most suitable.

Starting with a period of one day, it was clear that that was not sufficient to allow enough communication to happen among the participants. It is very unusual for an exchange of messages to occur on the same day. This is more noticeable only in core members, and even in these cases it is not a certainty.

The second and third attempts involved periods of two and three days, respectively. Once again the number of messages included in the conversation was not sufficient, showing clearly that other messages from the same thread were left out.

In the end it was decided to split the data into periods of a week. That hopefully encompassed the majority of the messages related to a specific thread. The intention was that if somebody could not participate in a conversation during the week, they could do so during the weekend.

Each week of data created a related matrix (in the spreadsheet) that represented the exchange of messages of the specific CoP. Observing the matrices, it could be possible to see the development of the activities throughout the weeks in that community. However, it is important to stress that not all the exchanges within communities can be considered part of a CoP's activity. Murillo has already highlighted this point in his work. He used the concept of *cliques* and *2-plexes* (Scott, 2000) to isolate the important conversation from the background noise. In the specific case of this research, the decision was made to use a matrix that could represent only the relevant activity of the community. For that, all the participants who did not engage in a bilateral conversation were removed from the matrix (see section 'Removal of self-loops, "sources" and "sinks"' on page 134).

Listing of all users (senders/receivers) and correction of problems with duplication of email addresses/users

A problem was present in the sample studied and it was also detected by Murillo in all the studied groups: the existence of messages apparently from different senders that in fact originated from the same person. This problem required that, before any analysis, each message be manually inspected to check if the sender was unique or not. For that a spreadsheet was created with the list of all users and their respective emails. The list was checked manually first checking for cases of the same name and different emails. For example: "`Antoun Kanawati <NO.antounk.SPAM@comcast.net>`" and "`Antoun Kanawati <antounk@comcast.net>`" are clearly the same person, but because information about him was collected from different messages sent to the group, without checking it would count as two different persons in the same thread. The practice of including extra words in the email was common place among the participants. It was an attempt to avoid what is called *email harvesting*, used by spammers as a way of collecting emails from the Internet automatically.

Another common situation was when a participant uses the same email, but different names, for instance: "`fabio <fabioppp_it@yahoo.it>`" and "`fabioppp <fabioppp_it@yahoo.it>`". Again it is clear that they are the same person.

In other cases the participant included extra information in the "sender" field, which could make our program understand that they are different persons. An example of such a case is: "`wizofaus@hotmail.com`" and "`wizofaus@hotmail.com (Dylan Nicholson)`"

After checking for duplicates and amending when necessary, a unique code was assigned to each user. The unique code was also used as a way of anonymise the data (in the sample and in the 4 large groups).

At the end of the process the number of unique users involved in the activities was counted as 755 in the sample of the *cplus* group used.

During the whole process significant attention was dedicated to the task to avoid making mistakes with the participants' identity. Moreover, this activity proved crucial to pinpoint the small groups inside the CoP which communicate frequently. Thus, thanks to this adjustment, it was possible to pinpoint core members, lurkers and occasional participants.

Creation of one matrix for each week of data

Each week of messages exchanged generated a matrix, pictured in a spreadsheet, with the rows representing the users sending messages, and the columns representing the ones receiving those messages. In this representation each cell shows the number of messages sent by (and to) the related node in that week. This type of matrix is known as a *sociomatrix* (Wasserman & Faust, 1994) and is commonly used in Social Network Analysis (SNA)[2].

Sociomatrices are adjacency matrices which quantify the social interaction and represent the network data of a group. They can be used to create a directed graph, where the arcs represent a social tie (in our case, the *exchange of messages*) from one participant to another. Through them it is possible to gather several different types of information from communities, such as cliques, for instance.

The matrices generated in the sample are sparse and have the size of 755.

- They are sparse, because the sender is targeting few specific recipients (directed messages) during the represented week and it would be very unlikely for one person to send messages to a large number of other participants in a week.

[2]For a detailed discussion regarding the history of SNA, see Wasserman & Faust (1994).

- The size of all matrices is 755, because that was the number of participants in the sample.

These matrices have been modified to better identify the type of community member and their typical behaviour. Consequently, some members were excluded (see section 'Removal of self-loops, "sources" and "sinks"' on page 134).

Creation of one matrix for the complete period of analysis

The weekly related matrices show the number of messages that each participant sent or received for a specific person and the total of messages exchanged in that week. It allows to visualise the behaviour of specific members during a week (detection of core members, occasional participants, etc) and it also makes it possible to study the development of exchange of messages related to a subject (via analysis of content). However, it became clear that it was necessary to see "the big picture" of the exchanged messages, in order to better understand the community participants.

To visualise all messages from the sample, it was necessary to create a matrix (via a spreadsheet) representing the whole period of 12 weeks. In that matrix the rows represent the participants and the columns the weeks. Thus, each cell shows the number of messages sent (or received) by each participant per week. The spreadsheet is divided into different tables showing senders and receivers with the same column titles in both. Two columns at the end (called *Total* and *Occur*, respectively) show the total of messages sent (or received) by the user during the complete period (*Total*), and the total of weeks in which the user participated in the exchange of messages (*Occur*).

These two extra columns helped to identify a set of characteristics of the group, such as the categorisation of the involvement of the participants, separating them into levels of participation (core member, casual participant or *lurker*). With these totals (of messages and participation) and in conjunction with the weekly matrices, it was possible to detect the level of engagement of a participant.

Further explanation about the decisions involved in this categorisation is as follows.

Removal of self-loops, "sources" and "sinks"

A good way to visualise communities is to think of them in terms of a graph. Therefore it seems easier to think of a participant as node and the exchange of messages as an arc of such a graph (see figure 8.1, on page 180 for an example).

This approach facilitates the understanding of some tasks that needed to be carried out in order to run the data analysis.

As part of the preparation for the data analysis some messages and types of nodes have been removed. This is necessary to concentrate on the community aspect of the group, where the communication needs to be in both directions to represent a real conversation and participation.

The first task was to discard messages that have been sent by and to the same node. This generates a self-loop if the sociomatrix is represented in a graph. Those types of communication were not added to the sociomatrix. One example of such a situation is when somebody sends a message (as a reply or not) and notices that additional information is missing in the original message, thus he (or she) sends another message as a reply to his (or her) previous message. In the matrix this could appear as a node sending a message to him(or her)self, which when visualised in a graph appears as arc leaving and reaching the same node (the *self-loop*).

Another example is when someone asks a question in a message and does not receive a satisfactory answer, thus he (or she) replies to his (or her) original message highlighting the problem.

Yet another example of self-loop appears in situations where somebody send thanks for all the replies received to his/her first message (i.e., the thread head message). Below is the cited example:

```
=== Begin of original message: ====
Subject: Can I avoided a memory problem doing this?
---
Suppose I am overloading an operator for class Zigid and my method
looks like this:
Zigid &operator+(Zigid &A)

Zigid *Sum = new Zigid();
...
return *Sum;


The code runs just fine, but the method allocates memory dynamically
and leaves it to the caller to clean up.  What I want to know is,
"How do I get the caller to delete the all memory pointed to by the
reference it returns?"  In particular an object of the Zigid class
```

```
must allocate memory dynamically when it is being created, although
this does not necessarily happen in the constructor.
Any help appreciated.
Achava
=== End of original message ===


=== Begin of reply message: ====
Subject: Re: Can I avoided a memory problem doing this?
---
Thank you all for your replies.  I have rewritten my code to return
the object rather than a reference to the object, and no longer do
I create the object on the free store.  I let the scope do the
clean-up.  I did in fact work in Java before taking up C++ again
after a long lapse, so I got used to using new for everything.

Regards,
Achava
=== End of reply message ===
```

Another task as part of the preparation for the analysis refers to the nodes that just send messages but never receive any reply. In that case those nodes are excluded from the matrix (they are known as *source* nodes). Those nodes need to be removed as they are not part of a Community of Practice (CoP).

Finally, if a node only receives messages, but never sends any, then it is also excluded from the matrix (it is known a *sink* node). They are removed for the same reason as the *source* nodes, i.e., they are not part of a CoP.

Those node removals are possible by reordering the rows and columns of the sociomatrix and removing nodes with "0" number of messages received or sent.

The main consequence of deleting nodes with "0" messages in the matrix is that it only kept the nodes with at least one complete conversation, which implies a true communication (sending and receiving at least one message). It is important to concentrate on the communication within CoPs, partially removing the background noise from the data.

In the end, the number of nodes used in the matrix fell to 324, thus generating a square adjacency matrix with that dimension.

6.3.4. Exploratory data analysis

Before using a method to search for the Recurrent CoPs within the data from the 52 week period, it was decided first to try any possibility in the data sample of 12 weeks. For this, it was decided that the main objective was to analyse the data and learn how the community behaves and communicates. Thus, an open-minded approach was adopted where no restricted rules were imposed in the attempt to reach these goals. Consequently, sometimes an attempt ended in a "dead end", which was taken as experience in the process of modelling the data analysis.

The first step adopted was to order the complete matrix (containing the 12 weeks of data) by total of messages sent and by weeks in which the nodes participated in the threads (as explained in section 6.3.3 on page 134).

Core nodes

With the matrix nodes ordered, it is possible to visually identify the core nodes (or core members). For that a mix of considerations was used.

First, looking at the tables from the matrix it is possible to notice that the nodes that have sent more messages (larger numbers in the *Total* column) are almost the same ones that have significant participation in the discussions (more occurrences in the *Occur* column). For a better illustration see tables 6.1 and 6.2 (on page 139)[3]. In the table ordered by total it is possible to notice that the nodes on the top belong approximately to the same group of core nodes in the table ordered by occurrence.

However, it was necessary to draw a line that could allow one identify which nodes could be considered a member of the core group. It was decided that it was necessary to combine participation and total of messages sent.

As far as the participation is concerned, it was decided that 9 weeks of 12 in participation could be considered a good threshold. That number came from the calculation of the average of participation from the nodes with 6 weeks or more of occurrence (50% of the 12 weeks). That average is 7.8 from the 36 nodes with 6 or more weeks of engagement (they sum 281 weeks in total).

Concerning the total of messages sent, the average of messages sent by the 36 nodes with 6 weeks or more in participation was 48 messages in 12 weeks. Therefore nodes with 49 or more messages in total could be considered for analysis as belonging to the core group. 8 nodes that fit this description were detected.

The combination of the two parameters led to designation of core nodes with participation of at least 9 weeks, provided that they have had 49 or more messages sent in total.

[3]These tables are only an excerpt. The complete tables are matrices of 324 rows.

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Total	Occur
155	7	9	5	21	20	23	14	24	25	26	3	2	**179**	**12**
377	21	26	35	33	22	29	33	27	24	18	20		**288**	**11**
96		9	9	6	9	8	12	5	10	6	4		**78**	**10**
464	3	1	3		17	5	4	2	2	5	2		**44**	**10**
493	6	3	7	4	4	2	3		1	2	1		**33**	**10**
25			3	7	4	7	12	5	7	1	1		**47**	**9**
225		3	6	2	3	10	26		7	9	4		**70**	**9**
301	3		4	3	2	11	1		1	2	2		**29**	**9**
424	7	2		2	3	1	10	4	3	1			**33**	**9**
717	4	2		4	3		4	2	3	1	3		**26**	**9**
27	3		1	9	2	3	5			2	5		**30**	**8**
45					10	10	11	14	9	1	8	5	**68**	**8**
59	5					5	14	6	3	2	6	1	**42**	**8**
91		2	3	2	3			2	6	5	8		**31**	**8**
178		5	8	7	6	2	6	23	3				**60**	**8**
235		3	8	1		3	7	10		5	5		**42**	**8**
536	1			5	4		7	23	12	2	8		**62**	**8**
590	9	4			4	8	6		1	4	2		**38**	**8**
621	4	1	5	5				2	11	2	5		**35**	**8**
650	4	2		1	3	1			1	2		2	**16**	**8**
683		9	7	7	13	7	2		1	1			**47**	**8**
730				5	6	7	7	24	16	12	2		**79**	**8**

Table 6.1.: *Cplus* sample: 21 top senders ordered by **participation** (descending)

In the sample of the *cplus* group studied it was determined that 4 nodes could be considered core nodes.

Concerning the total of messages sent by the 324 nodes, the average was 8.77 in 12 weeks. Therefore nodes with 9 or more messages in total could be considered for analysis as belonging to the core group. 68 nodes that fit this description were detected.

The combination of the two parameters led to designation of core nodes with participation of at least 9 weeks, provided that they have had 9 or more messages sent in total.

In the sample of the *cplus* group studied it was determined that 10 nodes could be considered core nodes. They represented 1.3% of the total of users in the reduced matrix. They alone were responsible for 29.1% (827 messages) of the total of messages sent (2,839 messages). The average of messages sent by the core nodes was of 82.7 messages in total, or 6.9 messages per week. These numbers show the importance of such core nodes. They alone were responsible for almost 30% of all messages sent during 12 weeks. Moreover, it is interesting to notice that among the 10 core nodes, two could be considered essential to the community

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Total	Occur
377	21	26	35	33	22	29	33	27	24	18	20		**288**	**11**
155	7	9	5	21	20	23	14	24	25	26	3	2	**179**	**12**
730				5	6	7	7	24	16	12	2		**79**	**8**
96		9	9	6	9	8	12	5	10	6	4		**78**	**10**
225		3	6	2	3	10	26		7	9	4		**70**	**9**
45					10	10	11	14	9	1	8	5	**68**	**8**
536	1			5	4		7	23	12	2	8		**62**	**8**
178		5	8	7	6	2	6	23	3				**60**	**8**
25			3	7	4	7	12	5	7	1	1		**47**	**9**
683		9	7	7	13	7	2		1	1			**47**	**8**
679	4	11		4	6	8	12	2					**47**	**7**
464	3	1	3		17	5	4	2	2	5	2		**44**	**10**
59	5					5	14	6	3	2	6	1	**42**	**8**
235		3	8	1		3	7	10		5	5		**42**	**8**
703						5	3	12	8	7	4		**39**	**6**
590	9	4			4	8	6		1	4	2		**38**	**8**
283		4	5	8	6	4	9						**36**	**6**
307		4					23		1		7	1	**36**	**5**
621	4	1	5	5				2	11	2	5		**35**	**8**
493	6	3	7	4	4	2	3		1	2	1		**33**	**10**
424	7	2		2	3	1	10	4	3	1			**33**	**9**

Table 6.2.: *Cplus* sample: 21 top senders ordered by **total** (descending)

(nodes 155 and 377). They were responsible for a total of 179 and 288 messages respectively (see table 6.1 on page 138). However, if the average of messages sent is considered, node 377 is surprisingly active with an average of 24 messages/week (or 26.2 messages/week if only the participating weeks are considered). Node 155, although not sending as much as node 377, represented an impressive amount of 14.9 messages/week.

These two nodes are too extreme if compared with the rest of the group. They do not represent a normal situation even for a core node. However, they show how important a person can be for the existence of a CoP (or VCoP in this case). Studies have already highlighted the importance of core members and the consequences of losing them (e.g. Gongla & Rizzuto, 2004), but in this case such importance was really clear. The loss of those two members could represent a big risk to the existence of the community.

Analysis of core nodes

After identifying the core nodes, a deeper analysis was carried out in their conversation. For that nodes 377 and 155 were selected. The objective of the analysis was to identify with which nodes they exchanged more messages and if the contents of those were really related to the thread.

The first conclusion was that there was not a noticeable pattern in the selection of nodes with which one node usually communicates. Normally the thread head (first message in the thread) was not intentionally targeted to one of the core nodes, but because of the expertise of those, the participants can specifically ask for comments from the core nodes. Some examples are as follows:

```
I'd love to have a way to tag a member function as being written
entirely in terms of the public interface, but that isn't in the
language. So there's presently a risk that private-member dependen-
cies could creep into an otherwise pure function during maintenance.
But aside for that risk, these functions shouldn't count in Meyers'
metric. That leaves the rest of the article open to question.

Scott?  Comments?
```

```
> > code like this in real life??").  So...yes - I wrote exactly this
> > and hopefully got error from VC++  :)

Comments left to Carlos.  :)
```

However, some threads could create a "ping-pong" effect between a few nodes. There was, nevertheless, usually a concern from some nodes about the quality of the discussion, exchanging messages until no doubts or issues were left regarding the subject. For instance:

```
Just to clarify: at least some the GNU C++ implementors have _known_
this rule for quite a while.  They may just not find it worthwhile
to implement it (yet). [...]
```

```
Just to clarify, for anyone that might be reading this, the function
"sample" has a parameter that is a function type that returns a
pointer-to-member-of-D-of-type-int. [...]
```

The core nodes play a fundamental role in the CoP's life, but it is necessary to search within the data for the Recurrent Communities of Practice (RCoPs), as this is the main objective of this study. Thus, the following sections will deal with this objective.

Recurrent nodes

As explained in section 6.3.1 on page 129, one of the objectives of the initial analysis is to search for RCoPs in the sample data. That search allows one to understand the temporal nature of the CoP and its activities, learning in the process how to use the acquired skills in the complete data available.

That temporal nature is not an easy matter. Due to the novelty of the idea of Recurrent CoPs, there are no studies explaining how to detect or analyse them, either in co-located or on-line communities. Therefore all activities connected with this task are new and untested. However, it is possible to draw a picture of what it is expected to find, i.e., approximately a fixed subset of nodes should exchange messages among themselves over and over again, having cycles of activity and inactivity.

Once again it is easier to think of the community and its members in terms of a connected graph. Similarly to section 6.3.3 (on page 134), it is simpler to imagine the CoP as a set of connected nodes, where the arcs represent the exchange of messages. In this scenario, the RCoP can be represented by a subset of nodes that should form an internal CoP. This internal CoP has a recurrent pattern of activities over time.

It is expected that if RCoPs do exist in virtual CoPs, that recurrent burst of activities will be the main sign to look for in the activities of the community. This sign is nevertheless not easily detected in a virtual community. The difference between the two types of CoPs is clear: in the co-located CoP it was possible to detect RCoPs using Grounded Theory applied to data gathered via interviews, therefore a microanalysis led to the discovery of RCoPs. When the amount of data is not too large, microanalysis can be used effectively, but applying the same technique to virtual CoPs (VCoPs) is not viable.

In such a scenario it is much more difficult to use Grounded Theory, as the data is formed by messages where the subject is not controlled (in contrast to direct questions from interviews) and where the number of messages is too large (2,839 messages just in the adjusted sample of a single group).

Consequently, it was necessary to try different techniques to find out which one(s) could be used to confirm the existence or not of RCoPs within the already detected CoPs.

Techniques used to search for Recurrent nodes

Once again the two type of matrix (weekly ones and the one for the whole period) described in section 6.3.3 (page 134) were used for the search for the RCoPs.

For the first step the complete matrix was used (see tables 6.1 and 6.2 on page 138). The first aspect checked was the existence of gaps in the columns referring to the weeks, in the matrix of participation (some of those gaps can be seen in table 6.1 on page 138, e.g., in nodes 27 and 590). They show the existence of periods of inactivity in the node's communication throughout the studied period. This suggests that the node might be a member of an RCoP. However, this alone cannot guarantee it.

It is necessary to analyse other factors, for instance the pattern of the gaps.

In a first approach taking into account the number of messages exchanged by the node in question during the whole period was considered. The idea was to calculate the rate between the number of messages sent divided by the number of weeks in which it participated. However, if the calculated rate is used to filter out only the nodes with large numbers (or numbers above average), it might exclude nodes within a (possibly existing) RCoP that has a low rate of communication. Due to the fact that RCoPs are subgroups of CoPs, and in this case the data is only a small sample of an activity pattern of a CoP, then the risks are high of losing nodes because of low rates, thus the idea was rejected.

Another problem that can be caused by the use of such rate is making blurring the distinction between levels of engagement. For instance, node 650 has a total of only 16 messages in 8 weeks, with an average of 2 messages in the weeks when he/she participated, while node 717 sent 26 messages in 9 weeks (an average of 2.9 messages/participated week). The difference between the rates in the two nodes is not significant, but node 717 sent 10 more messages and participated a week more than node 650, clearly showing a better engagement.

As a way of trying to understand better the group and as a way of searching for RCoPs in the sample, it was decided to try a different approach. It was decided to study two separate groups from the main matrix. The groups were formed by the nodes that participated during 8 weeks of the whole period of 12, and by nodes that participate during 4 weeks in the same period. Within those the nodes that presented recurrent behaviour, i.e. with gaps in their participation, were chosen.

The choice of these two groups was due to the scenario represented in the matrix of senders' node from the sample (an excerpt is presented in table 6.1). The group that participated during 8 weeks is the first group below the core nodes (with 9 weeks or more). This means that the number of messages available to study is high, increasing the possibilities of discovering any existing RCoP. The group that participated in 4 weeks has been chosen because they participated in half the number of the first group, representing a good contrast with the first one. In addition that group seems to represent the bottom limit for participation. Below that the number of messages drops considerably. It is also assumed by this study that a participation of 3 weeks or less in 12 is not sufficient engagement to be considered a member of a CoP, and consequently of an RCoP.

Material used for the analysis of subgroups with participation of 4 and 8 weeks

For the analysis be performed it was necessary to generate the relevant tables containing the exchange of messages between the nodes.

Listed as follows is the data referring to the group with 4 weeks of participation. Table 6.3 contains that group.

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Total	Occur
686			5	9	7	7							**28**	**4**
483						6	9	3	4				**22**	**4**
402	8	7	4	1									**20**	**4**
106			1				3			3	8		**15**	**4**
156		7	1	1				6					**15**	**4**
352				4				2	4	3			**13**	**4**
22									8	2	1	1	**12**	**4**
370			1		3	4	4						**12**	**4**
726		3	3	1	5								**12**	**4**
365						2		3	4		2		**11**	**4**
414								3	4	1	3		**11**	**4**
282	2	2	2							2			**8**	**4**
425							3	2	2	1			**8**	**4**
680	2	4		1			1						**8**	**4**
303	1	1			3	1							**6**	**4**
516				2			1	1			1		**5**	**4**
308	1		1			1					1		**4**	**4**
716							1	1		1	1		**4**	**4**

Table 6.3.: *Cplus* sample: senders with 4 weeks of participation, ordered by **total** (descending)

Additional spreadsheets have been created for the analysis. Those spreadsheets were designed to trace individual nodes, thus a set of additional data has been included on each spreadsheet.

Examples of the contents from one of those spreadsheets appear in table 6.4 and table 6.5.

	Tot msgs	**Tot nodes**	**Contacted nodes**			
Week 1						
Week 2						
Week 3						
Week 4						
Week 5						
Week 6	2	2	625	652		
Week 7						
Week 8	3	3	377	424	536	
Week 9	4	4	59	377	424	730
Week 10						
Week 11	2	2	593	703		
Week 12						

Table 6.4.: *Cplus* sample: Example of nodes contacted (4 weeks participation – node 365)

Week 9	
Node	**Subject**
59	Re: Extra access level
377	Re: Extra access level
424	Re: Which member functions will you provided for a class
730	Re: Two be or not two be? Throwing destructors in standard containers

Table 6.5.: *Cplus* sample: Example of subjects from messages sent (4 weeks participation – node 365)

Each spreadsheet includes:

- Total of messages sent per week (*Tot msgs* in table 6.4, on page 144);
- Total of different nodes contacted per week (*Tot nodes* in table 6.4);
- List of different nodes contacted in which week (example in table 6.4);
- Subject of messages exchanged divided per node (example in table 6.5, on page 144).

For the analysis of the group with 8 weeks of participation the material used was essentially the same. All spreadsheets created for the group with 4 weeks

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Total	Occur
730				5	6	7	7	24	16	12	2		**79**	**8**
45					10	10	11	14	9	1	8	5	**68**	**8**
536	1			5	4		7	23	12	2	8		**62**	**8**
178		5	8	7	6	2	6	23	3				**60**	**8**
683		9	7	7	13	7	2		1	1			**47**	**8**
59	5					5	14	6	3	2	6	1	**42**	**8**
235		3	8	1		3	7	10		5	5		**42**	**8**
590	9	4			4	8	6		1	4	2		**38**	**8**
621	4	1	5	5				2	11	2	5		**35**	**8**
91		2	3	2	3			2	6	5	8		**31**	**8**
27	3		1	9	2	3	5			2	5		**30**	**8**
650	4	2		1	3	1			1	2		2	**16**	**8**

Table 6.6.: *Cplus* sample: senders with 8 weeks of participation, ordered by **total** (descending)

have been replicated for the case of 8 weeks. The table containing all nodes that belong to the 8 weeks classification can be found in table 6.6 (on page 145) and the examples of a node from that group can be found in tables 6.7 and 6.8.

In both cases those spreadsheets were used to reach several objectives.

1. First, to detect if the studied node was communicating with (approximately) the same other node(s) or not;

2. Second, to check if there was an indication of the reason why that node was communicating with the others. The aim was to find out if the forces that drive the recurrence in the VCoP are the same as the co-located Recurrent CoPs;

3. Third, to check if the content of messages really reflects the subject the objective is to find out if it is possible to trust the subject line of the messages, as it would be impossible to check all the content of the messages in the complete data for the four groups;

4. Lastly, to create a set of procedures that could be used to search for RCoPs in the large amount of data originated from the 4 CoPs, given by Murillo.

Analysis of the subgroup with participation of 4 weeks

Regarding the subgroup of 4 weeks (shown in table 6.3, on page 143), and using the material listed previously, it is possible to draw some conclusions:

	Tot msgs	Tot nodes	Contacted nodes					
Week 1								
Week 2	3	3	46	323	672			
Week 3	8	6	46	275	283	377	382	619
Week 4	1	1	341					
Week 5								
Week 6	3	1	45					
Week 7	7	5	45	155	225	283	377	
Week 8	10	5	155	178	377	730	740	
Week 9								
Week 10	5	2	155	377				
Week 11	5	5	59	300	307	377	716	
Week 12								

Table 6.7.: *Cplus* sample: Example of nodes contacted (8 weeks participation – node 235)

Week 8	
Node	**Subject**
155	Re: RAII and resource release functions that can throw
	Re: RAII and resource release functions that can throw
178	Re: STL and friends too generic?
	Re: STL and friends too generic?
377	Re: Hypothetical: If we could rethink C++ from the ground up
	Re: RAII and resource release functions that can throw
	Re: STL and friends too generic?
	Re: STL and friends too generic?
730	Re: RAII and resource release functions that can throw
740	Re: STL and friends too generic?

Table 6.8.: *Cplus* sample: Example of subjects from messages sent (8 weeks participation – node 235)

Potential nodes The nodes with potential of participating in a Recurrent CoP are: 106, 156, 352, 370, 365, 282, 425, 680, 303, 516, 308 and 716. This is because those nodes contain gaps in their pattern of participation (the first step to be a RCoP).

However, that alone is not enough. It is necessary to notice if within the remaining participation any sign exists which shows that the node is leaving the conversation. That could be caused by the fact that it has already acquired the information it was looking for and it is no longer engaging in the community's communication. If this happens, then the node is not part of an RCoP, as it will not be participating in future community activity.

This condition can be noticed by the gaps in participation becoming sparser over time, and the node stopping the dispatch of new messages. Unfortunately, due to the number of weeks analysed in the sample, it is not possible to conclude anything on those grounds.

Conclusion 1 The constancy of contact with approximately the same nodes during the periods of activity (objective 1 from the listed aims) is not clearly defined by the data.

Once again the amount of data does not show any tendency clearly (e.g., see table 6.4 on page 144). The other nodes listed have the same characteristic.

Conclusion 2 The motivations for engagement are purely related to the topic discussed in the threads (concerning objective 2 – the reasons for the engagement).

The objective here is to compare detected motivations which are the main force for co-located and virtual RCoPs. In the case of co-located Recurrent Communities of Practice the motivations were mainly driven by projects that drove participants to work as a community. In the case of the analysed group the motivations are solely based on the subject discussed in the threads. There were no projects running that made the participants work together.

Conclusion 3 The message subject usually reflects the content of the message body (related to objective 3 – verification of relation between subject field and the content of the messages).

Although apparently seeming to be an obvious conclusion, this does not reflect the common sense in on-line communities. In this case, however, care has been taken to make the message's subject reflect its content. Perhaps this is due to the fact that the community is made up of highly technical people, who constantly search within the archive of exchanged messages. That can be attested by messages with the subject line containing information about the previous issue discussed in the thread. For instance:

```
Subject: Re: Lock-free concurrent algorithms and GC (was Re: C++ de-
sired features)
```

Or even:

```
Subject: Symbolic literals (was: Re: having the compiler enforce
"good programming style")
```

Conclusion 4 The amount of data used makes it very difficult to analyse patterns in behaviour.

As a consequence of being on the boundary of what was considered the minimum possible engagement in the community, the group with 4 weeks' participation presents few data for a deep analysis. In addition to that, the sample covers only 12 weeks of participation, which makes the data available even more restricted.

Analysis of the subgroup with participation of 8 weeks

The subgroup of 8 weeks (shown in table 6.6, page 145) led to the following conclusions:

Potential nodes The nodes with the potential of being a participant of a Recurrent CoP are: 730, 536, 178, 683, 235, 590, 621, 91, 27 and 650. Similarly to the group of 4 weeks, those nodes appear as potential because they have gaps in their pattern of participation (the first step to being an RCoP).

There is a node in table 6.6 that deserves a comment: node 59. That node contains a single gap in its pattern of participation, thus not leading to any satisfactory conclusion. It could be the case that more gaps appear in future participation, or conversely that it became a constant participant, or even that it ceased participating in the exchange of messages. Therefore node 59 was excluded from the potential nodes of an RCoP.

Once again similarly to the group of 4 weeks, it is not possible to draw any conclusion regarding the departure of nodes from participation in the community. The analysis which could help with the determination of the longevity in the participation could not be performed in those nodes due the lack of more weeks to study. Just 12 weeks it is not enough to conclude anything on that.

Conclusion 1 The constancy of contact with approximately the same nodes during the periods of activity (objective 1 from the listed aims) could not be attested by the data.

Although this time the group has more communication than the groups of 4 weeks, it is not possible to establish any conclusion regarding objective 1, listed previously.

Those nodes did not present a behaviour indicating that they were communicating with (approximately) the same nodes. It is possible to notice that even though sometimes the same recipient node appears more than once in different weeks, that only occurs to a very limited extent.

In addition, if compared with the number of different nodes which are contacted, the proportion shows that the repeating nodes are very few. For instance, in the case of node 235 (table 6.7 on page 146) it is possible to point to some repeating nodes: 45 (2x), 46 (2x), 155(2x), 283(2x) and 377(5x). From those, node 377 can been discarded as a member of an RCoP, as it does not present gaps in the participation pattern (see table 6.1 on page 138). Therefore only 4 nodes have the potential to be an RCoP. If it is noticed that each of them only appears in two of the 8 weeks of participation, it is possible to conclude that there is no relation between the exchange of messages and a possible repetition of nodes involved in the communication.

Conclusion 2 The motivations for engagement are purely related to the topic discussed in the threads (concerning objective 2 – the reasons for the engagement).

Once more the group with 8 weeks of participation is similar to the group with four weeks. The second objective targets similarities in co-located CoPs and Virtual CoPs, regarding the motivations that create the recurrence in the RCoPs' activities. Again the conclusion is the same as the group of 4 weeks: the activities related to the community members are driven by the discussion related to the community's domain (specifically to the thread's subject) and not by projects, as in the co-located Recurrent CoPs.

Conclusion 3 The message subject usually reflects the content of the message body (related to objective 3 – verification of relation between subject field and the content of the messages).

The messages seen in the group of 8 weeks are the same type as the group of 4 weeks, thus the conclusions regarding subject lines and content are naturally the same in both groups, i.e., perhaps due to the strong technical nature of the *cplus* group, the messages are carefully built, most of the time having a subject that reflects the message content.

Conclusion 4 The amount of data available in the group of 8 weeks is barely enough to do analysis on RCoPs.

Despite having more data available than the previous group, the group of 8 weeks does not present a substantial amount of information that allows one to conclude the existence or not of RCoPs. However, it is possible to notice some characteristics that are clearer in this group as a consequence of having more data than the previous one. For instance, in the case of conclusion 1, which shows that even with more communication with other nodes, there is no pattern indicating a repetition in the same nodes that exchange messages.

6.4. Conclusions

With this initial study it was possible to have a first glimpse at the four CoPs. Although it was not possible to notice any Recurrent CoP within the groups, it was a good opportunity to start to learn about the community's behaviour and functioning.

It was possible to notice that to understand better the communities' characteristics it was necessary to analyse more data at the same time. When the amount of data increased from 4 to eight weeks of messages exchanged, a better picture started to emerge. This indicated that for any technique used, it would be necessary to deal with the whole dataset to draw any strong conclusion. It would not be possible to start with a small sample and from there generalise to a single rule. Any analysis in a sample would need to be used just as a test bed for a more comprehensive study.

It was possible to notice the importance of the core members to the sustainability of the community's life. They were responsible for a significant number of the messages sent. As the newsgroups' existence is based on the exchange of messages, this alone makes the core members an important aspect in the community's functioning.

Regarding the time component, the initial analysis showed that it was necessary to study the whole data to understand how time influenced the community's behaviour, and to allow one to look for recurrence. 12 weeks of analysis is only suitable for initial tests, but to notice recurrence in the activities it was necessary to put together the maximum amount of data available: 52 weeks in this case.

7. Cluster Analysis

7.1. Introduction

Once the initial data analysis on the data sample was finished (section *Initial Analysis* on page 129), it became clear that the same technique could not be used with the complete data. That is due to the fact that the analysis carried out on the sample was only possible because of the small size of the data set.

Ironically this small amount of data that makes it possible easily to confirm the existence or not of patterns, does not allow one to draw any conclusion regarding the existence or not of Recurrent CoPs (RCoPs) due to its limitation in size and timespan. The amount of data available for analysis does not lead to strong conclusions and the twelve weeks period of analysis is not enough to perceive recurrences.

Doing data analysis with the complete data from the four CoPs required a rethink about the strategy used.

The main objective of the data analysis was to detect nodes with the same pattern of activity/no-activity within all participant nodes.

If the activity of the nodes could be traced on a graph, having the number of messages exchanged (represented in the 'y' axis) by time (represented in the 'x' axis), the nodes that formed a Recurrent CoP would produce 'peaks' in the graph followed by 'troughs' (see figure 7.1, on page 152). Moreover, the pattern of the ups and downs in the graph for each node of the same RCoP would probably be the same. This would be the sign of a high probability of nodes with similar curves in the graph to be exchanging messages among themselves.

One possibility to detect this pattern is to group the nodes with similar patterns in categories. Several different methods can be used to accomplish this, but two seem to be more appropriate for the job: *Categorisation* and *Clustering*.

'Categorisation' uses predefined categories, which the individuals are allocated into, whereas 'Clustering' does not have pre-conceived categories and does not know how the individuals will group. The categories in this case are constructed during the process of analysis.

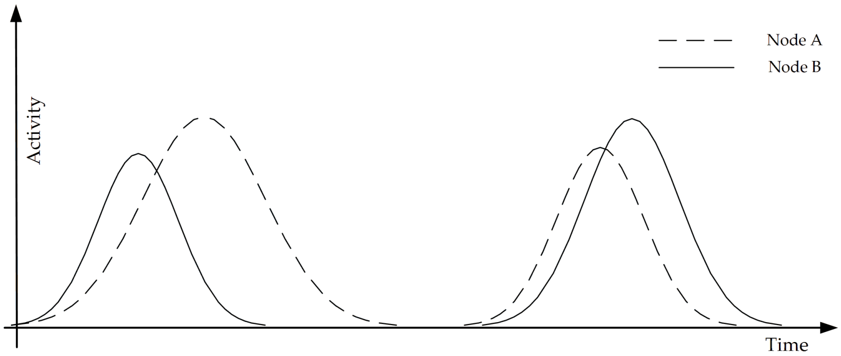


Figure 7.1.: Nodes with similar pattern of activities

Because in this study there is no predefined set of categories, Cluster Analysis (or Clustering) (Burns & Burns, 2008; Chatfield & Collins, 1980) was the tool of choice. Although it is not the only option, certainly it is a very robust one, which has been used for several years now for studies involving groups or communities.

However, before the use of Cluster Analysis in the Communities of Practice can be discussed, it is necessary to describe some definitions and terms used in this methodology. The following sections will introduce the necessary terminology for a better understanding of the discussion.

7.2. Definition of Cluster Analysis

Cluster Analysis is a set of techniques used to divide cases from a population into similar groups, i.e., to separate the data into groups whose members are arranged by a common characteristic (or are related). These groups are called *clusters* (Chatfield & Collins, 1980; Tan et al., 2006). These clusters are homogeneous among themselves and heterogeneous between each other (Mazzocchi, 2008). In this sense Cluster Analysis is the grouping of individuals on the basis of how similar they are.

Similarity can be measured in several different ways: Euclidean, Cosine, Pearson Correlation Coefficient, etc., but a measure is always based on a comparison of attributes. This study compares each member on 52 identical variables: the number of messages sent by week and they are equally relevant to how to clusters individuals. On the basis of these attributes, it is possible to say how far apart these individuals are and, therefore, how similar they are. Consequently, it is possible to cluster them according to these different measures.

In summary, the individuals are compared on the basis of the number of messages sent during each week, and this is the variable used to cluster the community's members.

7.3. Clustering, Partitioning and Dendrogram

The main concept in Cluster Analysis is the *cluster*. As already explained above, Cluster Analysis allows one to explore the data without not much previous knowledge about its nature. Such exploration is done, in summary, by clustering similar individual data points that have some characteristic(s) similar to the rest of the points in the same group.

Clustering can be found in different types (Hierarchical, Partitional, Exclusive, Overlapping, etc.). However, in this study the most common form was used: *Hierarchical Clustering*.

'Hierarchical Clustering' starts by grouping individuals into separated clusters, allocating each one to a unique cluster. From this point other clusters are created through the process of grouping previous clusters into new clusters. The process is repeated until no more clusters are left alone, resulting in a single cluster with all individuals allocated. Figure 7.2 shows an example of Hierarchical Clustering, via a *Dendrogram* representation.

The Dendrogram is a very useful tool for analysing the results of Cluster Analysis when Hierarchical Clustering is used. It shows the whole process of the creation of clusters in the Cluster Analysis. The lines show when individual clusters are grouped hierarchically into the next level of grouping, until all of them are joined into a single cluster. The graph is read from the left to the right.

The top of the dendrogram shows where the first merger starts to happen. It does not necessarily shows whether the individuals are similar in relation to the others, or how important they are to the cluster, but that they are more similar to each other. Thus, this "floating" to the top is an indication of high co-similarity between the nodes.

Another common term used in Cluster Analysis is *Partitioning*. This refers to the creation of what is known as 'Partitional Clustering'. Tan et al. define it as the division of the dataset into non-overlapping subsets (the clusters). The final outcome needs to be such that each data object is found within only one cluster (Tan et al., 2006, pp. 492). In a dendrogram this is accomplished by tracing a straight vertical line dividing the graph at specific levels. For instance, using the dendrogram in figure 7.2 as an example, one can imagine a vertical line traced between the numbers "5" and "10" in the x axis (on the top). This will give two

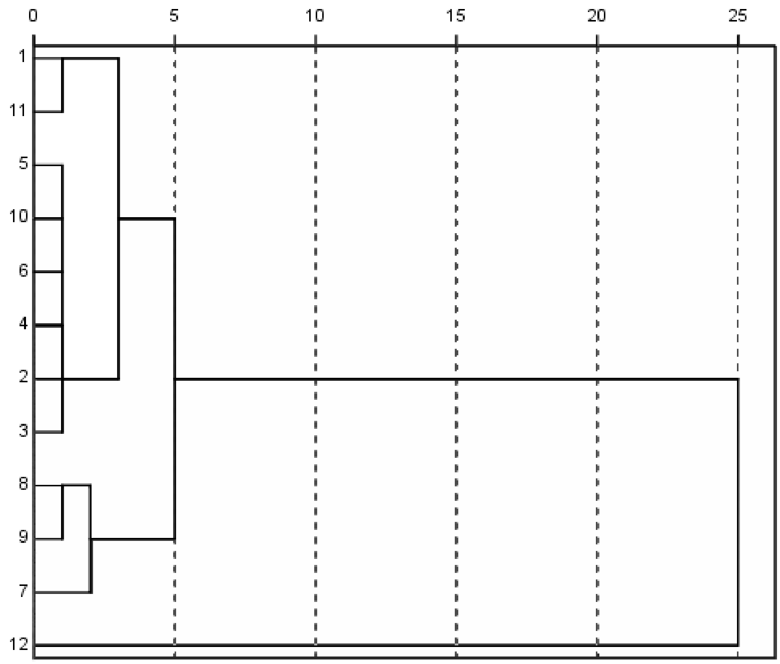


Figure 7.2.: Example of Hierarchical Clustering

clusters as a result, because there are only two cluster lines in the graph touched by the vertical line, while if one traces another line, now between the numbers "0" and "5", but closer to the number five, it will result in three clusters, as the traced line will touch three cluster lines. If the process is repeated with lines moving in the direction of the number "0", the number of clusters involved will increase, until this number is equal to the number of individuals in the set. Consequently, depending on the way the dividing lines are set, different groupings would be created. An indicator for a good location to draw the line is the existence of "clear air", meaning that a well-defined space exists between the lines that define the clusters (Bartholomew et al., 2002, pp. 24–25) (Everitt et al., 2011, p. 95).

This study planned to use partitioning in the hope of discovering Recurrent Communities of Practice (RCoPs). The plan was to divide the dendrogram into slices that could indicate those RCoPs or even new forms of recurrent communities in the main CoPs. The partitioning could highlight clusters with similar patterns in the number of messages sent. This means that Cluster Analysis would group the nodes that were sending or not sending, approximately at the same time. The searched 'peaks' and 'troughs' (shown in figure 7.1, on page 152) could be found by examining the communication's pattern of the nodes belonging to the same cluster. The difficult part would be finding a suitable level in the graph to create the partition (i.e., to draw the division line, as explained above). Unfortunately, the partitioning was never used, because the clusters were not well-defined in the resulting dendrograms. This is discussed further on in this chapter.

7.4. Techniques used in the Cluster Analysis

As explained above, Cluster Analysis is no more than simply the clustering of individual data. However, the main question is *how* this data is clustered.

First, it is necessary to define which method should be used to combine clusters at each stage. This method determines the distance between two clusters at each stage of the procedure (Norusis, 2011). The method used throughout this study was the *Average Linkage Within Groups*. This uses the distance between points in different clusters to calculate the next cluster.

Norusis defined it as the average linkage within groups. It groups the clusters in a way that the average distance between all cases is as small as possible (Norusis, 2011, p. 387). The name "average linkage within group" is due to the fact that at the end of the process the distance between two clusters is the average of the distances between all pair of cases in the final cluster (Norusis, 2011, p. 387).

The second necessary definition is the measure of similarity between the individuals, or measure for intervals, as named by SPSS. There are several different techniques for this, but this study used only two: *Euclidean Space* and *Pearson Correlation Coefficient*. These were chosen due to the nature of the studied communities and to the expected outcomes from the Cluster Analysis.

Regarding the nature of the communities, the two methods are useful because of the existence of a single type of variable (number of messages), making it easier to use these techniques.

In a very simplified explanation, the Euclidean Space technique (also known as *Euclidean Distance*) creates the clusters based on the relative distance in space between the clusters. This means that if one could trace each individual datum in the space (using the variables as spatial dimensions), the clustering would be formed by the points that were closer to each other.

Sometimes a variation of the Euclidean Distance was used, called *Squared Euclidean Distance*. This method removes the sign from the points and emphasises objects further apart, which increases the effect of outliers (Garson, 2010).

In this study, the Euclidean space would be formed by 52 dimensions (the weeks in which the messages were sent). Therefore, closer points would be the nodes with approximately the same number of messages in each week.

In Pearson Correlation Coefficient (again in a very simplified explanation) the clusters are formed by the similarity in the pattern of the individual data points or clusters, i.e., the clusters are created based on a correlation model of the data.

In this work the Pearson Correlation would also have 52 dimensions and the closer points would be formed by the individuals with variables that changed by a similar amount in the same period, i.e., the nodes would have similar variations in the number of messages sent in equivalent weeks.

The choice of these techniques was based on the hope that if some communities' members had recurrent patterns of activity and inactivity, the Cluster Analysis could group them together in a cluster. This could be indicative of the existence of a cohesive community within the main CoP.

The great advantage of using these two techniques is that the processes could pick small tightly connected groups in a significantly noisy background, caused by the large number of messages available in the data set.

7.5. Software used for Cluster Analysis

The chosen software for running the data analysis was SPSS (2010). That is owing to several reasons, among them the reliability and trust developed over the years of intensive use by the scientific community, and also the vast number of publications available, explaining how to run Cluster Analysis on it.

SPSS has several different settings for Cluster Analysis, but the methods used were the two described previously: 'Euclidean Space' and 'Pearson Correlation Coefficient'.

Although SPPS is unable to load matrices in Pajek's format, it is possible to do so using Excel as an intermediate step for this. Additional details of this procedure are explained below.

7.6. Data preparation

The data preparation consisted of transferring the data from spreadsheets (in the case of the data sample) or databases (in the case of the whole data set), and running Cluster Analysis in SPSS.

Before running the Cluster Analysis on the complete data, it was decided to run it first on the data sample of 12 weeks. The plan was to test the efficacy of the two methods on small data that could have all the characteristics present in the main data set. If the results could create the clusters in the expected way, i.e., selecting Recurrent CoPs within the data, then the next step would be to use the procedures with the main dataset.

For the tests with the data sample, the material used was the one resulting from the steps taken in section 6.3.3 (on page 130). Specifically, the data used for the tests is defined in a matrix containing the 12 week period of analysis, as shown in table 6.1, on page 138. The only necessary modification was the substitution of blank cells in the spreadsheet representing the matrix, with "zeros". This was required to inform SPSS that empty cells in fact represented cells with zero messages sent (SPSS could otherwise interpret blanks as a lack of data).

The following step was to transfer the data from the matrix to SPSS and run the Cluster Analysis on it.

7.7. Test with sample data – the first run

The sample used is an excerpt of 12 weeks of communications in the Community of Practice *cplus* (the same used in section 6.3, on page 129). With the same data it would be easier to make relations between the initial data analysis and the Cluster Analysis.

The method chosen for the Hierarchical Cluster Analysis in SPSS was:

- Cluster method: within-groups linkage, with measure for intervals: Squared Euclidean Distance.

The resulting dendrogram can be seen in figure 7.3 (on page 158).

Before discussing the results, it is important to stress that other methods were tested in order to cluster the individuals, and they produced similar outcomes. These results are not listed here, because they did not produce a difference which is worth reporting. This makes sense, as the methods are not so different. Moreover, if there are real groups within the data then the way in which the clusters are formed is not crucial for this study. The methods should produce similar groupings. Obviously, there are differences in the details about how they merge, but broadly they should produce the same clusters.

The different methods tested were: *Cosine* and *Average Linkage Between Groups*.

As far as the dendrogram produced by the method chosen here is concerned, it is possible to notice that in the figure the part on the top was cut off. This was done to save space, as the graph produced is very long and the missing part is not relevant to the analysis, being only a variation of the parts already shown.

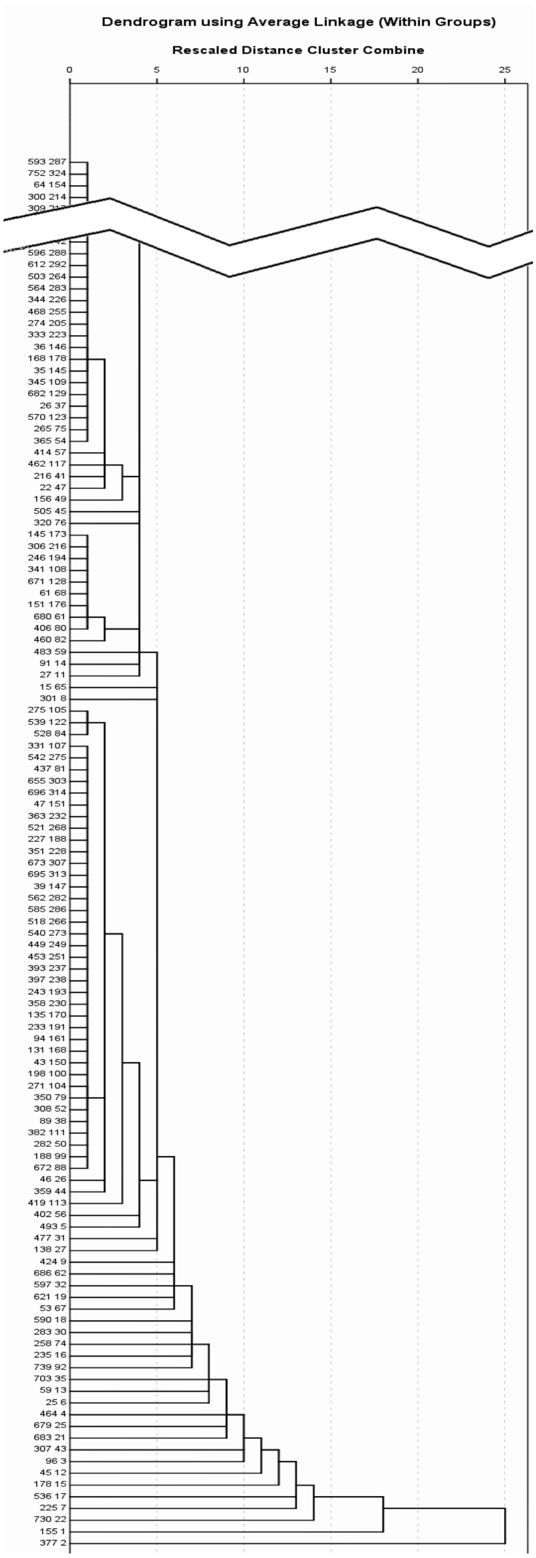


Figure 7.3.: Dendrogram from Cluster Analysis on data sample of 12 weeks – Squared Euclidean distance within-groups linkage

7.7.1. Quick analysis of the first run

The first aspect that draws attention in figure 7.3 is the long 'column' created by the nodes at the left of the figure. That is due to the first step of the analysis, which aggregates the nodes with similar activity.

Comparing the figure with the matrix that originated it, it is possible to understand why this column is formed: the cluster is the result of grouping nodes with very little participation (in weeks), which in the matrix represent nodes located on the bottom of it. The core nodes at the top of the matrix are at the bottom of the graph (nodes 155 and 377), and are also in a single cluster.

These two cases (core nodes and less active nodes) could be removed from the data to be analysed without problems. This is owing to the fact that the data analysis was trying to find Recurrent CoPs, and these two types of nodes are clearly not members of a RCoP.

In the case of the core nodes, this is because there is no recurrence in core nodes' activities. They are constantly very active, not having cycles of activity/ no activity, typical of Recurrent CoPs. At the same time, nodes with low activity lack the minimal participation necessary to be called member of a community, or member of an RCoP, specially. These nodes are the ones with 2 weeks or less of participation in the twelve weeks studied.

Additionally, the result showed that it was necessary to remove these two types of node, as they were causing 'noise' in the results. This means that they are increasing the computational time to create the dendrogram and creating a visual disturbance, making it more difficult to locate the searched clusters.

7.8. The second run

For the second run the the core nodes and the nodes with low participation were removed from the matrix used in SPSS. The resulting dendrogram can be seen in figure 7.4 on page 160.

It is interesting to notice that this time the dendrogram shows a more equally distributed set of clusters. One can notice that the 'column' at the top of the figure, which appeared in the first run, still appears, but at a much smaller scale, reinforcing the argument that the core nodes and the nodes with low activity were causing 'noise' in the overall picture.

Although the second run showed a more evenly separated picture, the result still lacks meaning. Trying several different configurations in SPSS just leads to different dendrograms, but without the clustering of nodes with possible recurrent

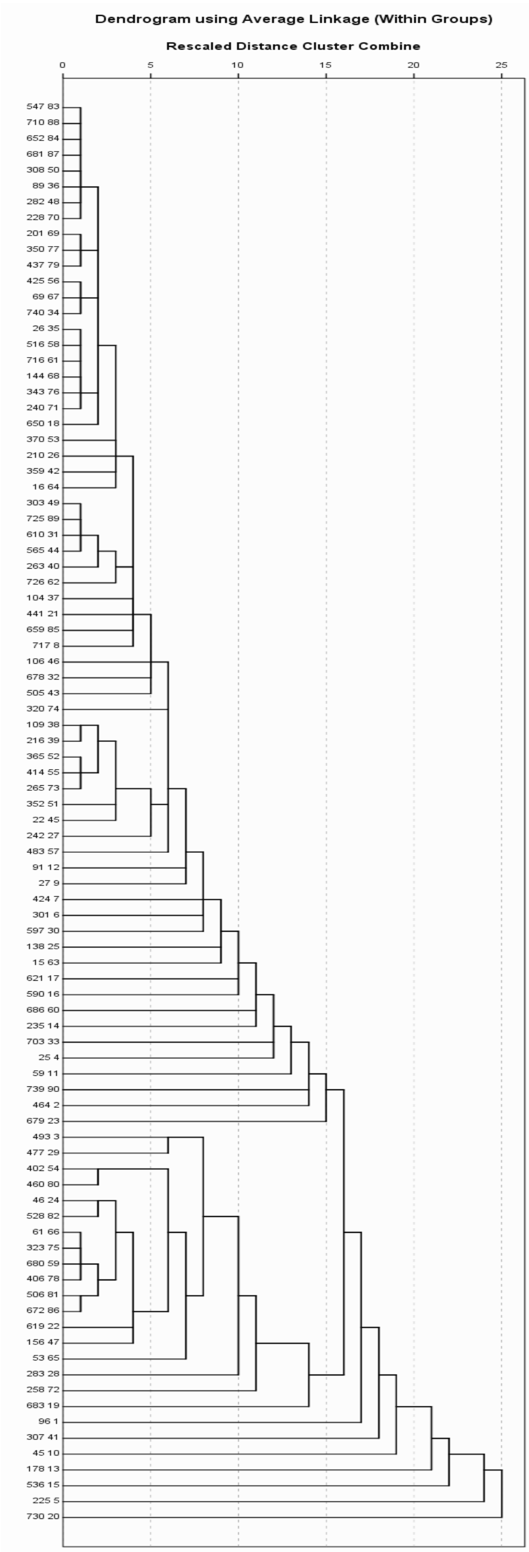


Figure 7.4.: Dendrogram from Cluster Analysis on data sample of 12 weeks – Squared Euclidean distance – Second run

behaviour. Moreover, it is possible to notice again the lack of 'clear air' to detect a good place to make a partition. This highlights the problem with the absence of meaning in the graph. In an attempt to find a solution for the problem, another test was carried out, but this time using a different approach.

7.9. The third run

For this new run of tests, a fresh set of data was created to test the ability of this approach to detect clusters. The new data has the same size and participant nodes as the data sample matrix.

The steps adopted for the new approach are twofold: to create a random matrix, and to modify it afterwards, introducing "artificial" nodes, which have a specific controlled behaviour. These nodes were created intentionally as *recurrent nodes*. Thus, their activity in the matrix has periods of activity and inactivity inserted on purpose. Moreover, the pattern of their activity was created to be deliberately very similar. This new matrix would make it easier to verify whether the Cluster Analysis was detecting (clustering) the introduced recurrent nodes.

An excerpt from the matrix with the artificial recurrent nodes is shown in table 7.1 (on page 162). The two inserted nodes are highlighted with lines in grey.

Two different methods were used to run the Cluster Analysis in SPSS:

1. Within-groups linkage, with measure for intervals: Euclidean Distance;

2. Within-groups linkage, with measure for intervals: Pearson correlation.

The resulting dendrogram for method 1 (Euclidean Distance) of clustering is shown in figure 7.5, on page 163.

It is possible to notice some important aspects in the result. First, the cluster analysis is still grouping the nodes with similar periods of activity, even with the random data. Second, the inserted recurrent nodes are grouped in a separate cluster (as highlighted in the figure).

In order to test the possibility of coincidence, the same data was used in a second dendrogram, which used the second method (Pearson Correlation) of clustering. The result is shown in figure 7.6, on page 164. Once again the result showed a similar outcome, where the recurrent nodes were grouped into a single cluster.

To try to remove any doubt from the results, other tests were carried out using 3 and 4 artificial recurrent nodes, respectively. These tests were also run using the Cosine and Pearson Correlation methods for each new set of artificial recurrent nodes.

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Total	Occur
155	1	8	4	3	10	9	4	2	2	7	0	7	**57**	**11**
377	0	4	6	1	7	8	6	1	3	3	4	2	**45**	**11**
96	6	9	5	7	7	5	8	3	6	7	10	0	**73**	**11**
464	7	2	6	5	9	4	8	9	3	3	9	8	**73**	**12**
493	7	3	4	3	4	5	4	4	2	1	3	7	**47**	**12**
25	5	2	10	5	7	1	1	5	4	6	5	4	**55**	**12**
225	4	3	3	6	5	8	5	6	8	0	5	6	**59**	**11**
301	9	8	3	2	10	5	2	1	10	8	9	7	**74**	**12**
424	4	4	8	5	5	5	5	8	2	2	1	8	**57**	**12**
717	8	5	2	8	5	9	3	9	8	1	4	0	**62**	**11**
27	6	9	7	2	3	2	1	4	9	4	4	8	**59**	**12**
45	8	8	10	5	9	3	5	3	5	2	6	3	**67**	**12**
59	2	6	2	5	5	5	7	5	3	6	3	2	**51**	**12**
91	9	4	8	4	10	2	0	0	1	6	7	1	**52**	**10**
178	7	5	7	5	2	7	8	5	3	9	2	10	**70**	**12**
235	2	3	7	7	6	5	4	3	7	8	1	2	**55**	**12**
536	0	7	8	3	10	7	1	5	2	6	1	0	**50**	**10**
590	10	7	9	7	0	3	3	0	2	6	1	5	**53**	**10**
621	6	8	2	0	4	2	1	8	10	8	6	6	**61**	**11**
650	3	5	6	3	7	7	10	4	5	6	1	3	**60**	**12**
683	2	4	3	10	4	9	9	3	7	1	2	2	**56**	**12**
730	7	2	3	5	7	9	4	10	4	2	5	6	**64**	**12**
441	6	2	9	1	7	4	5	3	6	4	7	9	**63**	**12**
619	4	3	7	3	6	7	9	2	4	5	4	5	**59**	**12**
679	5	3	5	7	6	7	2	8	0	6	9	0	**58**	**10**
46	6	1	1	0	1	3	4	5	3	8	6	0	**38**	**10**
138	3	6	5	3	6	8	2	3	4	1	2	5	**48**	**12**
210	1	9	7	1	6	5	5	8	1	8	3	6	**60**	**12**
242	4	7	9	6	2	3	2	1	6	7	7	6	**60**	**12**
283	1	4	3	1	3	4	2	8	3	7	4	7	**47**	**12**
477	5	6	3	5	9	5	8	7	5	9	2	3	**67**	**12**
597	7	7	2	1	5	9	3	4	1	1	1	4	**45**	**12**
610	8	7	8	10	6	5	7	7	9	0	5	6	**78**	**11**
678	4	9	6	2	1	8	7	3	6	6	4	1	**57**	**12**
⋮													⋮	⋮
732	4	5	0	0	6	7	0	0	8	7	1	0	**38**	**7**
747	2	2	6	8	5	9	1	4	1	2	8	8	**56**	**12**
748	7	1	2	5	1	6	6	9	4	7	2	5	**55**	**12**
750	0	8	8	7	10	2	0	7	10	1	1	3	**57**	**10**
751	2	3	8	4	5	9	0	2	4	0	7	1	**45**	**10**
752	8	7	0	0	6	5	0	0	8	10	2	0	**46**	**7**

Table 7.1.: *Cplus* sample: Excerpt from random matrix for testing Cluster Analysis (third run). **Two** artificial recurrent nodes are highlighted by grey lines

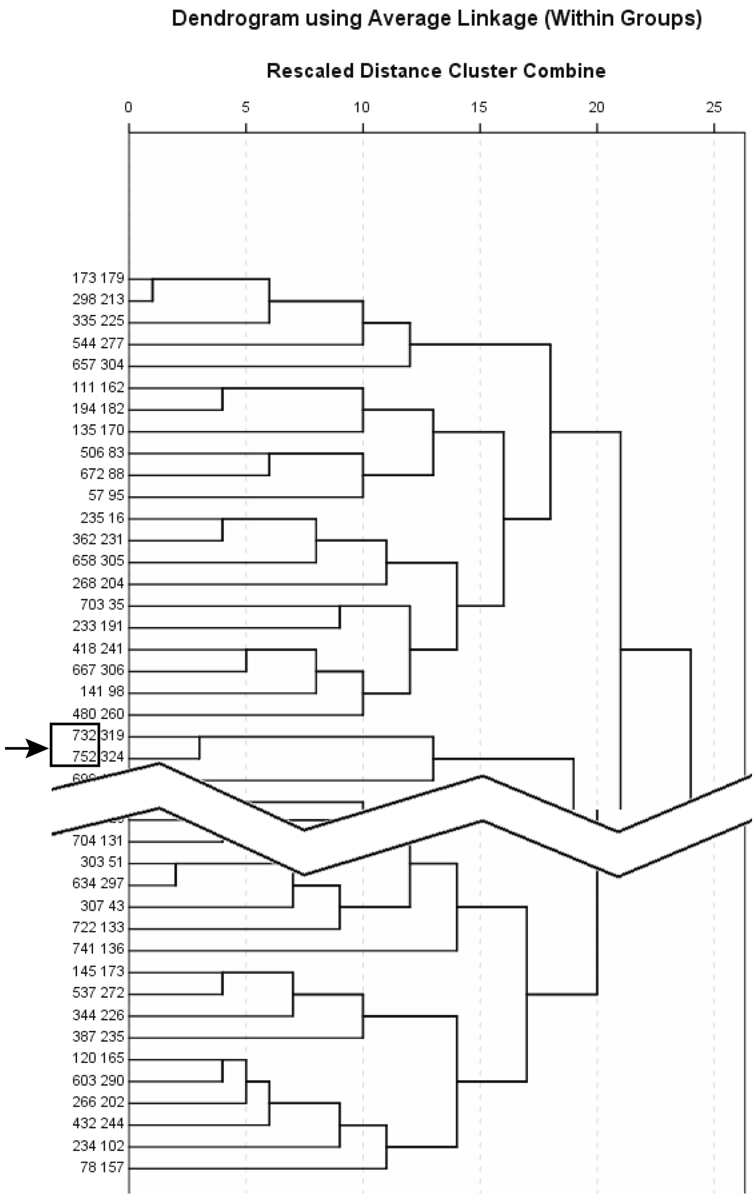


Figure 7.5.: Dendrogram from Cluster Analysis on data sample of 12 weeks – third run (**two** artificial recurrent nodes). Cluster method: within-groups linkage and measure interval Euclidean Distance

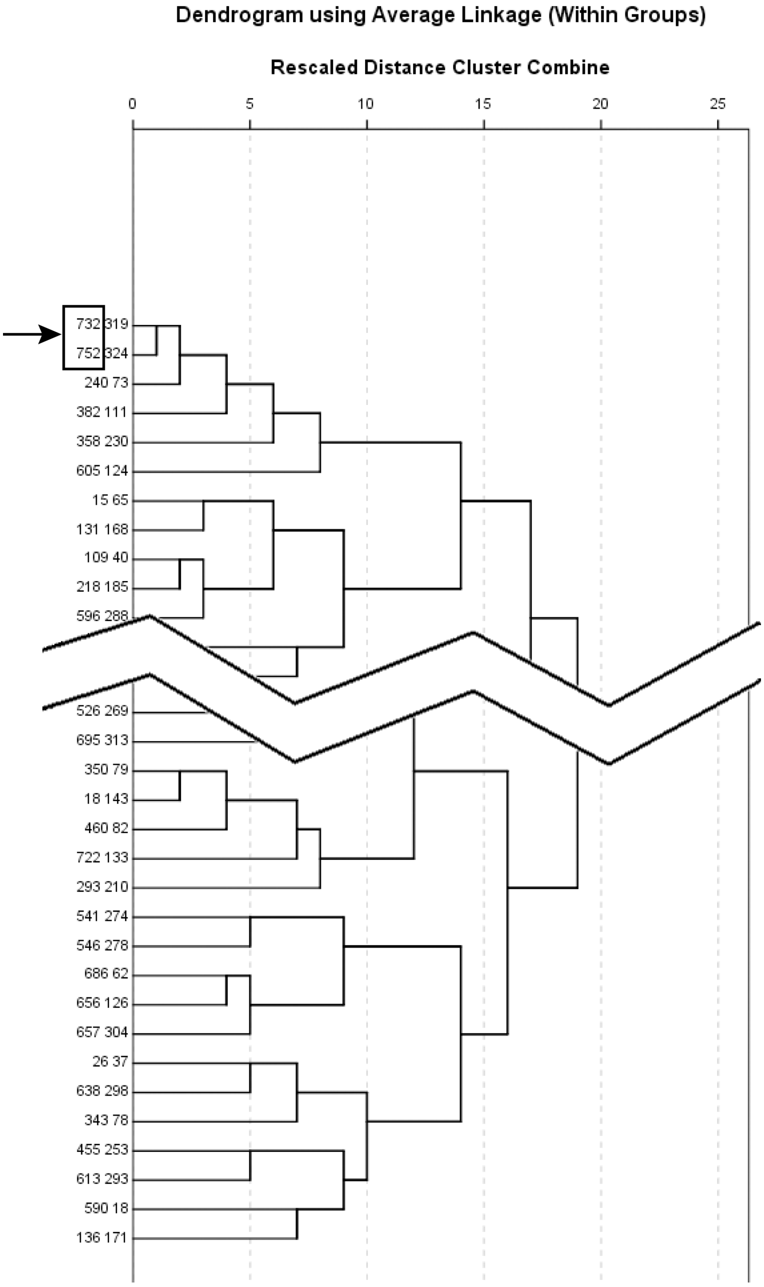


Figure 7.6.: Dendrogram from Cluster Analysis on data sample of 12 weeks – third run (**two** artificial recurrent nodes). Cluster method: within-groups linkage and measure interval Pearson correlation

The modified matrices for these cases are shown in tables 7.2 and 7.3. To save space, just the part that includes the recurrent nodes is shown.

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Total	Occur
719	1	6	0	0	3	5	0	0	10	3	3	0	**31**	**7**
727	9	5	1	9	0	6	3	4	1	5	10	5	**58**	**11**
732	4	5	0	0	6	7	0	0	8	7	1	0	**38**	**7**
747	2	2	6	8	5	9	1	4	1	2	8	8	**56**	**12**
748	7	1	2	5	1	6	6	9	4	7	2	5	**55**	**12**
750	0	8	8	7	10	2	0	7	10	1	1	3	**57**	**10**
751	2	3	8	4	5	9	0	2	4	0	7	1	**45**	**10**
752	8	7	0	0	6	5	0	0	8	10	2	0	**46**	**7**

Table 7.2.: *Cplus* sample: Excerpt from random matrix for testing Cluster Analysis (third run). **Three** artificial recurrent nodes are highlighted by grey lines

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Total	Occur
696	8	2	0	0	4	3	0	0	4	1	8	0	**30**	**7**
707	1	9	3	2	7	10	3	4	9	7	7	3	**65**	**12**
708	9	1	4	4	0	6	5	4	3	4	7	10	**57**	**11**
719	1	6	0	0	3	5	0	0	10	3	3	0	**31**	**7**
727	9	5	1	9	0	6	3	4	1	5	10	5	**58**	**11**
732	4	5	0	0	6	7	0	0	8	7	1	0	**38**	**7**
747	2	2	6	8	5	9	1	4	1	2	8	8	**56**	**12**
748	7	1	2	5	1	6	6	9	4	7	2	5	**55**	**12**
750	0	8	8	7	10	2	0	7	10	1	1	3	**57**	**10**
751	2	3	8	4	5	9	0	2	4	0	7	1	**45**	**10**
752	8	7	0	0	6	5	0	0	8	10	2	0	**46**	**7**

Table 7.3.: *Cplus* sample: Excerpt from random matrix for testing Cluster Analysis (third run). **Four** artificial recurrent nodes are highlighted by grey lines

The resulting dendrograms can be found in figures 7.7 (on page 166) and 7.8 (on page 167) for three artificial recurrent nodes (Euclidean Distance and Pearson Correlation, respectively), and in figures 7.9 (on page 168) and 7.10 (on page 169) for four inserted recurrent nodes.

It is possible to notice in the dendrograms that there is not clear pattern in the creation of the clusters. Sometimes the result showed a single cluster with all inserted recurrent nodes (e.g., with three recurrent nodes in the Euclidean Distance method), but in the majority of the cases this did not happen.

Even with different methods the results were not promising. What started as a good possibility using two artificial recurrent nodes proved to be unreliable when

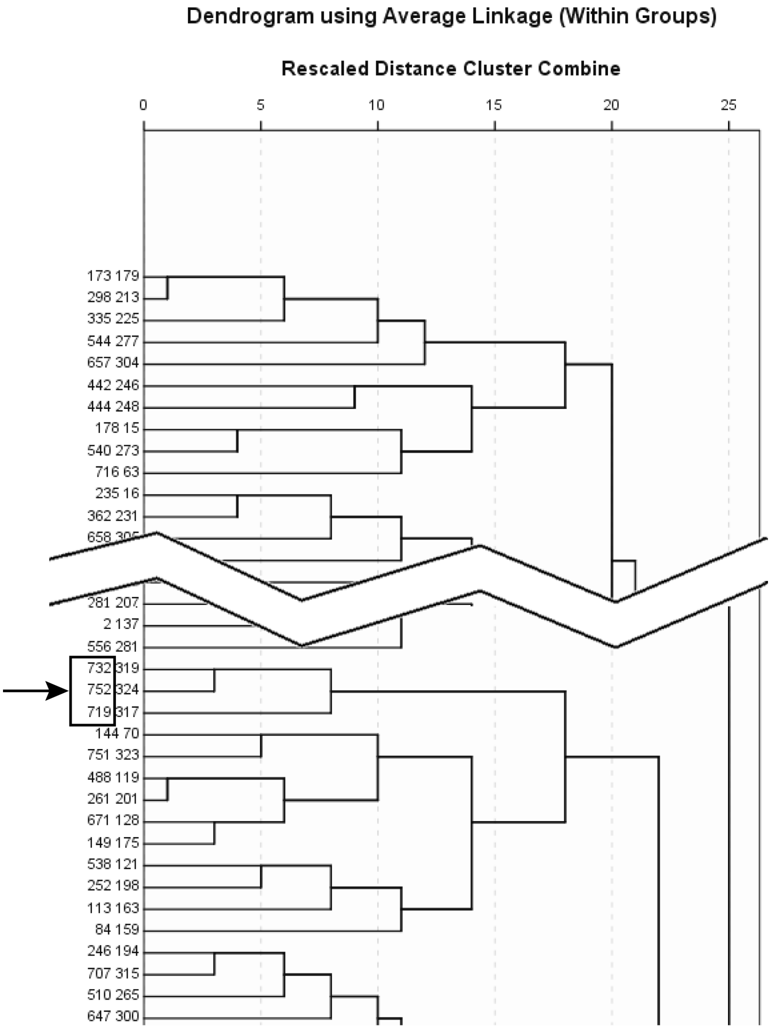


Figure 7.7.: Dendrogram from Cluster Analysis on data sample of 12 weeks – third run (**three** artificial recurrent nodes). Cluster method: within-groups linkage and measure interval Euclidean Distance

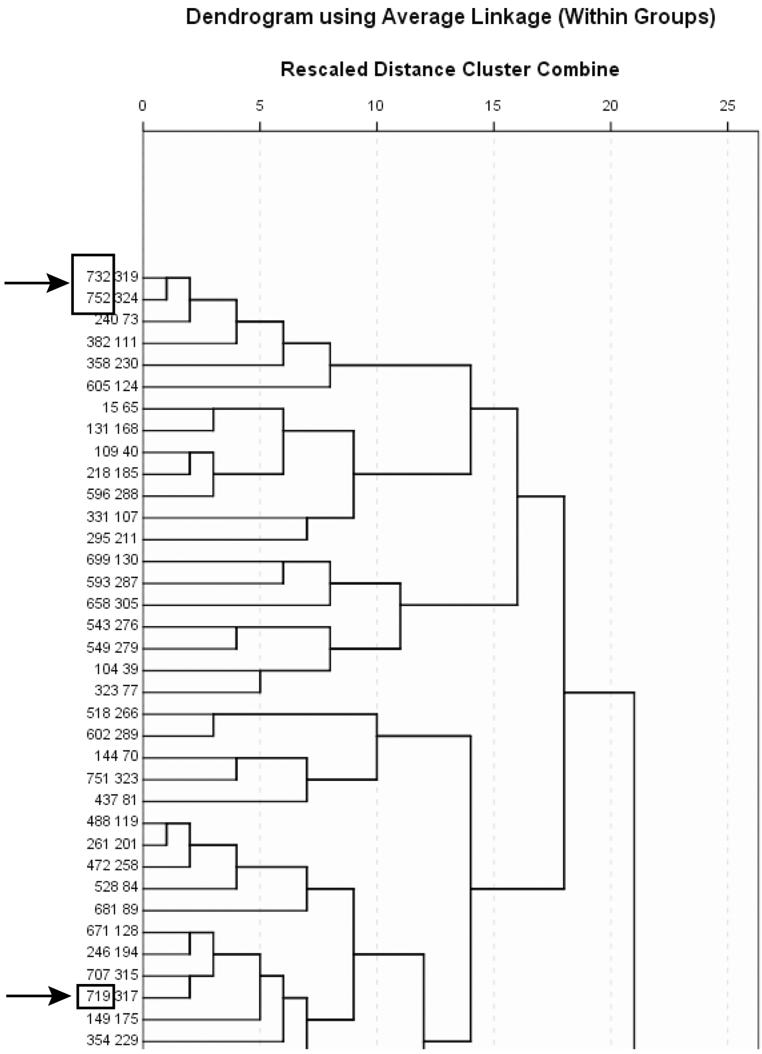


Figure 7.8.: Dendrogram from Cluster Analysis on data sample of 12 weeks – third run (**three** artificial recurrent nodes). Cluster method: within-groups linkage and measure interval Pearson Correlation

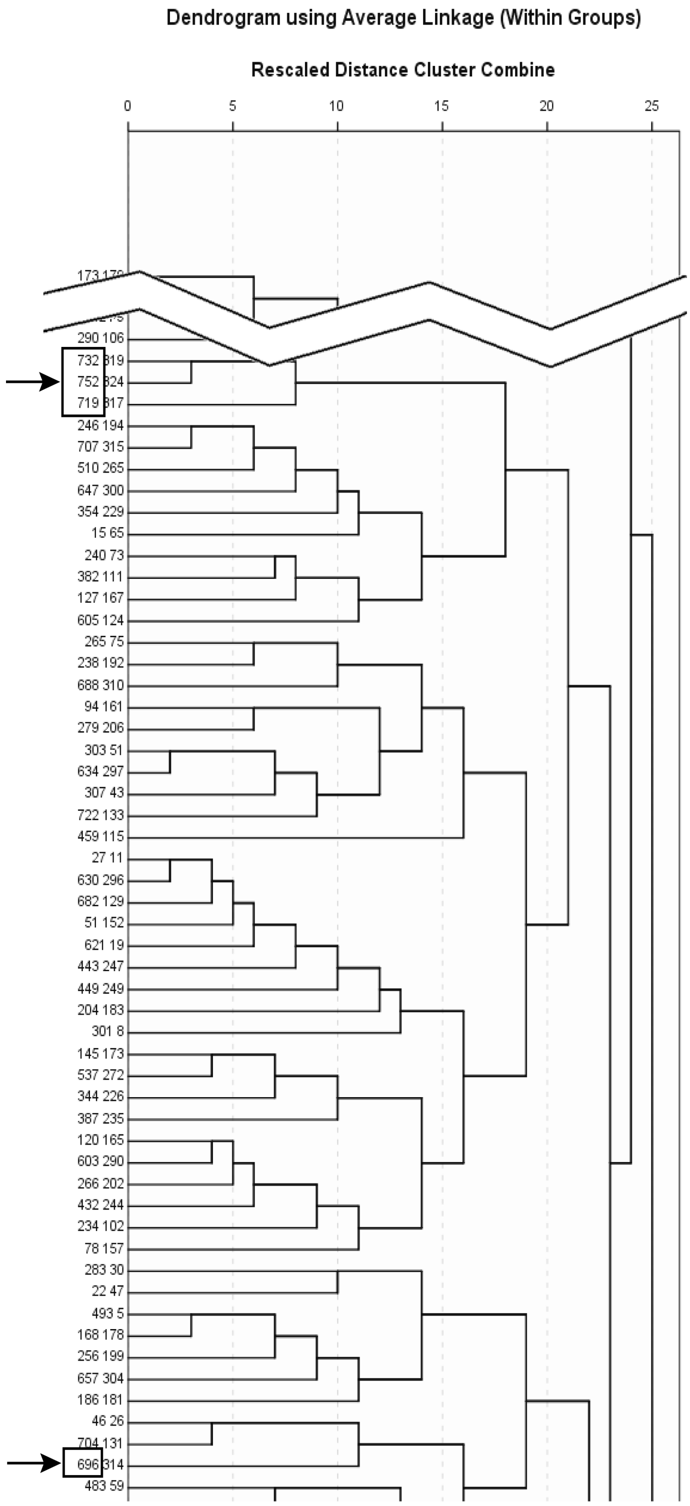


Figure 7.9.: Dendrogram from Cluster Analysis on data sample of 12 weeks – third run (**four** artificial recurrent nodes). Cluster method: within-groups linkage and measure interval Euclidean Distance

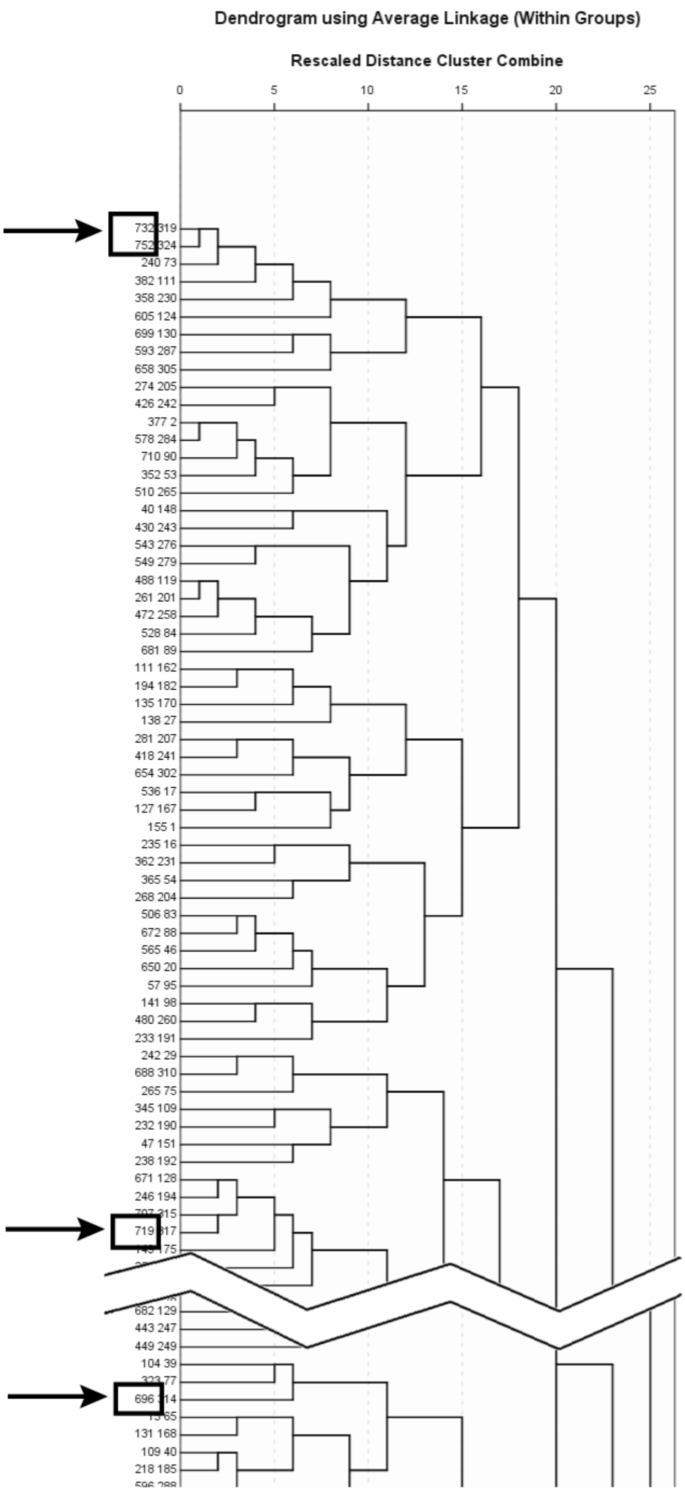


Figure 7.10.: Dendrogram from Cluster Analysis on data sample of 12 weeks – third run (**four** artificial recurrent nodes). Cluster method: within-groups linkage and measure interval Pearson Correlation

the number of recurrent nodes increased.

Due to the odd results from this Cluster Analysis, it was decided to carry out a different test.

7.10. The fourth run

This time the main objective was to analyse in detail the cluster(s) that could have recurrent nodes in the original data sample by artificially inserting "recurrent" individuals.

The plan was to check if the conditions that define a node as recurrent were present in the nodes of a cluster. For this, a series of tests was completed using the original sample matrix (see table 6.1, on page 138).

For this run, the chosen methodology for the Cluster Analysis was within-group linkage with measure for intervals Euclidean Distance. This is due to the fact that in several tests using within-group linkage and Euclidean Distance it was noticed that usually the inserted recurrent nodes were located at the top of the dendrogram. As discussed in section 7.3, on page 153, this is due to the fact that the cluster methodology starts to merge individuals and clusters that are more similar to each other (high co-similarity between the nodes). Thus, the plan was to analyse a few nodes that were located in the same cluster, at the top of the graph. Not all them needed to be analysed, as the objective was to check the potential for recurrence of these nodes, and for this a sample would suffice.

The resulting dendrogram from the Cluster Analysis is shown in figure 7.11, on page 171.

7.10.1. The fourth run – tests

Test 1

The first test on the data was to find out if the nodes in the first cluster (at the top of the dendrogram) were communicating with nodes from the same cluster. An excerpt from a matrix relating some of these nodes is represented in table 7.4, on page 172. Notice, however, that not all nodes involved in the communication are represented in table 7.4.

A table with only the nodes from the same cluster (and contacted nodes) appears as table 7.5 on page 173.

The test led to the conclusion that in this case the nodes from a cluster were talking to other nodes of the same cluster, but not exclusively (see table 7.5, on page 173).

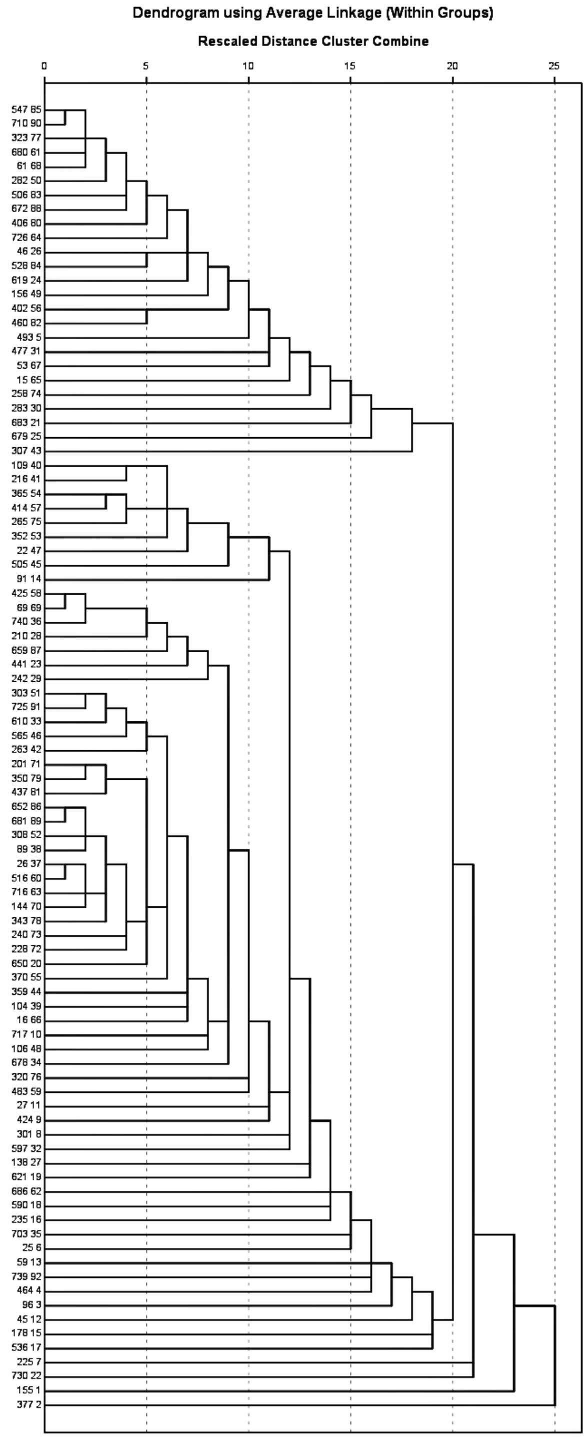


Figure 7.11.: Dendrogram from Cluster Analysis on data sample of 12 weeks – fourth run. Cluster method: within-groups linkage and measure interval Euclidean distance

Node	Total	Occur	Contacted nodes														
15	17	3	138	280	**282**	**402**	**460**	**477**	536	597	**679**	705	717	719	739	741	
46	15	6	39	106	138	225	235	**323**	377	393	420	441	605	**619**	**683**	739	
53	19	3	91	155	**156**	178	201	242	306	361	377	**493**	516	539	**547**	699	740
61	6	3	**402**	437	590												
156	15	4	48	**53**	155	178	228	**460**	597								
258	27	3	**61**	163	178	**283**	370	**402**	610	650	678	**679**	**680**				
282	8	4	**15**	377	**477**	526	739										
283	36	6	16	27	33	45	71	155	234	235	243	**258**	320	**402**	**406**	424	441
307	36	5	16	27	59	96	106	210	225	240	242	**283**	301	308	**402**	414	424
323	5	3	**46**	235	377	**683**											
402	20	4	33	**53**	178	**258**	330	377	424	441	**460**	610	621	**680**	686	717	
406	9	3	155	178	263	**283**	659										
460	14	3	**15**	**156**	188	**402**	**406**	424	**493**	**619**	**680**	681	711				
477	31	6	**15**	263	275	**282**	295	321	377	**547**	590	**619**	695	711	717		
493	33	10	9	16	43	51	**53**	57	78	113	120	168	178	198	233	303	320
506	7	3	4	**46**	71	621											
528	10	3	188	246	377	424	441	678									
547	4	3	**53**	345	**477**												
619	23	7	**46**	91	155	235	263	377	414	**460**	**477**	634					
672	10	3	96	155	235	424											
679	47	7	**15**	25	27	**46**	84	96	104	151	155	198	225	**258**	**307**	320	377
680	8	4	**15**	27	**258**	377	**402**	**460**									
683	47	8	**46**	96	155	229	419	424	461	536	540	542	658	671	686		
710	5	3	9	335	396	441	650										
726	12	4	**53**	173	317	377	419	464									

Table 7.4.: *Cplus* sample: Excerpt from matrix for Cluster Analysis (fourth run). Contacted nodes from the same cluster are represented in bold

Test 2

A randomly chosen node was selected to conduct a deep analysis on its contact activity. The node select was '680'.

The node was chosen to discover if the communication is reciprocal between the selected nodes from the same cluster. Node '680' sent message to four nodes ('15', '258', '402' and '460') that belong to the same cluster. Of these, three ('258', '402' and '460') also sent messages back to node '680'.

- Node '680' sent messages to node '258' in week 1 and week 2.
- Node '258' sent messages to node '680' in weeks 1 and 2.
- Node '680' sent messages to node '402' in week 2.
- Node '402' also sent messages to node '680' in week 2.
- Node '680' sent messages to node '460' in weeks 1 and 2.

Node	Contacted Nodes						
15	282	402	460	477	679		
46	323	619	683				
53	156	493	547				
61	402						
156	53	460					
258	61	283	402	679	680		
282	15	477					
283	258	402	406	460	679		
307	283	402	493	679	680		
323	46	683					
402	53	258	460	680			
406	283						
460	15	156	402	406	493	619	680
477	15	282	547	619			
493	53	402	460	528			
506	46						
528							
547	53	477					
619	46	460	477				
672							
679	15	46	258	307	680		
680	15	258	402	460			
683	46						
710							
726	53						

Table 7.5.: *Cplus* sample: Table with contacted nodes only from the same cluster

- Node '460' sent messages to node '680' only, in week 2.

This test showed that in this case the communication with the nodes from the same cluster was reciprocal. This is not surprising, as the community is an active one, and replying to messages is a signal of participation and politeness. However, the main point was to find out if this reciprocity was linked to nodes in the same cluster, and the answer was affirmative.

Interestingly, the results of this test give the first clue that something different existed in this community. The high level of connectivity between some members is the first evidence of a strong engagement, not necessarily related to a subgroup of the CoP (an expected characteristic of a Recurrent CoP). This was the first glance at what was named *Transient Core Members (TCMs)*.

7.11. Analysis of CoP *cplus* in the 52 week period

Although the previous analysis already showed that Cluster Analysis could not be used to find the Recurrent Communities of Practice, or any similar cohesive group within the main CoP, it was decided to run this same analysis on one of the four main Communities of Practice to check for any possibility of success with this technique. Moreover, this attempt could shed light on the possible existence of recurrence over a longer time scale.

The chosen CoP was *cplus*, as previous tests had already shown how a sample of this was represented in a dendrogram created by the Cluster Analysis. The original matrix had the core nodes and the nodes with low activity removed to avoid 'noise' in the results, as previous tests proved that this was a crucial decision.

Following the same standard used in the other analysis, the methods used were Within-groups linkage, with measure for intervals Euclidean Distance and Within-groups linkage, with measure for intervals Pearson Correlation. The results can be seen in figure 7.12, on page 175, for Euclidean Distance and in figure 7.13, on page 176, for Pearson Correlation.

It can be noticed that although the dendrograms are shown at a very small scale, it is perceivable that there is no pattern that can be used to detect a recurrent CoP, or any similar recurrent subgroup. The clusters are very evenly distributed, lacking any 'clear air' that could help to partition the clusters. It is not possible to draw a line (as explained in section 7.3, on page 153) to divide the dendrogram into a specific level and choose clusters on that level.

Therefore, it is not possible to use Cluster Analysis to select nodes the are behaving as a single and cohesive small group within the main Community of Practice.

7.12. Conclusions

After several different attempts with different methods and data, no results could be drawn from the Cluster Analysis. Every time that a small clue led to a significant result, new tests proved it was not reliable for different amounts of data involved or different methods used.

The interesting aspect is that Cluster Analysis is designed to find clusters, and those were found, but without consistency between variations of data input. Methods such as Euclidean Distance or Pearson Correlation are designed to find groups with similarity in patterns, but in this case they proved disappointing.

This was a complete mystery until it was decided to run Social Network Analysis (SNA) on the data (see next chapter). Through SNA it was possible to notice that there were no cohesive subgroups inside the four Communities of Practice, but instead there were individual members with recurrent behaviour. This could explain the problems faced by the algorithms used in the Cluster Analysis, and clarify why, when the methods were varied, different clusters were formed.

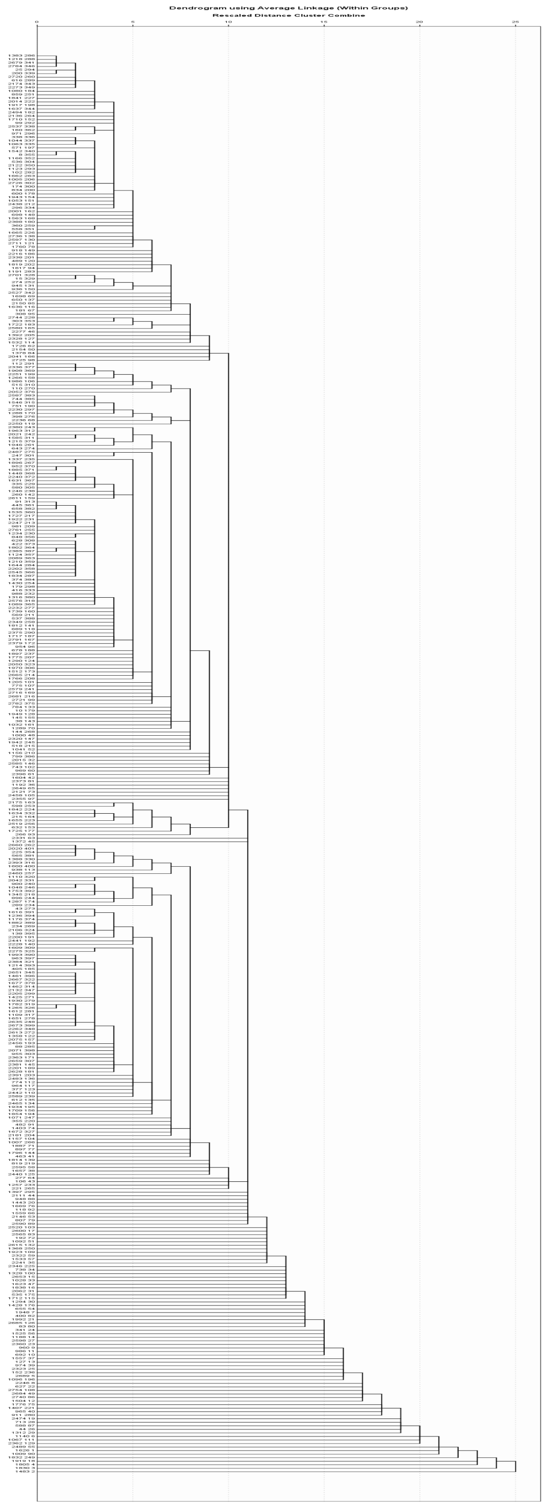


Figure 7.12.: Dendrogram from Cluster Analysis on complete data of 52 weeks in CoP *cplus*. Cluster method: within-groups linkage and measure interval Euclidean Distance

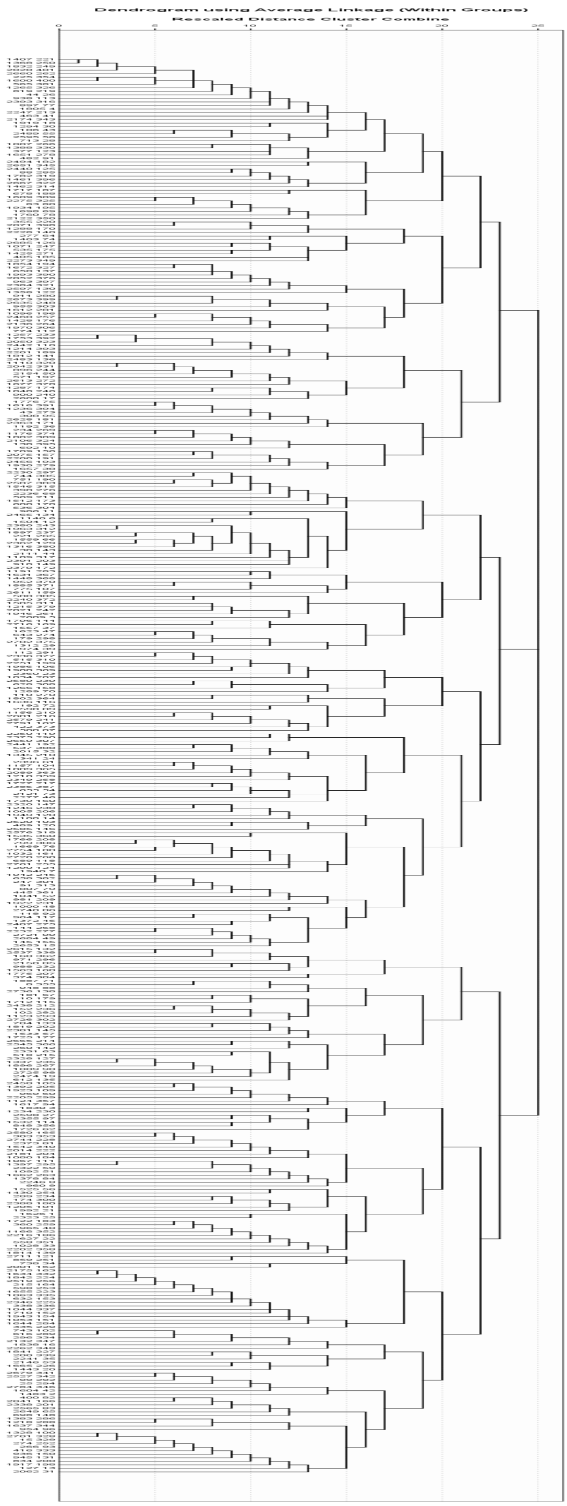


Figure 7.13.: Dendrogram from Cluster Analysis on complete data of 52 weeks in CoP *cplus*. Cluster method: within-groups linkage and measure interval Pearson Correlation

Cluster Analysis is still a very important and well-established technique for the analysis of groups or communities, but the nature and functioning of the Virtual Communities of Practice, at least in the cases studied in this work, rendered this tool unsuitable for this data analysis. A solution to the problem was the use of a technique that made it possible to carry out a visual data analysis.

A methodology that is appropriate and created for this purpose is Social Network Analysis, and this is discussed and applied in the next chapter.

8. Social Network Analysis for Recurrent CoPs

8.1. Introduction

The main purpose of the data analysis in this study was to understand the behaviour of Communities of Practice (CoPs) and to detect the possible existence of Recurrent Communities of Practice (RCoPs) within electronic networks.

Following the inability of Cluster Analysis (CA) to provide the type of analysis necessary for this study, the Social Network Analysis (SNA) approach seemed promising, as it allows to use a visual technique, not only an algorithmic one. The choice of a visual approach using SNA tools was in order to allow a visual inspection of the characteristics of Communities of Practice, as Social Network Analysis (SNA) has a good potential to reveal previously unconsidered associations between people.

Additionally, visualisation is extremely powerful when data is organised in the right way. The literature contains several cases explaining the importance of good data visualisation and its implications for a better understanding of the related information (Card et al., 1999; Shneiderman, 1996; Tufte, 2001). Because improved understanding was the aim of the data analysis in this study, SNA seemed a good choice.

There are many tools available to run Social Network Analysis. However, not all are necessarily robust or provide the functionality that was necessary in this work. Therefore, it was necessary to develop a process to prepare the data ready for the form of analysis performed.

8.2. SNA and RCoPs

Before discussing the details of its use, it is necessary to clarify what Social Network Analysis is. *Social Network Analysis (SNA)* (Scott, 2000; Wasserman & Faust, 1994) represents the social relations (or *social ties*) of individuals within groups through graphs called *sociograms*[1]. Figure 8.1 shows an example of a sociogram. The circles are called *vertices* and represent the individuals involved in the study. The arrows (directed lines) are called *arcs* and represent a tie between two nodes. Undirected lines are called *edges* (there are none in the graph).

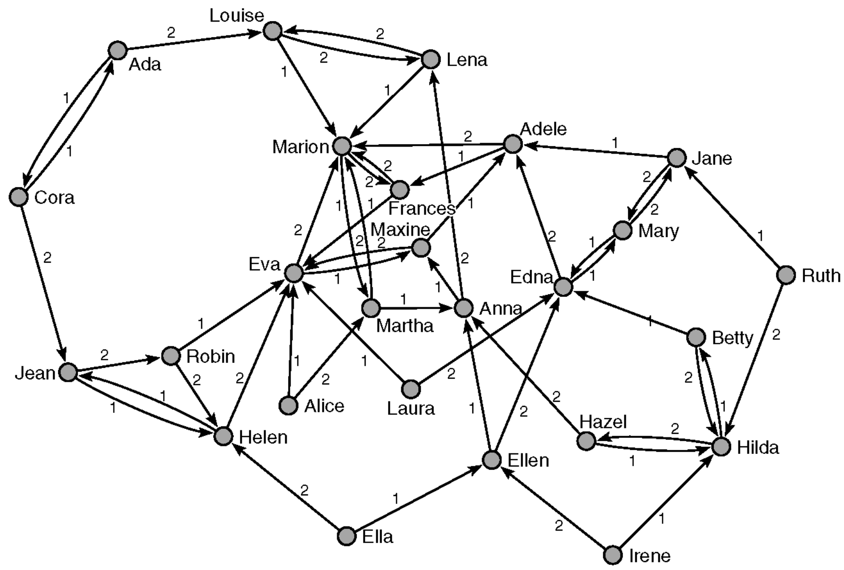


Figure 8.1.: Example of a sociogram (source: de Nooy et al. 2005)

Usually the graphs contain extra information associated with the arcs. This can represent any additional data necessary to explain the tie between the vertices. In figure 8.1, for example, the graph represents choices for dining-table partners. The numbers associated to the arcs represent their first or second choice of partner.

Social Network Analysis was used in this work to represent the social ties among participants via the delivery of messages. In the graphs related to CoPs, the vertices represent the community's members and the arcs represent the delivery of messages. The arc's direction represents the source and destination of each message.

Social ties can also be represented by *sociomatrices* (Wasserman & Faust, 1994). These matrices are adjacency matrices that represent the social ties of a group. In these matrices the columns and rows represent the participants and the matrices' elements represent their social ties. These sociomatrices are the raw material for the data analysis. Social Network Analysis programs can analyse sociomatrices, as long as they are in a format accepted by the program.

[1] *Sociograms* show the structure of social ties inside groups via graphical representation (de Nooy et al., 2005).

To analyse the data it was necessary to visualise the sociogram formed by the move of messages between members of the CoPs. Consequently, it was necessary to develop a workflow to move the data from the original format (plain text) to a format accepted by the SNA software (sociomatrices).

A summary of this workflow is as follows:

- Convert original messages (in plain text) into database records (Microsoft Access)
- Export messages to a sociomatrix format (via Microsoft Excel)
- Prepare data for analysis (e.g., cleaning from self-loops)
- Convert matrices into Pajek format (as will be discussed below)
- Import into SNA program
- Run analysis

Using this procedure the outcome was a set of visualisations showing the activities of the four Communities of Practice (CoPs) in the 52 week period. These visualisations showed a certain recurrence in the communities' activity, but what at first seemed to be a signal of the existence of Recurrent CoPs (RCoPs), in the end appeared to be a different class of event. Rather than finding a coherent group that cyclically returned to the pool of activities generated by the community, it was found that the recurrence was mainly individual related. However, this newly detected characteristic showed a strong connection with the whole community, matching the core members in importance. This new concept was named *Transient Core members (TCMs)* due its characteristic of becoming highly active (as a core member) for just a specific period of time and always related to the subject discussed. When seen individually the TCMs were not a Recurrent CoP, but when seen as a group their importance and engagement was clear.

8.3. SNA software

In order to understand why the workflow led to the scenario showing the TCMs, it is important to understand the capabilities and limitations of the SNA software used for the analysis. Thus, this section gives a brief overview of each program used for the visual analysis.

Temporal concerns

Although apparently simple, the main objective involved a significant challenge: the temporal component, typical from Recurrent Communities of Practice (RCoPs), needed to be properly represented.

Typically Social Network Analysis software, when describing groups or communities, shows a snapshot of a moment in time or the whole studied period in a single graph. However, several programs already consider time as a part of the dynamic components, allowing the graphs to show the development of the groups/communities with the time.

Some of the programs capable of dealing with time as dynamic component are: *Pajek* (Batagelj et al., 2003), *Gephi* (Bastian et al., 2009), **ORA*, *Visone* (Brandes & Wagner, 2004) and *SoNIA* (Bender-deMoll & McFarland, 2006; SoNIA, 2011). However, several of these have issues that made them inappropriate for use in this study. The programs that did not present these problems and consequently were used in this work are discussed below.

8.3.1. Pajek (version 2.04)

Pajek (Batagelj et al., 2003) is the oldest and the most well-established program for Social Network Analysis. Every SNA program launched after it necessarily includes a function to import and/or export to the Pajek format (*.net*). It is a complete program that has numerous possibilities of data processing and visualisation of sociograms. Pajek defines *networks*, which are the same as sociograms, as a graph and additional information on the vertices or lines of the graph (de Nooy et al., 2005, p. 7).

Time component

Pajek is capable of dealing with the change over time of graphs (it calls them *longitudinal networks*). For this, its native file format ('.net') allows the definition of the existence in time for vertices and arcs (and edges). When representing time in graphs Pajek allows a view in "steps", with each time slice in a window. Figures 8.2 on page 183 shows a complete snapshot of the graph, with all vertices and arcs in a single time slice, whereas page 184 shows two slices in time. Notice that the combination of the two parts from figure 8.3 forms the graph in figure 8.2.

The great advantage of Pajek is its acceptance as standard, allowing it to be used as a way to convert between the different formats used by the different SNA

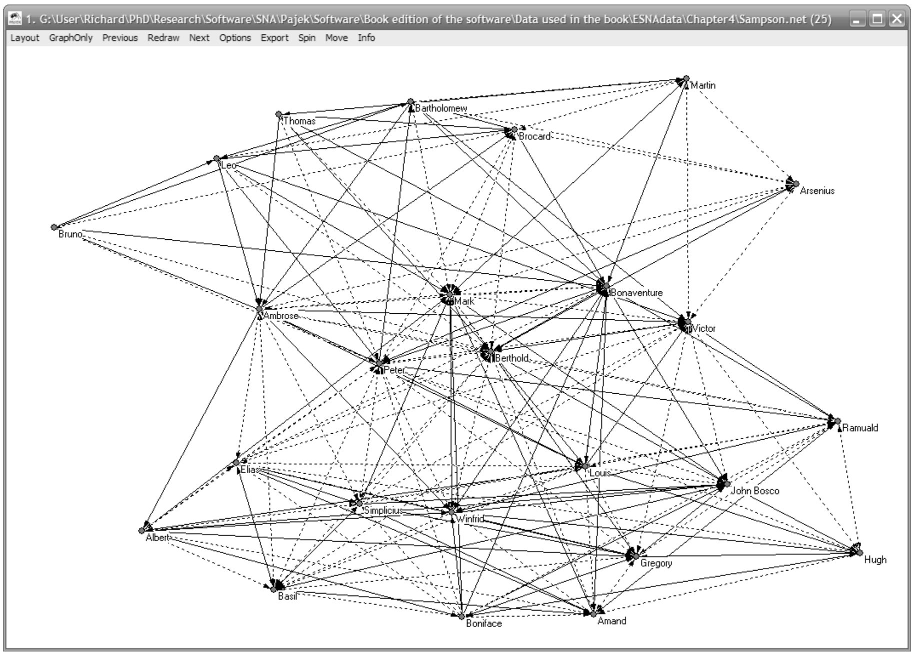


Figure 8.2.: Example of a graph in Pajek with time component (total time) (source: de Nooy et al. 2005).

programs. Moreover, several times Pajek has been the only solution to problems of incompatibility between the formats used in these programs.

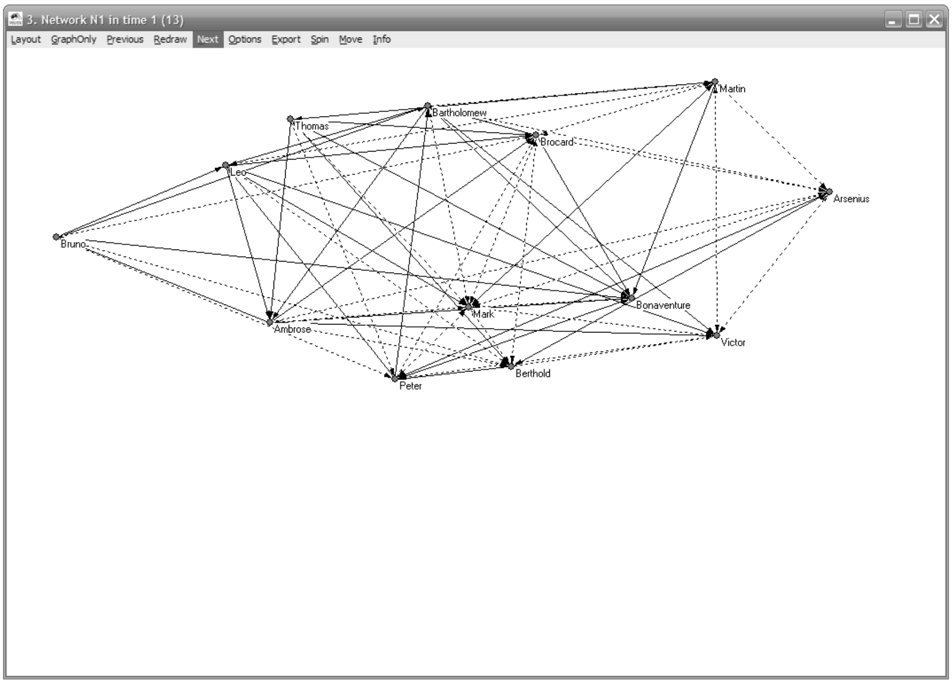
However, Pajek's interface makes it difficult to identify patterns visually, such as the one being searched for in this study. The problem becomes worse when the number of nodes increase, making it very difficult to identify isolated nodes.

8.3.2. Social Network Image Animator (SoNIA) (version 1.2.)

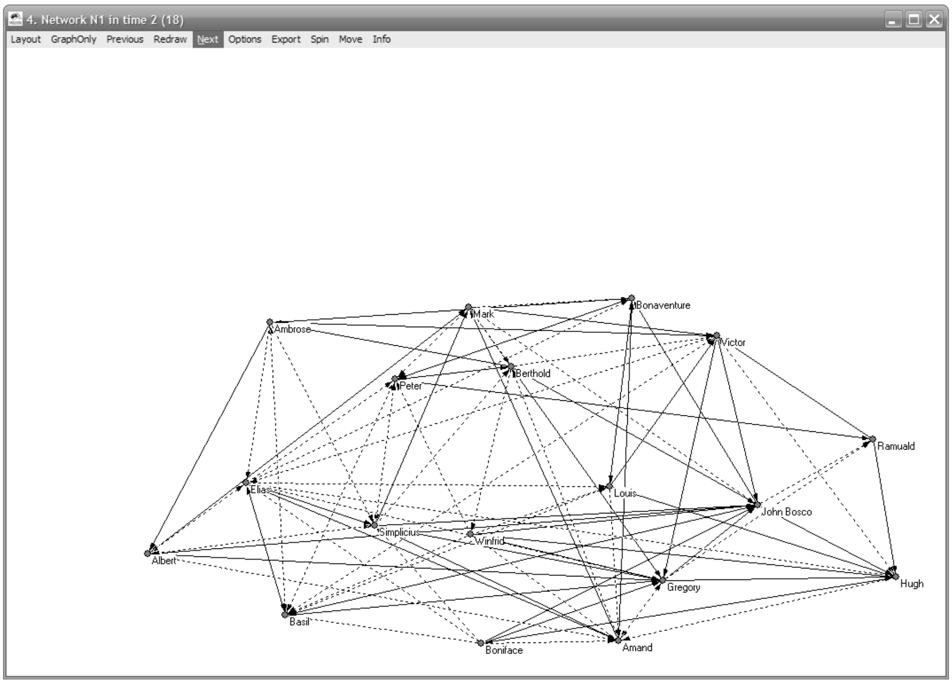
Although SoNIA (Bender-deMoll & McFarland, 2006; SoNIA, 2011) was released years ago, it still is not as well-known as Gephi or Pajek. Maybe the reason for this is that SoNIA was intended specifically for animation of graphs with a time component, making its target audience very limited. However, for this work SoNIA is a very useful tool.

In its website SoNIA is described as Java-based software for dynamic (also called longitudinal) visualisation of network data. Dynamic is used as a term to explain that in addition to information about the relations between the nodes, the program also provides information about the time when the relations occur (SoNIA, 2011).

SoNIA's interface is not as polished as Gephi, but it is simple and objective (see figure 8.4, on page 185). The program can import from a few known formats,



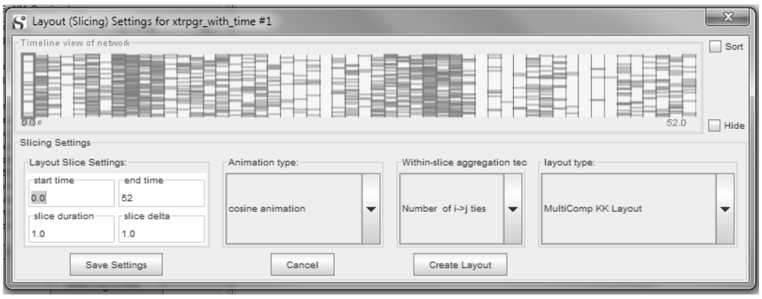
(a)



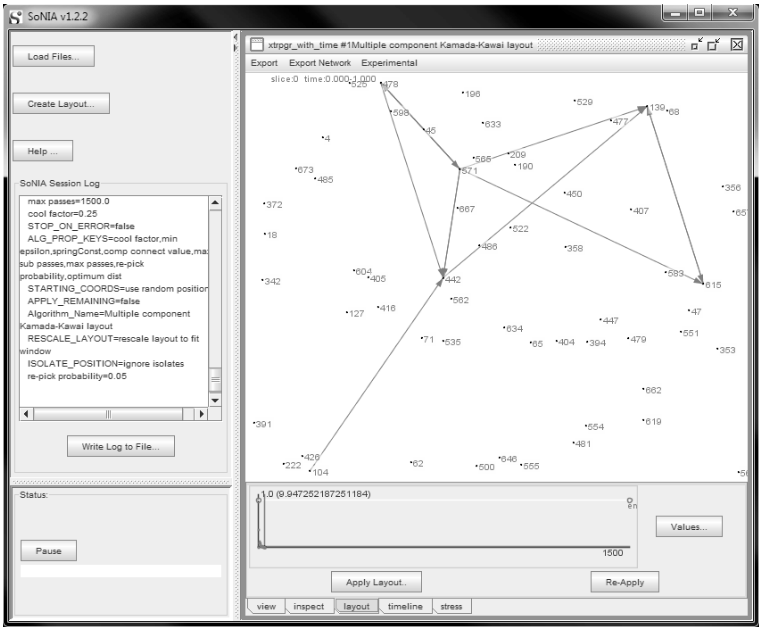
(b)

Figure 8.3.: Example of a graph in Pajek with time component (two time slices) (source: de Nooy et al. 2005).

but all them are very common and used by other SNA programs. One of these is Pajek's (.net) format.



(a) Time slices



(b) Main interface

Figure 8.4.: SoNIA's main user interface.

Time component

SoNIA's objective is to be capable of reading different formats of graphs (or *networks*, as they are referred to) and export the resulting sequence of time slices of the graph as "movies", either as a graphic animation or a sequence of static images.

One can notice that SoNIA's objective is essentially what was aimed in this study, i.e., to visualise the Communities of Practice (CoPs) behaviour over time, as a sequence of snapshots. However, SoNIA lacks some functionalities available in Pajek or Gephi. For example, it is not possible to handle nodes individually after the graph is generated (real-time interaction). This feature was crucial in the visual analysis to check the connections of core members and transient core members. As a workaround, this part of the analysis was done by Gephi.

8.3.3. Gephi (version 0.8 alpha)

Gephi (Bastian et al., 2009) is relatively new software for Social Network Analysis. It does not have all the options for analysis and transformations that Pajek has, but it has the most common and most frequently used ones. It also has strong support from its community of users and developers, which helps with its use.

Gephi's interface is more up-to-date than Pajek's, which makes the analysis easier. However, as a consequence of being an *alpha* version, the program sometimes presents problems that forbid adequate analysis. An example of such situation is the problem with the time component presented by the previous version *0.7 alpha*, rendering that version unsuitable for this study.

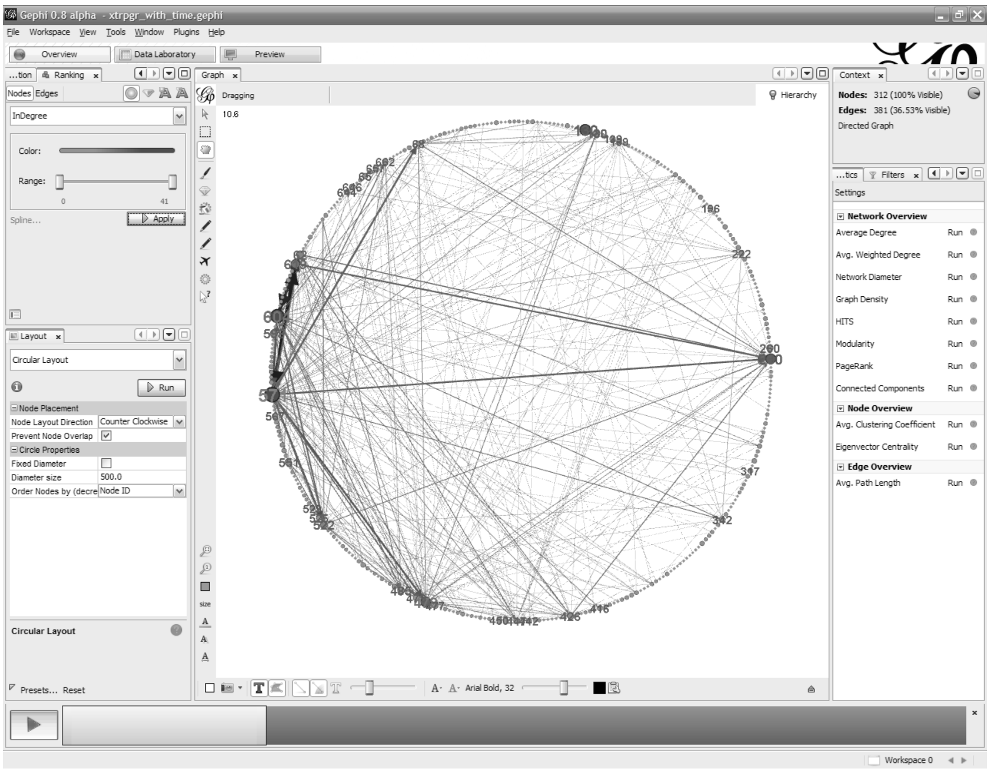


Figure 8.5.: Gephi's user interface.

Time component

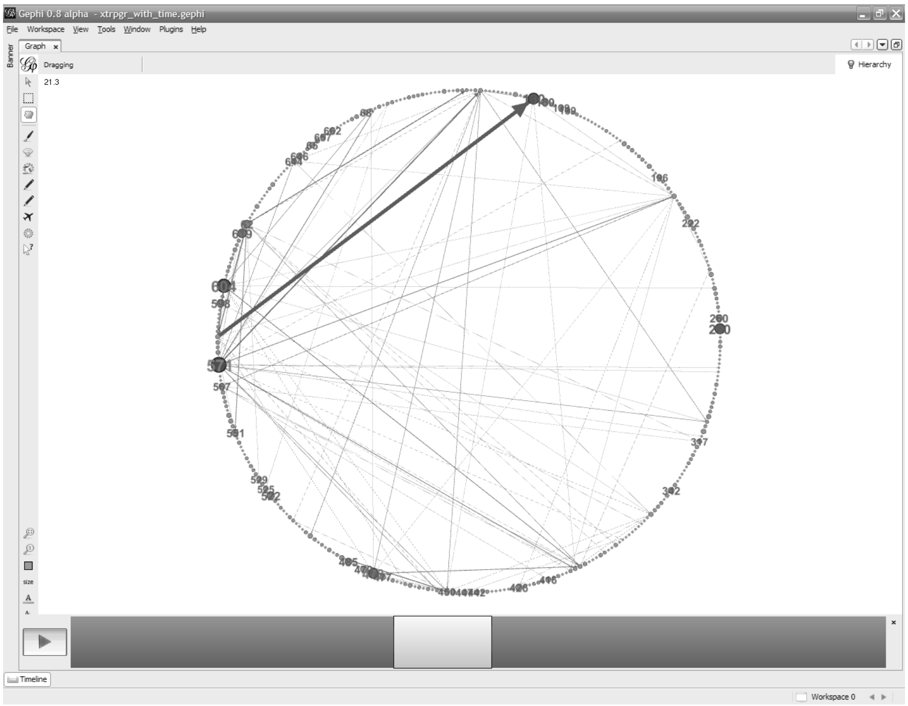
The use of software for Social Network Analysis to study graphs with a time component is sometimes called *Dynamic Network Analysis (DNA)*. Gephi refers to this type of graph as a *Dynamic Graph*.

Until version 0.7 alpha, dealing with the time component in graphs was a difficult task. The program had a glitch that made it impossible to import and use Pajek's format that contained time components. The newly released version, 0.8 alpha, had the problem fixed and now it is possible to use the time component in graphs adequately.

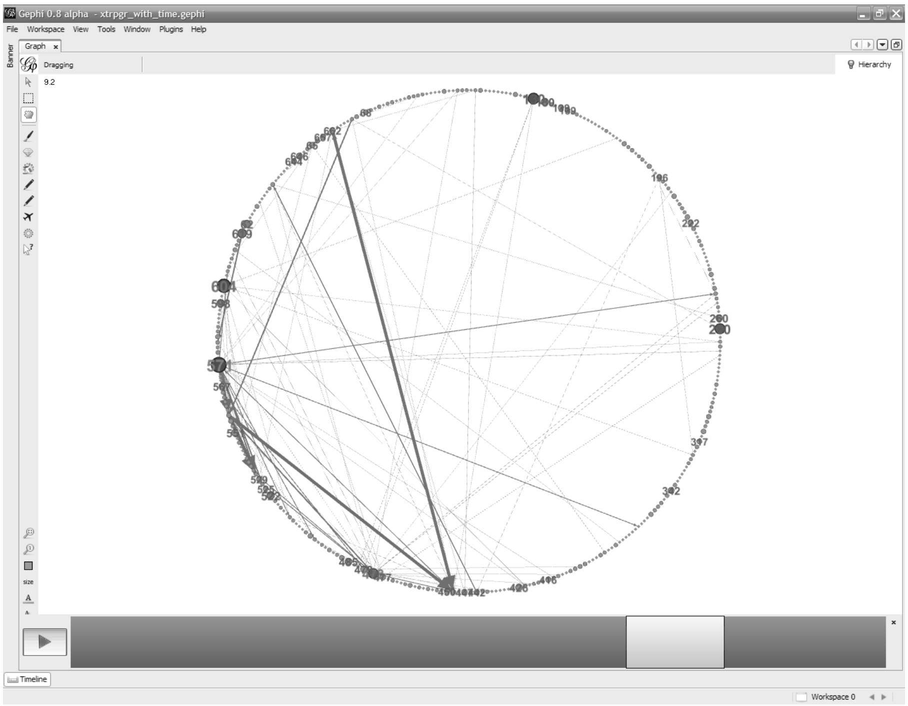
To deal with time, Gephi shows a 'scrollbar' that allows one to 'slide' on time. The main interface presents a 'play' button, which detects the presence of a time component in the graph. The interface can be noticed at the bottom part of the figure 8.5. After pressing the 'play' button, the user can move the scrollbar on the right to change the time shown in the graph. Figure 8.6 on page 188 shows the interface in two moments of the graph's development in time.

The advantage of Gephi is its modern interface and its capacity to manipulate time in an easy way. Moreover, unlike Pajek, Gephi can properly present graphs with a significant number of vertices and arcs, becoming the program of choice for this study. Another major advantage of it is that it allows one to manipulate vertices in the graph in real-time. This was particularly important for the visual analysis.

One of its disadvantages is that it is not capable of dealing with parallel arcs, leading to the duplication of vertices when such situations occur. The current version 0.8 alpha has this problem when importing files in Pajek's format. For instance, in files with a representation of two vertices with parallel arcs, the program interprets them as three vertices with arcs between them, duplicating the destination vertex. However, this limitation does not affect the conclusions drawn based on Gephi's results, as long as one is aware of it. Therefore, when the visualisations were ready, they passed through a process of analysis and adjustment that compensated for the duplications of vertices. In these cases the vertices were put very close to each other in the graph, facilitating the visual identification of such cases (e.g., in the case of analysis of core members). This could be done due to the fact that during the duplication process, the vertices received the same identifier (the vertices' number), which made the task of identifying these easier. The resulting graph would be used to analyse the activities of the community (hence, of the vertices), and would therefore not be affected by the fact that some of the nodes were duplicated.



(a)



(b)

Figure 8.6.: Gephi's user interface for time component (two time slices)

Another drawback is the existence of a serious problem in the software that could delete some data during its use. This was caused by a glitch in the creation of a specific layout: *YifanHu's multilevel*. After applying this layout some vertices lost their time component. Because such a layout was not required for the visual analysis, the problem did not affect the work or the results.

8.3.4. The use of Pajek, SoNIA and Gephi together

Although Pajek could perform more analysis and operations on the graphs related to CoPs than any available program, it became clear that it was not appropriate for this study. This is due to the problem caused by graphs with large numbers of vertices and arcs, not because of any problem in the program, but rather because of its interface, which becomes packed with lines, making it impossible to draw any conclusion based on visual information. The problem becomes even worse with graphs with a time component.

However, Pajek proved very useful in this study to check data files against problems and to use as a bridge between different SNA tools.

To perform the visual analysis, first the sociomatrices were loaded into spreadsheets. After passing through a series of steps (described bellow), they were exported as 'csv'[2] files. The next step was to use a converter (Bender-deMoll, 2001) to transform the files into Pajek's network files. Using Pajek, the files were loaded and checked against problems, such as loss of data or errors in the conversion. Next, the sociomatrices were loaded into SoNIA, where the communities's activities over time and their connectivity were studied. Finally, the data was examined in Gephi. This allowed the study of individual members' connectivity within the whole Community of Practice. However, due to the problem with duplication of vertices caused by Gephi the analysis regarding the communities' activity as a whole was carried out in SoNIA.

8.4. Data analysis on CoPs

8.4.1. Methodology

In order to analyse each detected Community of Practice (CoP), the following methodology was applied.

[2]Comma-separated values, or 'csv' files, are plain text files used as a way of importing and exporting tabular data. Because of its simplicity (it is just a text file with several lines of text or numbers separated by commas) it is the preferred choice for saving/retrieving matrices.

First, a matrix containing the number of messages exchanged per week (and per node) in the 52 week period was used. This matrix was generated exporting the messages from the database related to the CoP into a spreadsheet.

Each one of the four Communities of Practice (CoPs) generated one spreadsheet, in a similar manner as explained in section 6.3.3, on page 130. However, these new spreadsheets have 52 weeks of data, instead.

The matrices are too large to be shown here in their totality, but an excerpt from them can be found in Appendix B, on page 241. Table 8.1 (on page 190) shows an example of these (in this case, it is an excerpt from the matrix related to the *xtrprg* CoP).

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	...	wk50	wk51	wk52	Total	Occur
130	7	23	11	6	11	9	10	24	12	6	1	...	5	6		**342**	**50**
571	14	17	9		11	20	17	35	33	23	10	...	14	6	13	**520**	**49**
478	6	14	10	3	4	11		3		8	1	...				**184**	**38**
604		14	3	12	18	21	3	21	4	6	5	...	1			**300**	**38**
260	3	5	7		5	21	10	19	23	17	11	...	17	6	31	**249**	**28**
62					3	16	5	3	18	3	18	...				**206**	**27**
104	1	4	1		3	2		2	1			...		5	3	**51**	**26**
139	5	7	1		2	1		6			1	...				**53**	**23**
447	1	6		5	4	5	1	1	2	2	3	...	3		1	**60**	**23**
426		1	1	2						1	21	...				**103**	**23**
477	1	2				1		1	3		1	...	1		1	**34**	**22**
222		4	2		5	3	1	4	1	1	3	...				**57**	**22**
662					3				7	6	8	...	2		1	**66**	**22**
551		4	3		2		3	5	6	6	4	...				**51**	**21**
416				3	8	5	2			1	1	...	8	2		**47**	**20**
598		1	1	2				12	6	4	1	...	2	1		**61**	**18**
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 8.1.: Excerpt of CoP *xtrprg* activity – Data from 52 week period

The initial matrix has all communications that happened in the period, including the ones from core nodes and from nodes without strong participation (*noise nodes*). For an adequate search for Recurrent Communities of Practice (RCoPs), it is necessary to remove these two types of node from the matrices, as they cannot be part of an RCoP[3]. Consequently, it was decided in this work that *core nodes* are the nodes with 50 or more weeks of participation in the 52 week period, and that *noise nodes* are the ones with three weeks or fewer of participation in the same period. This step generated another matrix for each CoP.

A second matrix was created to help with the temporal component. This matrix was necessary to identify when a node sent a message (i.e., in which week). That

[3] *Core nodes* do not have the recurrence in activity expected from Recurrent Communities of Practice (RCoPs), and *noise nodes* do not have the strong engagement also expected from RCoPs.

information was vital to allow the temporal nature of the communities' activity to be adequately studied.

This last matrix was created once again using the database related to the CoP. However, now only three fields were exported: the node number who sent the message, the node number who received it, and the week number in which the message was sent. The resulting matrix is called an *edge list*, as it contains the list of edges of the graph representing the node's communication. An excerpt from this matrix is shown in table 8.2[4]. The data came from the exchange of messages within the *xtrprg* CoP.

code_from	code_to	msg_week_num
3	3	5
4	193	48
4	260	50
4	52	50
4	589	51
4	292	51
4	290	51
4	260	52
4	47	52
4	4	52
4	537	52
5	53	39
5	555	39
5	478	39
5	571	50
6	479	2
7	139	50
7	328	50
⋮	⋮	⋮

Table 8.2.: Excerpt from matrix showing CoP *xtrprg* and related week of activity

Notice that in this table there is a self-loop, where node 4 sends a message to itself. This type of self-loop was later removed in Excel.

The following step was to include the resulting matrix in the Social Network programs (Pajek, SoNIA and Gephi) and analyse the results.

8.4.2. Social Network Analysis on CoP *xtrprg*

It was decided to run the first analysis in the smallest group to see if the procedure would be successful and could have significant results.

[4]An extended version of the table can be found in Appendix C, on page 313.

The CoP *xtrprg* generated 4,468 messages during the 52 week period studied. This total includes self-loops and messages from *core* and *noise nodes*. If these types of messages are discounted, the number in the period drops to 3,321 messages.

Due to its size, the *xtrprg* CoP would allow an easier Social Network Analysis to be carried out. The hope resided in the fact that the graph generated would be easier to understand and to study.

After the initial tests on *xtrprg*, the same analysis was carried out in the other three Communities of Practice (CoPs).

8.4.3. The visual analysis

Microsoft Excel, SoNIA and Gephi were used for the visual analysis.

Excel was used to visually identify which members could be considered core members. This was accomplished through the visualisation of the matrix containing information about the number of messages exchanged per person and per week (as described in section 8.4 on page 189).

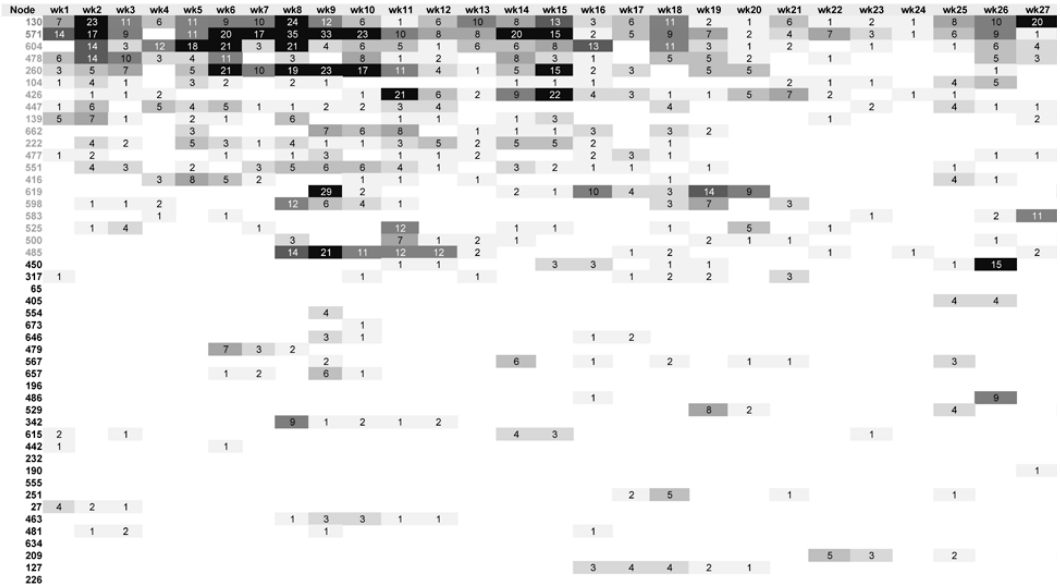
To help the visual identification, each cell in the spreadsheet received a shade of grey depending on the number of messages sent by the member. Values closer to 1 generated shades with lighter grey, tending to white. When the number of messages increased, the colour became darker, reaching black if the amount was equal to or greater than 15. The matrix related to the CoP *xtrprg* can be seen in figure 8.7, on page 193[5].

There is only one core member (node 130, in the first row), under the definition established in section 8.4.1, on page 189.

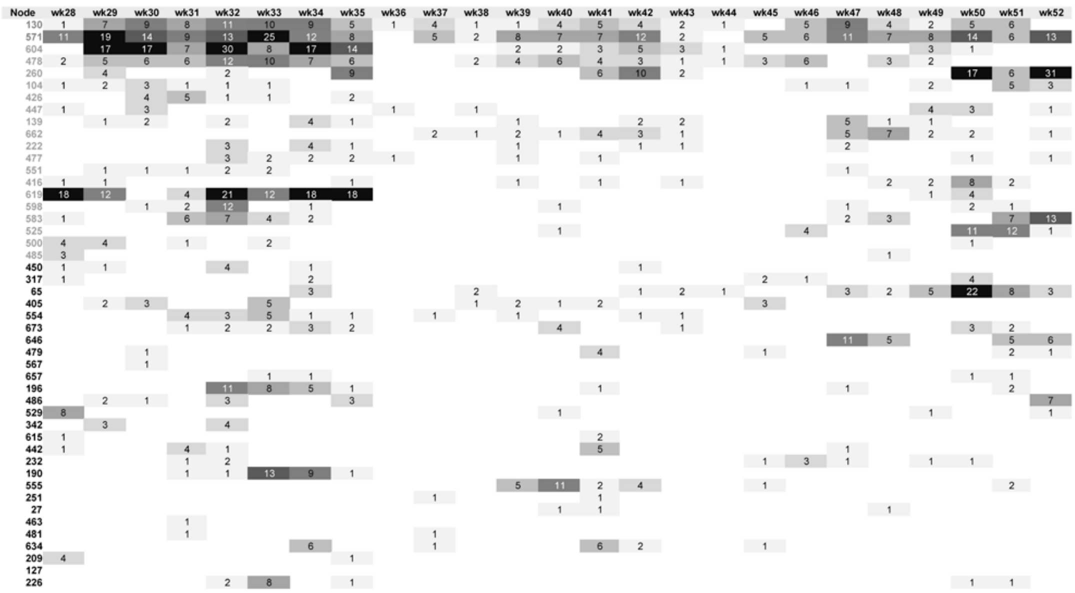
SoNIA was used to detect patterns of recurrence in the analysed period. To accomplish this, all communication in the period was plotted into graphs, each one corresponding to a week of message exchanges. An example of a week's communication related to the CoP *xtrprg* can be seen in figure 8.8, on page 194. The circle is formed by the vertices (nodes) representing the communities' members and the arcs represent the exchange of messages between the members.

SoNIA plotted the vertices in the circle in a clockwise order as they appeared in the loaded file, starting at the 3 o'clock position of the circle. Because these vertices were exported from the Excel file, it was possible to order the communication, i.e., the vertices, by time, thereby guaranteeing that in SoNIA the vertices appeared in the sequence in which they participated in the exchange of messages over time. This allowed to find out if a recurrence occurred looking in the circles formed by the weeks. If a recurrence was present, it could be noticed by an increase and

[5] All matrices related to the four CoPs can be found in a larger version in Appendix B, on page 241.



(a) Week 1 to week 27



(b) Week 28 to week 52

Figure 8.7.: Exchange of messages in the 52 week period – CoP *xtrprg*.

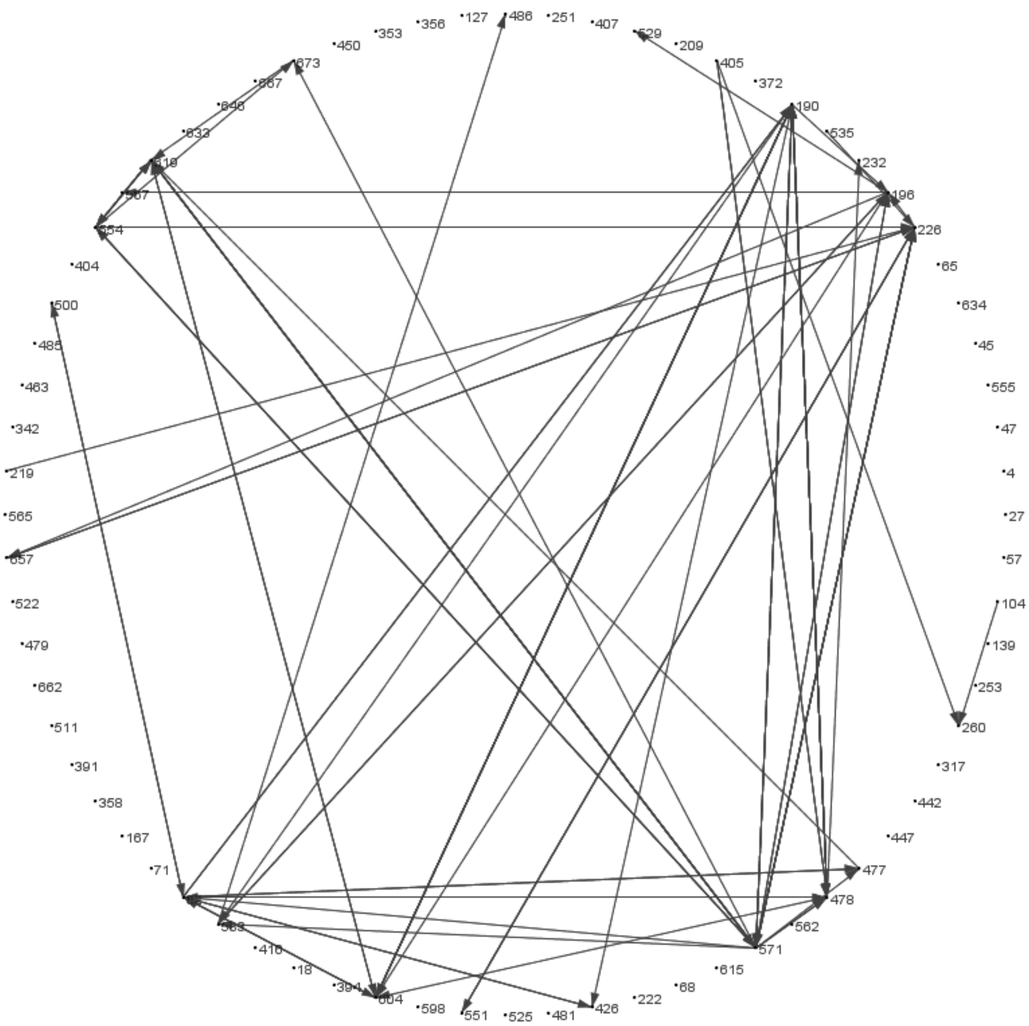
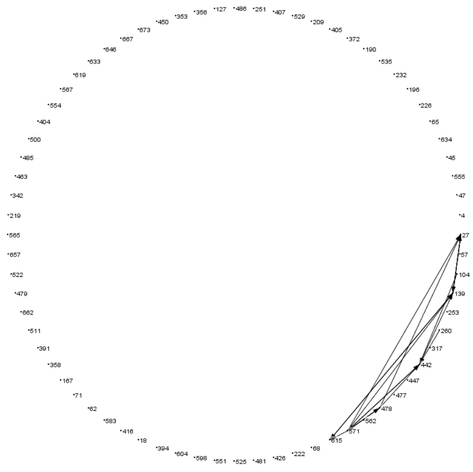


Figure 8.8.: SNA using SoNIA - CoP *xtrprg*.

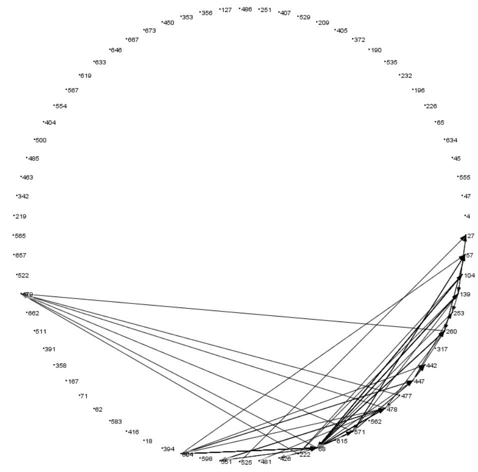
decrease in activity at the same region(s) of the circle in the whole period. An excerpt from the graphs generated by the communication in CoP *xtrprg* can be seen in figure 8.9, on page 195. The complete series of graphs for the four CoPs can be found in Appendix D, on page 317.

No recurrence related to RCoPs was found in the CoP *xtrprg*. However, recurrence related to individual nodes was perceived. Additional discussion about this phenomenon can be found in section 8.5, on page 196.

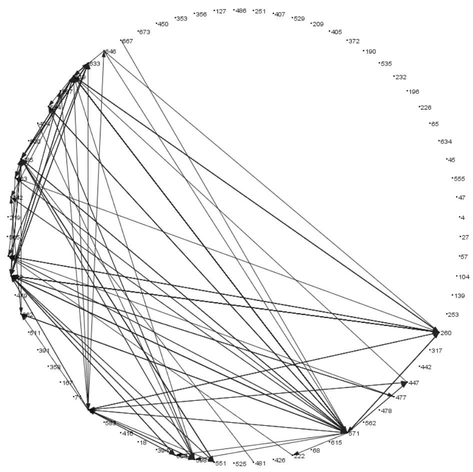
Using Gephi a new graph was created. The core members identified by the visual analysis of the matrix (shown in figure 8.7) were selected. These members were highlighted and moved to the centre of the graph (see figure 8.10, on page 196). This move aimed to identify the connectivity among the core members and the rest of the community.



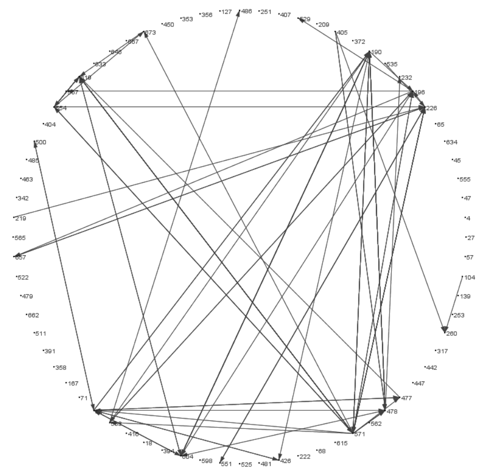
(a) Week 1



(b) Week 2



(c) Week 8



(d) Week 32

Figure 8.9.: SNA analysis using SoNIA - CoP *xtrprg*.

With this, Gephi made it possible to identify the vertices contacted by a vertex at any moment, just by hovering on it with the mouse cursor. Figure 8.10, on page 196 shows an example. The three darker vertices in the centre of the circle are the core members. Notice in the figure that some vertices in the border of the circle have a dark spot within them. These spots are in fact the node number, which appears to identify who is being contacted by the selected vertex (in this case, core member '571' in the middle of the graph).

Gephi was used to study the communities' activity during the period of 52 weeks, seen it as a single snapshot and as a series of individual time slices, each slice corresponding to a period of a week.

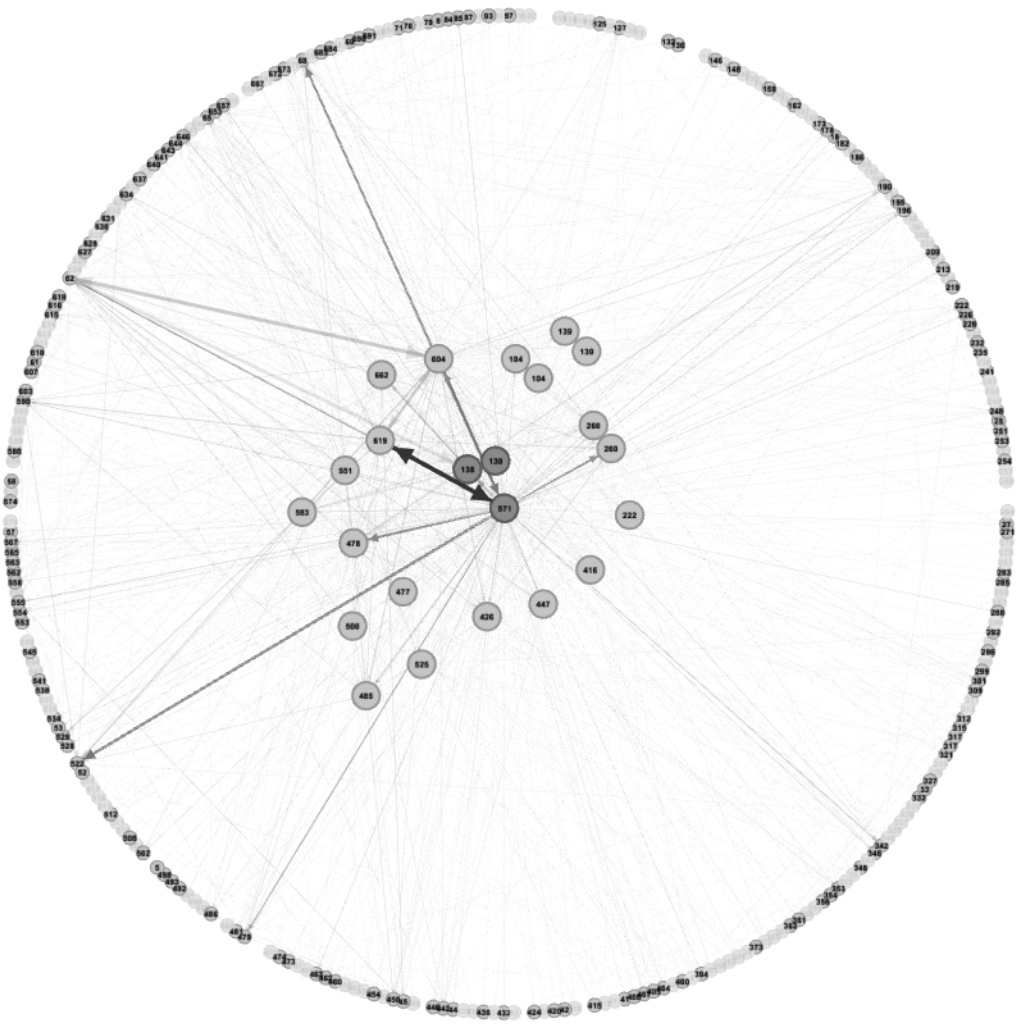


Figure 8.10.: Connectivity in *xtrprg*.

8.5. Results

Upon completion of the visual analysis in the four Communities of Practice (CoPs), it was possible to notice that the graphs did not reflect what was expected.

The initial idea was to try to find Recurrent CoPs (RCoPs) within Virtual CoPs, thus the main aspect searched for was a recurrence similar to the one found within the Psychology Network, i.e., a small sub-community of the main Community of Practice (CoP), where the members were summoned upon a common trigger, like a project. However the results proved this not be the case.

The analysis of the matrices (described in section 8.4.1, on page 189) clearly showed a recurrence in the activity of individual members. This could be seen as bursts in their activity for a few weeks, followed by periods of inactivity for other weeks. In the matrices this was shown as rows with dark cells, followed by blank ones, creating the effect of 'gaps' in the activities. However, no conclusions could be drawn about small subgroups based only on these matrices.

SoNIA, however, provided the necessary information for the analysis of subgroup activity.

First it is important to understand how the graphs were generated. As explained previously, the graphs are divided per week. The circle is formed by all members (nodes' numbers) that sent messages during the 52 week period. Each circle shows the messages sent by the community's members involved in the activities of that week. Each arc shows the sender and the recipient of the message(s).

The nodes are plotted in the circle by the order in which they began sending messages and by the time, i.e., the nodes that sent messages in the first week were plotted first in the circle (at the 3 o'clock position). After this were plotted the subsequent nodes that sent messages in the following weeks, if they are not already plotted. All the graphs for a specific CoP have the same nodes forming the circle and in the same sequence. When looking at the circles in sequence it is possible to see the change over time of the communication within the Community of Practice (Appendix D on page 317 has the complete graphs for all four CoPs). The arcs are plotted showing the communication among the members of the related week, thus seeing the graphs in sequence it is possible to see approximately a "movement" of rotation, in which the arcs tend to move in a clockwise direction. It is possible to notice the activity of the core members in the graphs observing a specific region in the circle where there is constant activity throughout all weeks.

The graphs can also be used to search for Recurrent CoPs (RCoPs). If a subgroup (or subgroups) existed within the main CoP acting as an RCoP, it could be noticed in the circle as approximately the same region (or regions) with periods of activity and inactivity in different weeks, thus showing a cyclical burst of communication in the subgroup(s). It would be roughly the same region because if they were acting as a small community, the members (i.e., nodes) would be the same, and would be participating in the exchange of messages in different weeks. Therefore, it would appear in the graph as a sequence of images where a region (or more) of the circle would become active after a period of inactivity of a few weeks, creating an effect of "rolling back" in the apparent movement of the arcs. However, this did not appear in the graphs. What did appear, though, was a region only occasionally returning to activity. There was no consistency or stability in the recurrence, giving the strong impression of it being a coincidence, rather than a typical activity of the same subgroup.

Nonetheless, it was possible to find recurrence, but at an individual level. Several particular individuals presented a strong recurrence. This was confirmed crossing the nodes' numbers with the matrices where their activity could be seen isolated from the others. It was clearly an individual attitude, not one related with a subgroup. Seeing it as a single member (or a single node in the graph) it would appear as a non-important phenomenon, but when multiplied by all members having similar behaviour, their activity have a strong impact on the overall amount of communication in the CoP. These individuals were named *Transient Core Members (TCMs)*. This denomination was due to the fact that when active they had the same level of importance than as core members. Even their levels of activity were similar to those found in core members. They were called 'transient' due the irregular cycle of activity shown.

These characteristics explain the inability of Cluster Analysis to find reasonable results. The technique is aimed at detecting groups with similar intermittent behaviour, not individual cases.

The next step was to use Gephi to detect the level of importance and connectivity of the TCMs.

Gephi generated graphs similar to SoNIA's, making it possible to see the change over time of the activities of each CoP. However, unlike SoNIA, Gephi did not divide the activities into weeks. Rather, its interface allowed to see all the communication in a single graph, or use the interface's 'play' button to scroll back and forth in time.

Gephi allowed to move the core nodes and the nodes identified as 'potential' TCMs to the centre of the plotted circle. This, together with the software's capacity to highlight all nodes in contact with the selected one, made it possible to visually analyse the connectivity of each node in the centre of the graph.

Upon the selection of a node in Gephi, all nodes that did not receive or send any message to/or from the node were faded out, leaving only the nodes with relations with it visible (an example of this can be seen in figure 8.10, on page 196). With this technique, it was possible to verify that the TCMs were in constant contact with the nodes involved in the discussion. In addition, they were also responsible for a significant number of the messages sent, making them very important to the life of the community.

Finally, it is important to understand that unlike the co-located Recurrent CoPs, the TCMs were not driven by projects, but purely by interest in the topic discussed.

8.6. Conclusions

It is important to highlight that this is the result of an analysis in only four particular on-line Communities of Practice. It is not possible to generalise from these conclusions to all types of on-line CoP, as that would require a study beyond the scope of this work.

The first question to be answered by the data analysis is: *Is there any Recurrent Community of Practice (RCoP) in the analysed CoPs, similarly to the detected co-located RCoPs?*

Having the definition of Recurrent Community of Practice as stated in 5.6 (on page 111) in mind, the short answer is *No*. No communities could be found that have the same behaviour as the co-located RCoPs, and that are driven by projects.

However, a novel type of dynamic activity was found in specific members. It has a behaviour that differs from what is known as a community, where the members work with a sole objective, acting as a single entity. Instead, the Transient Core Members act as individuals, with different motivations, which is represented by their participation in discussions of only personal interest. However, when seen as a whole, the TCMs have an important participation in the community's life, being responsible for a great number of the messages exchanged. They are part of the main Community of Practice, and are very active, but they are not constant as are the core members.

Interestingly, they have recurrence, but not triggered by projects. Their recurrence is triggered by the interest in a topic, which makes it very irregular and inconstant. However, they also present periods of intense activity, usually followed by periods of inactivity.

Another interesting aspect of TCMs is that they give support to the entire community, helping the core members. This is an important characteristic, if TCMs might be considered for use within companies or institutions. Reports of failing Communities of Practice due to issues related to changes in core members exist in the literature (Gongla & Rizzuto, 2004) and TCMs might help with a solution for this.

This analysis has only initiated the study of the Transient Core Members. More work is necessary to understand the whole implications that TCMs might have in the life of Communities of Practice.

9. Conclusions

9.1. Introduction

This research aimed to discover how Communities of Practices behave under normal circumstances and which temporal aspects are involved in this behaviour, what lead to the development of the following research questions as consequence: *how do individuals dynamically engage with Communities of Practice?* and *What is the sense of continuity throughout?* At the end of the study it was possible to discover two major aspects related to this objective: first, a new type of Community of Practice, never cited in the literature before, was discovered: the *Recurrent Communities of Practice (RCoPs)*; and second, the research identified a different type of behaviour in specific members of a Virtual (and Distributed) Community of Practice, who were named *Transient Core Members (TCMs)*. These findings will be detailed in the following parts: section 9.2 (Findings) provides an analysis of the discoveries in chronological order; sections 9.3 (Theoretical contributions of the research), 9.4 (Practical contributions of the research) and 9.5 (Methodological contributions of the research) explain the findings' contributions to different areas of Communities of Practice and Knowledge Management.

9.2. Findings

In this section are listed all the findings produced by the research process, with each subsection giving an overview of them; however, the details about methodology and steps followed during data collection and analysis are not included, being found instead in the main body of the thesis, in the respective sections or chapters (references to these parts can be found in each subsection).

9.2.1. 1st discovery

The study started with a preliminary case study on the researcher workplace (the Higher Education Academy Psychology Network, U.K.), at the moment of the research. The main objective of the case study was to test Wenger's indicators that a Community of Practice has formed (Wenger, 1998b, pp. 125–126). The indicators are discussed in detail in section 2.9, on page 45. Using the methodology described in section 3.4, on page 68, the study demonstrated strong indications of the existence of a CoP within the workplace (the case study is described in chapter 4).

During the interviews almost all indicators showed a positive response for the existence of one of the three main components of a Community of Practice (*mutual engagement*, *joint enterprise* and *shared repertoire*). The few items that did not present a clear and unanimous answer could be disregarded due to the redundancy of the indicators, having several items to check for the same characteristic (the questions always fell in three categories: *mutual engagement*, *joint enterprise* and *shared repertoire*). This redundancy had already been noticed in the literature (Li et al., 2009; Murillo, 2011).

In summary, the first outcome of the research was the discovery of a Community of Practice in the Psychology Network, U.K., using Wenger's indicators (Wenger, 1998a, pp. 125–126) as the basis for a quantitative analysis based on structured interviews.

9.2.2. 2nd discovery

The results from the preliminary study showed strong signs of the existence of a Community of Practice (by Wenger's definitions) formed by employees, in the Psychology Network, U.K. The good results acted as an incentive for further analysis in the workplace. Several questions appeared as a consequence of the preliminary study. It was important to discover how the CoP worked, how the members were affected by time, and if they were aware that they worked within a CoP, just to cite a few of them. Therefore, another case study was planned and conducted in the Psychology Network.

For this second study qualitative analysis via semi-structured interviews was used. A questionnaire with open-ended questions based on Wenger's indicators that a CoP has been formed (Wenger, 1998b) was created, and Grounded Theory (Corbin & Strauss, 2008; Glaser & Strauss, 1967; Strauss & Corbin, 1998, 1990) was used to collect and analyse the data generated during the interviews. The methodology used in the new case study is discussed in section 3.5, on page 71, and the details of the steps taken, the analysis carried out and the results achieved are described in chapter 5.

The first aspect noticed during the analysis was the existence of several smaller communities within the previously noticed CoP that followed the definition of

Communities of Practice by Wenger (1998b). Additionally, they had something different: a recurrent characteristic, i.e., they had periods of activity and inactivity throughout the studied time. Moreover, these periods were usually triggered by a project related to their members, and presented an irregular periodicity. These communities were named *Recurrent Communities of Practice (RCoPs)*, due to these recurrent nature.

Main characteristics of the detected Recurrent CoPs

After the data analysis a framework was defined through the use of categories, properties and relationships (shown in section 5.6.2, on page 113) to explain and characterise the Recurrent CoPs.

In addition to the theory developed through Grounded Theory, it is possible to discuss key aspects detected in the RCoPs to help to understand these communities better. These aspects are listed as follows.

The work of Roberts (2006) was used as the basis for some aspects listed in this part, although some on them could not be included due to the existence of some particularities such as the lack of information, or the researcher's personal involvement in the study. For instance, it was not possible to discuss the relations of power within the community, for ethical reasons. Hopefully, further research into Recurrent CoPs might shed some light on the absent subjects.

It is important to stress that some of the conclusions discussed below are based on the researcher's experience of working in the Psychology Network. All effort was made to base these conclusions on the data collected during the Grounded Theory study; however, on some occasions it was not possible to base this conclusion in the data, because the interviewee did not comment about it, or the interview did not cover the discussed aspect. Instead, the researcher needed to use his experience in working with the involved communities, and his knowledge about the employees, recalling a previous experience where a fact happened in which the discussed aspect was present. In the few cases that this happened, such interpretation was made clear.

Trust Trust is a not an easy matter. Lazaric and Lorenz have already created a general definition of it (Lazaric & Lorenz, 1998), but a precise explanation of its functioning is complex and covers areas as diverse as Psychology and Social Science. Nevertheless, it is possible to use a more focused approach considering its existence in Communities of Practice.

It is evident that it is necessary for trust to exist for sharing to take place, but in order for transfer of knowledge to occur successfully it is crucial to have, familiarity and mutual understanding along with the trust (Roberts, 2006). Moreover, as Roberts (2000, p. 434) states, "*[h]igh levels of face-to-face contact and a process of socialization are usually required to establish and reinforce a relationship of trust and confidence between agents.*". These were common aspects found in the main CoP and in the detected RCoPs within the Psychology Network. The trust created in the socialisation that happened between the members brought the ability to share a mutual understanding as a consequence, built on a shared social and cultural context (Roberts, 2000, p. 434). Consequently, it is possible to say that in the existing communities studied in the Psychology Network, the transfer of knowledge occurred naturally as a consequence of the daily social interactions.

Additionally, in all internal RCoPs formed in the Psychology Network there was a natural need to trust the participants due to the fact that all them were employees of the same organisation. This does not imply that the trust was forced upon all due to the situation, but without it the whole workplace could not keep its normal functioning. If there was any problem that could compromise the trust, it needed to be solved before the summoning of the RCoPs, in order to avoid jeopardising the projects involved. In the case of mixed RCoPs, with external and internal participants, the trust was more evident than in the previous case. This can be understood analysing the situation in which they were formed. The mixed RCoPs had their activity usually triggered by opportunities or recurrent projects, thus the person in charge of the project would only invite external participants if s/he trusted that person. This could be the result of a previous experience of working with the person, or because of a recommendation received from a trusted contact.

Sub-CoPs and subgroups Interestingly, the analysis showed that the RCoPs were usually sub-communities of a main CoP, as they exhibited typical features of Communities of Practice. For example, in addition to the existence of domain, and practice, the community showed a clear sense of identity and meaning, presenting a strong commitment for their tasks, which is commonly found in CoPs. Their shared repertoire was clearly visible in their stories, wording, tools and concepts, although they could not notice that. This shared repertoire was a consequence of their joint enterprises, as explained by Wenger (1998b, pp. 49, 72–85).

However, they lacked the constancy factor, stopping working on the projects as soon they were accomplished. This is understandable, as the members had other tasks and projects to do. Thus, there were rarely situations where some time was spent on one finished project that would be started again in the future (for an improvement in the process, for example). Members only returned to a project when they were summoned again. Upon this call they returned to it with all the vim and vigour that one would expect from a normal CoP.

This time allocation (or work in "time slots") explains the drastic drop in activities related to a project for a period of time (see figure 5.3, on page 113). Perhaps due to this, the employees never noticed the existence of the recurrent communities, seeing these patterns of activity as simply part of the working model.

It is important to notice that the existence of sub-CoPs showed that a main CoP can have smaller CoPs inside it, justifying the assumption made by Wenger that an internal subgroup of a CoP can still be considered a CoP (Wenger et al., 2002). This theory has a high plausibility as it was corroborated by others like Gongla & Rizzuto (Gongla & Rizzuto, 2001) and Kim (Kim, 1999). However, the issue of subgroups is not new, as Wenger et al. (2002, pp. 36, 81–82) already referred to subgroups when discussing (formal or informal) leadership roles within CoPs. Kim (1999) also discussed subgroups within CoPs, arguing that a consequence of the growing of a community is the appearance of subgroups. He even recommended helping to create member-run subgroups, as one of the basic design principles for on-line communities (within what was called "Social Scaffolding"). Likewise, Gongla and Rizzuto (2001) noticed the existence of subgroups in communities and recommended the use of e-meeting technologies to enable these groups to engage in collaborative work. However they did not give further explanation of the characteristics and behaviour of these subgroups. Therefore, it seems that some authors in the literature had already started to notice the existence of subgroups within CoPs. However, in these cases they usually assumed that the subgroups were Communities of Practice without analysing the possibility further. Moreover, in the cited cases the authors did not refer to any recurrence in the subgroups, indicating the unlikelihood of those subgroups being Recurrent CoPs. Obviously additional studies are necessary to verify the possibility of existence of these sub-CoPs and the implications (good or bad) that this brings.

The dual meaning of boundaries When explaining the concept of boundary in communities, Wenger embedded two ideas in the same concept (Wenger, 1998b, pp. 103–121) that can be found not only in Communities of Practice but also in Recurrent CoPs. One relates to the sense of belonging to a community and the other refers to the interactions that happen between communities. This two concepts are detailed as follows.

The first idea expresses the sense of membership felt by the communities' members. In this case the boundaries serve as a defining border for the community, encompassing its members, keeping them united in a virtually protective environment, where all them can act as part of an entity, united by their commonalities, passions and objectives (Wenger, 1998b). Within these borders one can find the shared repertoire, the common enterprise and the mutual engagement. These are the boundaries formed by the practice of a CoP (Wenger, 1998b, p. 103).

This sense of boundaries was also found in Recurrent CoPs, though they were flexible and informal. Sometimes RCoPs were made up only of internal members and at other times of both internal and external members. For example, some Recurrent CoPs involved people from different countries with different time zones (as distant as Australia or Brazil). This was only possible because of the intense and almost natural use of electronic networks (specifically Internet). Furthermore, the members used the difference in time zones in their favour, allowing continuous work on the project, i.e., while members in the U.K. finished their part and went home, the person in a country with a different time zone kept working. The next morning the members in the U.K. could find a new version of the project in the file server already ready for the next step.

On a few occasions the formation of RCoPs with members of different institutions in the same city was also noticed. This showed that joint enterprises were not limited by the fact that the participants were working in different institutions. Amin (2002), when discussing globalisation, has already suggested that Communities of Practice might have an important role in organisational and relational proximity. Lave and Wenger were aware of the possibility of the formation of CoPs without the restrictions of boundaries, as can be noticed by their first definition of Communities of Practice, when they made clear that the community is not necessarily well-defined in location and visibility (Lave & Wenger, 1991, p. 98). When Nonaka started divulging his ideas about the SECI model and the transfer of knowledge within companies, he also realised that *Communities of Interaction* might span internal and external boundaries in the organisations (Nonaka, 1994, p. 15). Lesser and Prusak (1999) also commented on this flexible sense of boundary (as membership) in CoPs. When analysing a definition of the concept of Communities of Practice by Snyder (1997), they highlighted how the word *community* suggests that CoPs are not restricted by "*typical geographic, business unit or functional boundaries, but rather by common tasks, contexts, and work interests*." (Lesser & Prusak, 1999).

The second idea that Wenger used when explaining boundaries is related to the process of intercommunication between Communities of Practice (Wenger, 1998b, pp. 103–121). Wenger argued that CoPs cannot be seen as isolated from the rest of the world, as their enterprises are interlinked. Their members and artefacts are influenced by their interactions with worlds internal and external to the CoP (Wenger, 1998b, p. 103). This idea is usually referred to by specialists as CoP's *porous boundaries*. Roberts, for example, cited this porousness when discussing the interactions between boundaries and their influences on the change of CoP's size and on the creation of constellations (Roberts, 2006, p. 631). The concept was also discussed by Klein and Hirschheim, who argued that the notion of porous boundaries allows the introduction of the idea that different CoPs can cooperate, despite communication barriers (Klein & Hirschheim, 2008, p. 283). DeSanctis, when speaking about social interactions, explained the formation of boundaries, and in doing so she spoke about the porousness of boundaries (DeSanctis, 2006). These porous boundaries allow separated CoPs to interact with each other, bringing novelty into the community and preventing the community from becoming insulated (DeSanctis, 2006, p. 167).

In regard to the Psychology Network, the porousness of its boundaries was quite natural. Its internal and external communities had an inherent design that facilitated the creation of bridges between them and the external world, overstepping these boundaries. This was clear in the Psychology Network's internal communities. Perhaps this is linked to the fact that the employees shared the working environment, objectives, challenges, opportunities, contacts and countless aspects present in the daily life of all members and communities. On several occasions it was possible to see individual members of an RCoP looking for advice or even simply commenting on situations with members of other RCoPs. It was common to notice modifications in the communities as a result of such encounters, from small aspects such as requests for advertisements of events related to RCoPs, until alterations in the internal procedures of these communities.

In the case of its external communities and also of its mixed communities, the Psychology Network always worked towards the involvement and contribution by the students, teachers and practitioners in such communities, therefore creating a natural environment for the existence of porousness in their boundaries. This could be verified by its constant contact with the psychology community and its countless invitations to people related to the teaching and learning of psychology to engage in one of its several CoPs.

Certainly, those porous boundaries might have helped the creation and maintenance of the Recurrent CoPs, or at least it could have been more difficult to form RCoPs if they did not exist.

Constellations of Practice As noted previously, the term "Communities of Practice" was created having the intrinsic idea that the participating communities were not restricted by their size nor by their spatial reach (Lave & Wenger, 1991, p. 98). The term is not restrictive and the communities do not have precise boundaries (here *boundary* means the community's membership, as explained in the previous section). Also, Wenger stated that a CoP can be part of any number of Constellations of Practice, as a consequence of interactions between practices involving boundary processes (here, the meaning of *boundary* is related to communication, as also explained previously) (Roberts, 2006, pp. 630-631).

As discussed before, the detected Recurrent CoPs were free from physical boundaries, having members in different places (even abroad). Moreover, the intense use of ICT blurred their classification as Distributed CoPs or Virtual CoPs. Therefore, it is possible to say that the RCoPs were part of several different Constellations of Practices in the environment where the Psychology Network existed. Some examples can be given on this.

First, the Recurrent CoPs, as part of the Psychology Network, were member of a Constellation of Practice formed by 24 subject centres that worked as supporter for students, teachers and practitioners from different areas in the Higher Education in the U.K. Another similar constellation in which the RCoPs participated was the one formed by the institutions that gave the same type of support for teaching and learning in Europe. The same can be said about another Constellation of Practice formed by similar institutions with similar objectives to the Psychology Network, but involved with learning and teaching in different countries.

As can be seen, Wenger was right when he said that constellation "*is a particular way of seeing them [stellar objects] as related, one that depends on the perspective one adopts*" (Wenger, 1998b, p. 127). The only requirement for this participation is the existence of some common ground between the communities, through the sharing of common elements, such as historical roots, enterprises, artefacts, etc.

However, among all possible Constellations that Recurrent CoPs could be part of, the most evident is the one formed by the small CoPs that existed within the main Community of Practice, found in the Psychology Network.

The Constellation of RCoPs and its boundaries When Wenger (1998b) explained the details of Communities of Practice, he also discussed the processes related to Constellations of Practice (Wenger, 1998b, p. 126). After this several other authors analysed the elements and processes associated with these constellations (e.g., Coe & Bunnell, 2003; Roberts, 2006; Star & Griesemer, 1989). It is possible to use this knowledge to analyse the Constellation of RCoPs found in the Psychology

Network. However, due to the limited number of interviews and the difficulty of allocating time for additional questioning, this analysis was limited. Nevertheless, it is possible to describe some core aspects of it.

Constellations of Practice such as the one from the Psychology Network can be defined through the interactions between the practices of their constituent CoPs (or Recurrent CoPs, in our case). This approach uses boundaries in the sense of communication between communities (as described in 9.2.2, on page 205). Such analysis is possible using Wenger's concept of the CoP's boundary and its interactions (Wenger, 1998b, pp. 103–121, 126–133).

Wenger described a Constellation of Practice through the following aspects:

- Boundary objects
- Brokering
- Practice as connection
- Shared elements of style and discourse

These aspects are discussed in detail as follows.

Boundary objects Boundary objects (Star & Griesemer, 1989; Star, 1989) were first defined as objects that are sufficiently flexible to adapt to the local needs and to the limits of the parties using them, and at the same time, are robust enough to maintain a common identity throughout the sites (Star & Griesemer, 1989, p. 393). They are objects, concrete or abstract, that have different meanings in different social worlds, while keeping a common structure that allows them to be recognised in different worlds, as a means of translation (Star & Griesemer, 1989, p. 393). Brown and Duguid (1998) referred to them as objects of interest to the involved communities, but viewed or used by each of them in a different way. A community can use these objects to understand other communities, regarding their practices and world view, in addition to the common and different aspects between these communities (Brown & Duguid, 1998, p. 104). Wenger defined them as the artefacts, documents, terms, concepts and other types of reification used by CoPs to deal with the interactions between each other (Wenger, 1998b, p. 105).

Regarding the existence of boundary objects in the constellation of practice, formed by the RCoPs, it is possible to say that several objects existed in this constellation. As an example of these boundary objects, it is possible to list the products/services generated by these RCoPs. In this category we can list the (trimonthly) Psychology Network Newsletter, the (semestral) PLAT journal, the (biannual) PLAT conference, among others. These objects functioned as an interface to discuss values, terms, concepts, ideas, and other forms of reification produced by these Recurrent CoPs. It is important to highlight that other boundary objects also existed, such as the terms, concepts and jargon that existed in the discourse from the community's members. The boundary objects also helped the RCoPs interact with the main CoP. Figure 9.1 shows how these objects worked.

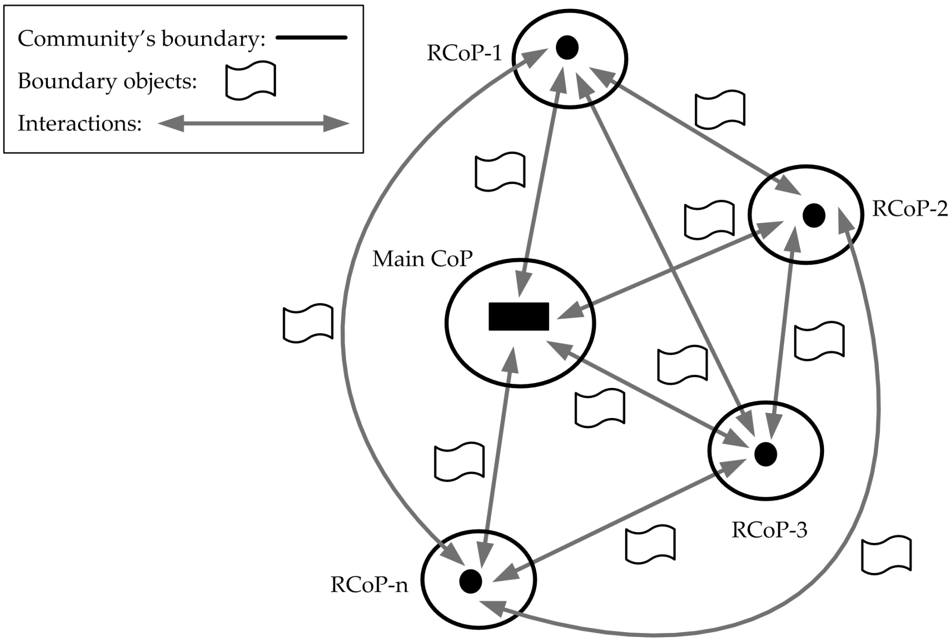


Figure 9.1.: Boundary objects in the constellation of RCoPs.

Brokering Similarly to the boundary objects, brokering was first defined by Star and Griesemer (1989); however, they used a different term to describe it. They defined the concept of *marginality* to refer "*to a person who has membership in more than one social world*" (Star & Griesemer, 1989, p. 411). These *marginal people* function as an interface between different communities to transfer ideas, concepts, terms, and other aspects inherent to a community, and were called by Wenger, *brokers* (Wenger, 1998b, p. 105). They can be visualised using figure 9.1, but in place of the boundary objects, one just needs to imagine a person (the broker).

Brokers have a similar role to the boundary objects, but they are more capable of transferring the new concepts to the other community. Due to their knowledge of languages, method, habits and customs inherent to the involved communities, they are able to do better work on presenting and transferring new ideas between these communities.

As Wenger pointed out (Wenger, 1998b, p. 109), managers are more likely to be involved with brokering, but this is not always a rule. Although it is a complex task some persons are more willing to assume this position. He also commented how these people "*love to create connections and engage in 'import-export'*", preferring to stay on the periphery of the practices and engage in brokering rather than moving to the core in any of them (Wenger, 2000, p. 235).

In the case of the constellation of practice formed by the RCoPs, it is possible to say that the existence of these brokers was quite natural. This was due to the several RCoPs present in the workplace, allowing the employees to participate in several of them at the same time. There were no clashes in time allocation as conflicts were solved by the participants. It was natural to see in meetings, for instance, presentations of ideas or experiences that occurred in different RCoPs. These exchanges of concepts and ideas helped the RCoPs to develop their projects faster and more easily, as they learned with the other communities and used the acquired experience to find the best way to run their tasks.

Interestingly, the brokering was done not only by the managers, who were more likely to be involved in several RCoPs, but it was also done by different participants involved in these communities, even when external to the workplace, confirming Wenger's opinion.

Practice as connection Wenger defined an interesting concept to explain the relations between communities: *practice as connection*. In this concept, boundary interactions create connections that are kept for a long period, becoming part of the practice (Wenger, 1998b, p. 113). Using this concept as a foundation he defined three types of practice-based connection: *boundary practices*, *overlaps* and *peripheries*.

Boundary practices happen when a boundary encounter becomes constant and established as an accepted forum for mutual engagement, becoming a practice for the involved communities (Wenger, 1998b, p. 114), forming a form of collective brokering. Examples of this are executive committees and task forces.

In the constellation of RCoPs, it was possible to identify some examples of this type of connection, such as the RCoPs formed by the Postgraduates Who Teach (PGwT) Regional Coordinators. This boundary practice was formed by the PGwT coordinator from the Psychology Network and by the regional coordinators from each of the regions supported by the Psychology Network. The boundary practice worked to connect the (PGwT) RCoP in the Psychology Network with the regional (PGwT) RCoPs formed by students of psychology in the U.K. Figure 9.2 shows this practice-based connection.

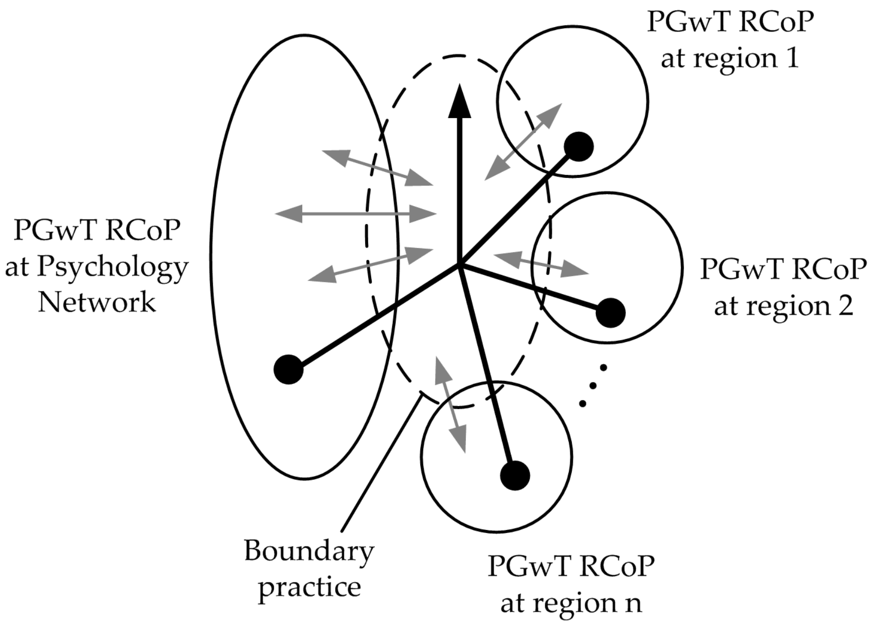


Figure 9.2.: Boundaries practice in the constellation of RCoPs [based on (Wenger, 1998b, p. 114)]

In the same way, there was a boundary practice formed by the main CoP (in figure 9.2 it would be represented by the ellipse on the left) and the (PGwT) RCoP (in the same figure it would be one of the circles on the right), both communities existed within the Psychology Network.

The second type of practice-based connection, *overlaps*, refers to the connections that, without requiring a boundary enterprise, exist as a stable and constant overlap between two practices (Wenger, 1998b, p. 115).

The constellation of RCoPs, in the Psychology Network, showed that this type of connection was quite common, as several members participated in different RCoPs. In doing so, the member also participated in different practices, being capable of acting sometimes as a broker, delivering new ideas and concepts, and sometimes as common member, participating in the practice related to the community. This brokering behaviour was predicted by Gertner et al., who stated that the role of brokers becomes significant where boundary practices, overlaps and peripheries are identified (Gertner et al., 2011, p. 630).

An example of overlap was found when the employees participated in the RCoP related to the bi-annual PLAT conference (see details of this in section 5.4.2, on page 104). The interaction with several CoPs and RCoPs found in the conference usually influenced procedures and ideas in the internal RCoPs within the Psychology Network.

Another example, although on a smaller scale, was when a member of the Psychology Network needed to act as a broker, combining the practices of an RCoP related to the tri-monthly newsletter with the practices of the RCoP related to the semestral PLAT journal. In this case, administrative issues, such as coordination of tasks, deadlines and reviews related to each RCoP, needed to be contemplated without conflicts or redundancies. Additionally, the two communities had different objectives and different approaches that needed to be addressed. At the same time, questions related to the selection of articles to be published in both publications needed to be addressed by another member, who needed to participate in the two RCoPs to know which articles would be more appropriate for each community. The task was only possible because the member was a participant in both RCoPs and had profound knowledge of the practices in these communities. This situation is represented in figure 9.3.

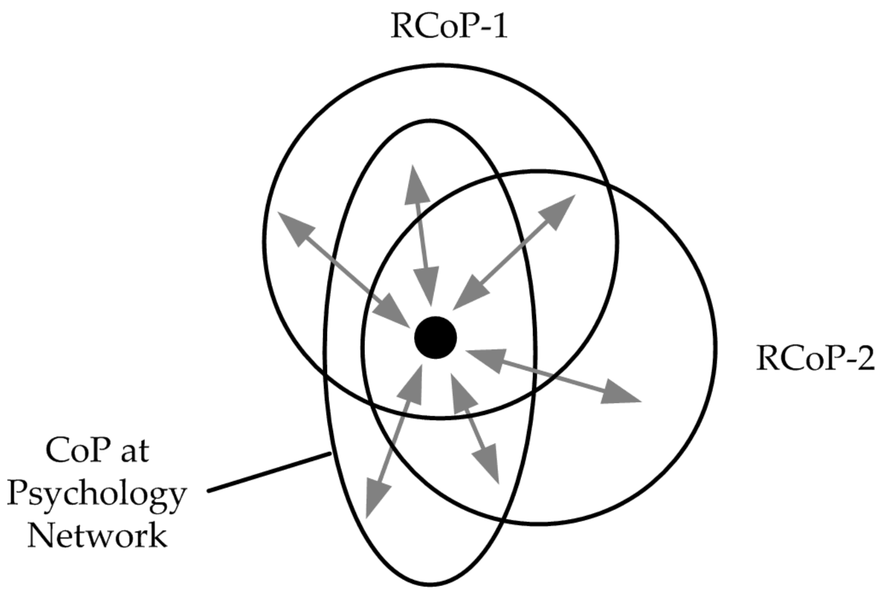


Figure 9.3.: Example of overlap in the constellation of RCoPs [based on (Wenger, 1998b, p. 114)]

The third and last type of practice-based connection, *periphery*, works as a gate to allow contact with the world external to the community. Its objective is to provide connection via casual experiences without the requirement of a full membership (Wenger, 1998b, p. 117). It can be used for several different purposes, such as a way of attracting new members, to allow public scrutiny, or even to sell services or products (Wenger, 1998b, p. 117).

Interestingly, the Psychology Network had a configuration that changed the way periphery connections were used. Due to the fact that it was a workplace, the Psychology Network was made up of employees, thus the membership of any internal CoP or RCoP did not depend on attracting new external members. However, peripheries could also be used for explaining the community's internal processes to an outsider, as a way of justifying/explaining a decision, what was a normal procedure in the Psychology Network. For instance, sometimes feedback from the practice developed in the PGwT community would generate a modification in the next offered events, which would then lead to modifications in the advertisement for these events in the community related to the Newsletter, and in the community related to the website. Thus, the PGwT community used the periphery to explain the reasons for the changes and consequently to request the necessary modifications in the work of other communities. This situation is shown in figure 9.4.

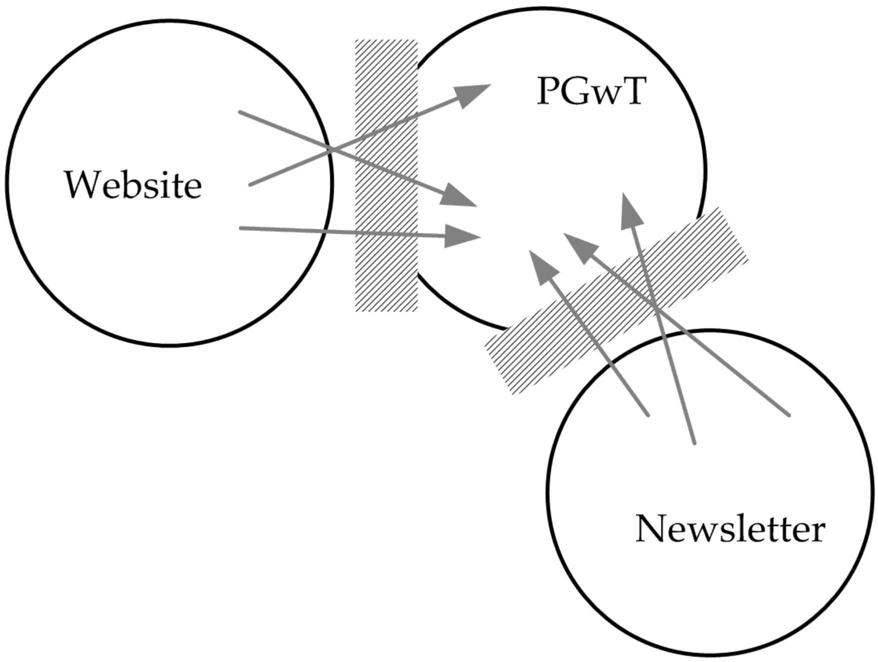


Figure 9.4.: Example of periphery in the constellation of RCoPs [based on (Wenger, 1998b, p. 114)]

Additionally, peripheries were used to deal with the world external to the Psychology Network, and for this the internal CoP and the RCoPs used the peripheries as a way of attracting new members, in addition to the process described above.

These types of use for periphery were not possible in all communities, due to the high level of specificity found within them (e.g., in the Newsletter RCoP).

However, sometimes a person who could contribute to the practice was invited to participate on a specific occasion, and if both the community and the guest felt "connected" after this, more work would be done together. This connection seems to be a sign of a sense of belonging to the community. The guest shared a common identity with the community. This common identity in Communities of Practice has already been discussed in details before (Brown & Duguid, 1991; Handley et al., 2006; Wenger, 1998b); however, what makes this case remarkable is that in addition to involving Recurrent CoPs, it shows a practical case of the access of newcomers to a CoP.

Elements of style and discourse The last aspect used by Wenger to describe a Constellation of Practice refers to the shared elements of *style* and *discourse*.

When defining and discussing Constellations of Practice, he explained that styles and discourse are aspects of the shared repertoire that are exportable and importable, and that they are capable of crossing boundaries, being interpreted and adapted to the local practice (Wenger, 1998b, p. 129).

Although the subject is still understudied, some authors have already discussed it (Coe & Bunnell, 2003; Czarniawska & Sevón, 1996; Gertner et al., 2011; Roberts, 2006, 2010).

Regarding the elements of style, these can spread throughout different communities, crossing boundaries, as "*people copy, borrow, imitate, import, adapt, and reinterpret ways of behaving in the process of constructing identity.*" (Wenger, 1998b, p. 129). The same can happen with discourse as "*people coordinate their enterprises, convince each other, reconcile their perspectives, and form alliances.*" (Wenger, 1998b, p. 129). As these discourses and elements of style spread across the constellation, they can be used in several different practices, creating continuities that might generate a common character (Roberts, 2010, p. 121).

As far as the Psychology Network is concerned, the constellation formed by the Recurrent CoPs and by the main CoP presented a formation that facilitated the spread of styles and discourse. This is owing to the fact that the workplace was in a single open space, and the number of involved members was small. This could explain the use of similar (or sometimes the same) metaphors, narratives, jargon, examples and other forms of expression of their identity in the RCoPs and CoP. Moreover, the style of dealing with aspects such deadlines, schedules, presentations and descriptions presented a remarkable resemblance. Terms such as "PLAT" and "IPDPS" were used in different RCoPs, like the *PGwT* and *Newsletter* ones, without further explanation of their meaning (*PLAT* could refer to the journal or to the bi-annual conference, depending of the context of the conversation, and *IPDS* stands for *Improving Provision for Disabled Psychology Students*).

Another factor that could explain these similarities is that although the RCoPs were relatively independent, they all need to follow the same directive: to provide support to students, teachers and practitioners of psychology in the U.K. This would narrow the set of procedures advised by the regulators (Higher Education in the U.K.) and by the administrative structure governed by it (see figure 5.1, on page 102, for an overview of the administrative structure of the Psychology Network). These guidelines directed the work in the Psychology Network, influencing the elements of style and discourse adopted in the workplace and consequently in the CoP and RCoPs.

Recurrence The main aspect defining the characteristics of the Recurrent Communities of Practice is the one used to label them: the *recurrence* in the pattern of activity they possessed. This is the aspect related to their "momentary disappearance", where all their activity ceases to exist for a period of time, returning back to activity afterwards. Interestingly, for the purpose of certifying their existence, the RCoPs still continues to live, although with very little to no activity during certain periods of time. This characteristic was represented in figure 5.3, on page 113. This behaviour would probably pass unnoticed in a context of a Constellation of Practice, if all involved RCoPs were active at the studied moment.

This cyclical variation in CoPs' activity was found in several small communities within the studied workplace, the Psychology Network. These cycles of activity were usually triggered by a project that needed to be completed by a specific date. After the end of the project, the RCoP changed to a period of inactivity until the next trigger was activated.

Chapter 5 in this thesis introduces the concept of Recurrent CoPs and gives several examples of these communities found in the Psychology Network. Additionally, the chapter describes the steps involved in the case study that led to the discovery of the Recurrent CoPs.

Due to the novelty of the subject, no literature has been found discussing similar recurrence in Communities of Practice to this date. Perhaps this is caused by the fact that recurrence is related to the temporal aspect of Communities of Practice, and time is still an understudied subject. Some attempts to find publications analysing time in CoPs are discussed in section 2.11, on page 53. Through the analysis of the few available publications that discussed the subject, it was noticed that until recently, time was treated as a static component of CoPs, and that the studies usually analysed the CoPs using a time snapshot at a random moment of the existence of the community, or analysed the life cycle of the CoP.

Some examples of the Recurrent CoPs found at the Psychology Network are the tri-monthly Newsletter, the semestral PLAT (Psychology Learning And Teaching) journal and the bi-annual PLAT conference. In all cases there was the same pattern in their cycles of activity/inactivity. A trigger, generally a project or a periodical, made the members start to exchange emails, have face-to-face or virtual meetings, and develop a series of already known and established practices in order to deliver the expected outcome. Moreover, the RCoPs had a fairly fixed number of members, only changing it (usually including new ones) when a new requirement appeared that demanded a skill not available in the current configuration of the community.

Another characteristic that was noticed is that the recurrence presented by the RCoPs did not alter any characteristic already seen in common CoPs, as far as the case study could show. All aspects noticed in CoPs (based upon *domain*, *practice* and *community*, as defined by Wenger (1998b)) were also present in the Recurrent CoPs.

This concludes the analysis of the second finding from this research: the Recurrent Communities of Practice.

In the following section the next research finding is discussed and an analysis similar to the previous one was implemented to understand the implication of such a finding in the light of the existing literature.

9.2.3. 3rd discovery

The discovery of Recurrent CoPs was so fascinating that the possibility of the existence of the same phenomenon in Virtual Communities of Practice was immediately considered. To verify this, a dataset containing the activities of four verified CoPs was kindly provided by Murillo, who collected it for his research (Murillo, 2002, 2006, 2008; Murillo-Othon & Spicer, 2007).

A discussion about the methodologies used in the analysis of the case study is presented in section 3.6, on page 80. The details of this study are available in chapters 6 (Quantitative Analysis), 7 (Cluster Analysis) and 8 (Social Network Analysis for Recurrent CoPs).

Upon the study of the dataset nothing similar to a Recurrent CoP was found in the four Virtual CoPs studied. Even with the intense use of different methods of analysis no traces of recurrence in the activity patterns were detected in the analysed newsgroups. However, two main aspects were noticed.

The first one was not new, but it was surprising to see it so clearly in the analysis. It was related to the importance of the communities' powerhouse: the core members. This is known in the studies of Communities of Practice (as already discussed in Gongla & Rizzuto, 2001; Wenger, 1998a,b; Wenger et al., 2002); yet, during this study their importance became evident in the four analysed communities.

The second aspect is greatly fascinating, and as far as the literature is concerned, it was never noticed before. It is a new form of dynamic activity noticed within the four studied VCoPs, and it was related to a special type of node, named *Transient Core Member (TCM)*. Due to the novelty of the concept of TCMs, an analysis in depth was developed to discover more about them. The following sections discuss the main aspects related to the TCMs found in the research.

Main differences between Transient Core Members and Recurrent CoPs

Before discussing the aspects related exclusively to TCMs, it is necessary to explain why the discussion needs to be adapted from the one implemented in the case of RCoPs presented in section 9.2.2, on page 203.

While a discussion about Recurrent CoPs is mainly a debate about relationships between CoPs, the discussion about TCMs is a discussion about relationships within a CoP. This can be noticed looking at the aspects presented when Recurrent CoPs where analysed. It was necessary to explain characteristics that are important to define relations between communities such as groups, sub-groups, boundaries and Constellations of Practice.

In the case of TCMs this is not possible as they do not form sub-groups or internal communities (temporary or not). The term *Transient Core Members* refers to individual members from the same community, who are analysed as a group because they all acted as a core member, but only for a short period of time and not all them at the same time. Transient Core Members are highly engaged in the communities' life, but they do not form a cohesive subgroup in the way RCoPs do. In fact, they act as individuals. However, when seen as a whole, they have an immense importance in the community's amount of communication and consequently in the life of the Virtual CoP. Additionally, the TCMs differ from the RCoPs with relation to the trigger of their activity. Whilst the Recurrent CoPs' activities are usually related to a project, the TCMs only act when they find messages with subjects of their (individual) interest.

Another difference if that there are no cycles of activity/inactivity in TCMs, like the ones found in Recurrent CoPs. However, when seen as a group they exchange messages for continuous periods of time, similarly to core nodes. This helps to keep the community active and to attract new members.

However, due to the variety of activities and to the personal characteristic of the activity's triggers, it is not possible to predict who will generate the next exchange of messages among the TCMs, or even when this will happen.

Interestingly, the TCMs give immense support to the community, probably without noticing. This can be understood when it is considered that in newsgroups (the case of the studied CoPs) core members are generally noticed by their high level of activity. Hence, a regular member of the community will think that his/her own participation is not very important due to his/her low number of messages, if compared with the core members. However, if this member is one of the TCMs, as a group they will generate a significant number of messages, equivalent to the core members. If it is considered that the existence of a Virtual CoP depends on the exchange of messages between participants, the TCMs play a very important role.

The possible origin of RCoPs and TCMs

Interestingly, the places where RCoPs and TCMs were found might help to understand some of the reasons for the origin of these communities.

Digital forums such as newsgroups may help to create TCMs, due to the spontaneous nature of such forums. Their active members are not obliged to contribute or take part in the community, only participating if they feel inclined to. In this type of VCoP, the core members transform this inclination into passion, dedicating their time and effort to keeping the community alive. This can be noticed by a high level of exchanged messages originating from the core members. However, Transient Core Members are not aware of their contribution, thus feeling free to only engage in communication when the discussed subject is of interest to them. This attitude is similar to the common active member, but a TCM has a more intense participation, giving their occasional support to the core members and to the community more frequently.

On the other hand, the RCoPs seems to exist as a consequence of co-located CoPs, or at least of the ones with a strong presential component. In the case of the studied RCoPs, they were discovered in a workplace, which naturally required the members to take part in the community, making the existence of TCMs unlikely. However, as a consequence of having several tasks and projects to develop at the same time, a natural allocation of the available time was created, leading to the creation of bursts of activity over time. These bursts were usually related to projects with deadlines. This, together with the natural tendency from the Psychology Network to form communities, seems to have facilitated the creation of Recurrent CoPs.

Trust in RCoPs and TCMs

Although the roots of trust are the same (Lazaric & Lorenz, 1998), Recurrent CoPs and TCMs build their trust upon different aspects. While RCoPs (and the internal CoP) seem to follow Roberts's opinion (Roberts, 2006, p. 434) about the establishment and reinforcement of trust via face-to-face contact and socialisation, the TCMs followed the pattern found in Virtual CoPs, where these social traits are almost non-existent.

For VCoPs trust seems to be based on the perception of the members toward the community and the other members. Ardichvili (2003) reached this conclusion analysing a case study in a Virtual Community of Practice at Caterpillar company. He states that when participants see knowledge as a public good belonging to the whole community, knowledge flows without problems (Ardichvili et al., 2003, p. 64). Lesser (2001) corroborates this idea, stating that the development of shared repertoires and discussion databases acts a mechanism to nurture a sense of mutual trust (Lesser & Storck, 2001, p. 836). The implementation of these two systems allows the participants to judge other members by their contribution to the well-being of the community, becoming mechanisms for evaluation of the trustworthiness and reciprocity of members (Lesser & Storck, 2001, p. 838).

Newsgroups have the two systems described by Lesser (a shared repertoire and a discussion database). They also have the sense of common good described by Ardichvili. Therefore, one could argue that the studied VCoPs represent examples of Ardichvili's and Lesser's idea of a trusted Virtual CoP.

Finally, the analysis showed that the members knew who the ones with more knowledge in the community were (and consequently who made a major contribution to the community). These were usually the core members, and were the ones perceived as the more reliable. TCMs had a similar recognition by the community, but not in all cases, as this recognition was related to the level or significance of the contribution to the discussion by the TCM.

Comparison between TCMs and Core Members

Transient Core Members resemble core members in several respects, but differ in others, thus it is important to compare the two as a way of clarifying their own characteristics.

As explained previously, a discussion about TCMs is about relationships within a CoP. The same is true for core members. Therefore, in order to adequately develop the discussion between TCMs and core members it is necessary to use aspects that define the internal structure of Communities of Practice, and for this the three main components of a CoP will be used: *mutual engagement*, *joint enterprise* and *shared repertoire* (Wenger, 1998b, pp. 49, 72–85).

Regarding the first component of a CoP, *joint enterprise*, core members and TCMs present the same characteristics described in the section entitled *The main concepts*, on page 32. This is understandable as in both cases they are part of a Community of Practice with very clear objectives and enterprises, none of them having different enterprises from the ones found in the main CoP. Moreover, TCMs and core members are part of the same community that was formed to reach an objective. Even in the case of the TCMs there is no formation of subgroups or sub-CoPs. Their joint enterprise is the same as the rest of the community.

In the case of the second component, *shared repertoire*, the same situation happens again. The TCMs and the core members are part of a Community of Practice that has a set of repertoires that is shared among all members, as described in the section *The main concepts*, on page 32. There is no special repertoire only available for TCMs and/or core members. Once again, TCMs do not form a subgroup or a sub-CoP with a different shared repertoire.

In the case of the third component, *mutual enagement*, the situation differs from the previous two cases, as TCMs and core members have a slightly dissimilar behaviour. Although both still follow what is described in the section *The main concepts*, on page 32, they have a difference that can only be noticed if one analyses their activities in depth.

Core members have a more frequent engagement than TCMs, although the quality of the engagement is the same. This is due to the fact that the Transient Core Members only engage in discussions if the subject involved is interesting for them. The core members are responsible for a great amount of the total of messages exchanged in the group. This makes them an important part of the community (Gongla & Rizzuto, 2001; Wenger, 1998a,b; Wenger et al., 2002), specially in the case of Virtual CoPs.

The TCMs, although not being responsible for a great number of messages, participate in an important part of the exchanged messages when seen as a whole. Sometimes without noticing they release the pressure from the core members answering questions or complementing replies that otherwise needed be done by the core members.

With the main findings explained it is now possible to discuss what contributions the research has provided. The following sections detail these contributions in three areas: theoretical, practical and methodological.

9.3. Theoretical contributions of the research

The most remarkable contributions from this research to the theory related to Communities of Practice are centred in three main points.

The first one relates to the notion of Recurrent CoPs, developed during the second case study. The methodology used in this case study is available in section 3.5, on page 71. The description of the processes that led to their discovery can be found in chapter 5 (Grounded Theory of Recurrent Communities of Practice).

Recurrent Community of Practice depicts a type of community that has as its main characteristic cycles of activity/inactivity triggered by projects with specific deadlines (see figure 5.3, on page 113). These Recurrent CoPs are sub-CoPs of a main CoP and seem to be the result of the tendencies currently present to divide the work time into slots (to allocate all due projects), and to form work teams and/or working groups (which, in turn, might become CoPs).

This discovery might create a new range of possibilities, not only in studies involving Recurrent CoPs, but also in research into the temporal aspects of CoPs, filling the current gap in this area.

The second point that contributes to enriching the theory related to CoPs is related to the discovery of what was called *Transient Core Members*. The methodology used in the case study related to their detection is presented in section 3.6, on page 80, and the complete description of the study is described in chapter 8 (Social Network Analysis for Recurrent CoPs).

TCMs do not represent a new type of community, as RCoPs do, but rather they describe a type of behaviour that exists inside a CoP (or Virtual CoP, as in the case of the studied community). It was detected that a group of members (the TCMs) behaved as core members of the community for a short period of the time, doing this as individual members and separately in time, without the creation of subgroups. They give important help to the CoP's core members, helping to relieve the pressure on these members.

Similarly to RCoPs, the TCMs not only contribute to existent theory related to CoPs, but also incentive additional studies in the influence of time in Communities of Practice.

The third and last point related to the contribution to the theory of Communities of Practice refers to the discussion and operationalisation of Wenger's list of 14 indicators that a CoP was formed (Wenger, 1998b, pp. 125–126) (see section 2.9, on page 45 for a detailed discussion).

Although commented on several publications (e.g., Amin & Roberts 2008; Thompson 2005), Wenger's indicators have been little analysed (Cox, 2005). Contributing to this discussion, section 2.9, on page 45, analyses Wenger's indicators in detail, presenting the interpretations for each indicator adopted in this research, as well as the relations between the indicator and the respective CoP's component (from the three possible ones listed in section 9.2.1, on page 201) used in this work. This discussion on Wenger's indicators helps to call attention to a part of his work that is little studied. This part of the research debated each indicator in the light of the existing literature on the subject, what hopefully can help to spark new discussions on something that has already proved to be a powerful tool in this research.

9.4. Practical contributions of the research

It is unclear at this point what practical contributions this research can offer, but it is possible to speculate about them. Any contribution in this area is related to the main findings from this research: the *Recurrent Communities of Practice* and the *Transient Core Members*.

In the case of the Recurrent CoPs it is possible to speculate that organisations can incentivise the creation of RCoPs, making the work environment more suitable for their emergence. This might be achieved by creating workplaces that nurture characteristics found in RCoPs, such as collaboration and time allocation. For example, to incentive collaboration, organisations could promote the advertisement of opportunities for projects and resources managed by communities (internal or mixed ones). As for time collaboration, a policy of incentives together with proper training on time allocation might help to create a habit among the employees. It is important to highlight that these recommendations cannot be imposed or implemented forcefully, otherwise the spontaneous nature of Communities of Practice will be compromised. The great advantage of the creation of RCoPs is that due to their small size the amount of resources allocated to nurture them is less than that required for a common CoP.

Regarding the contributions related to the Transient Core Members, it is possible to speculate that organisations could use these TCMs to help potential or existing Virtual CoPs. It is possible, for instance, to imagine a scenario where organisations identify TMCs to check if some of them would like to become core members. This could allow the Virtual CoPs to increase the number of core members, reducing the risk of collapse of the community due to the loss of the main core members, as described by Gongla and Rizzuto (2004). Additionally, the nurturing of TCMs might even alleviate some of the pressure imposed upon core members to keep giving support to discussions within VCoPs.

Another possibility is to encourage porousness in the boundaries of existing co-located CoPs. This may open up opportunities for CoPs to expand. Moreover, if this porousness happens through CMC, it can lead to the formation of Virtual CoPs. Making a CoP become digitally present might consequently foster the appearance of Transient Core Members, or maybe even Recurrent CoPs (in co-located CoPs), if more aspects, such as time allocation, are present. To promote this porousness organisations need to try different combinations of approach. There is no single solution for several different communities; each one will need to be evaluated and tested. Such techniques could be: incentives and training for the formation of communities based on projects; advertisement of projects based on communities developed by organisation' branches; creation of internal events promoting collaboration between employees from different areas to solve specific problems related to the organisation, and so on. These are just some ideas of approaches that might lead to more porous boundaries among internal communities, but much more can explored in this field.

9.5. Methodological contributions of the research

As far as the contributions from this research in the area of methodology are concerned, it is possible to highlight some important points.

The initial point relates to the implementation of the first and second case study, which were developed based on Wenger's indicators that a CoP was formed (Wenger, 1998b, pp. 125–126). A methodology needed to be implemented in the first case study, to convert Wenger's list into a questionnaire, and in the second study to convert it to a guide, in order to study Communities of Practice in the Psychology Network. For the first case study the details of the methodology can be found in section 3.4, on page 68, and the complete description of the case study is found in chapter 4. As for the second study, the methodology is explained in section 3.5, on page 71, and the description of the case study is found in chapter 5.

These two case studies are important because no examples of implementations of Wenger's indicators were found in the existing literature. Even analyses of Wenger's indicators are very rare in the literature (see discussion about this matter in section 2.9, on page 45).

The second important point that highlights the methodological contributions of this research relates to the use of Grounded Theory for the study of Communities of Practice. This is not an uncommon practice implemented in the study of CoPs (e.g., it was used by Rothaermel and Sugiyama (2001), and by Geiger and Turley (2005)). What makes this contribution important is the use of Grounded Theory together with Wenger's list of indicators, as the existing literature does not show any examples of similar procedures. This point is significant because it shows the implementation of a methodology that can be used for other studies where Wenger's framework of CoPs is used, and there is a necessity to study the inner functioning of a CoP, with very little bias. The methodology implemented can be found in section 3.5, on page 71, while the case study is explained in chapter 5.

The third contribution in the area of methods is related to the potential for using the visual aspect of Social Network Analysis to study the temporal nature of Communities of Practice. The use of Social Network Analysis in Communities of Practice is not new, having been used by Murillo (Murillo, 2002, 2006, 2008; Murillo-Othon & Spicer, 2007), Tomlinson (2002) and others. However, the use of SNA with a time component is rare and few programs can deal with it. Nevertheless, new versions of SNA programs already prepared to analyse time are becoming common. In this research only a small fraction of Social Network Analysis was used: the visual component. None of the aspects related to graph theory was used, as it was not necessary (a discussion about SNA can be found in the section on *Reasons for choosing Social Network Analysis*, on page 86 and in *The use of Social Network Analysis*, on page 87). The visual tool, together with the analysis of the socialmatrices related to the VCoPs, were enough to detect the TCMs. One can wonder what more can be discovered if more sophisticated analysis techniques involving time are used in Virtual CoPs and/or co-located ones.

Even the case of unsuccessful use of Cluster Analysis in VCoPs contributes to a better understanding of the behaviour of VCoPs. Perhaps future research involving VCoPs and Cluster Analysis can make use of the lessons learned in this research and avoid some of the problems.

9.6. Limitations of the research and possible future work

This study found a new type of Community of Practice by studying a small workplace with ten employees, one of whom was the researcher. However, the involved institution was very specific. It was one of the 24 subject centres that gave support to the main areas in Higher Education in the U.K. Therefore the institution was naturally inclined to cooperation, having itself several communities already linked to its normal life. Nevertheless, this does not invalidate any finding in the study. It is possible to imagine similar environments elsewhere.

Similar studies in different institutions or companies might lead to discussions that can enlarge the knowledge acquired in this research. Probably it could be a good idea to have new studies in larger companies or institutions. These might show even newer types of Communities of Practice, not seen in this work. It would have been good to build up a fuller picture of how these communities work. However the access to them is quite challenging, and would probably require extra time not available in the current circumstance.

Regarding the study in Virtual Communities of Practice, this work could have looked at different electronic networks, as it looked primarily at the Usenet. It could have looked at different type of forums, not only at newsgroups, for example, *Yahoo! Groups*, *Flickr* (specifically in groups within Flickr (Cox et al., 2011)), *YouTube*, or any other user generated content website. However, this research was looking for the understanding of the internal functioning of a Community of Practice. To use these communities, first it would be necessary to certify that they fall into Wenger's definition of a Community of Practice (Wenger, 1998b). In the case of VCoPs used in this study, Murillo had already done this verification in a remarkable study during his research. Any attempt to do the same in a different community would require time not available for this research.

With regard to the Transient Core Members, although their discovery was a very fortunate event, it happened in a very specific environment: in CoPs within newsgroups. Therefore, this limits our understanding of TCMs, requiring more studies on this subject to answer questions like: are TCMs a specific phenomenon related to newsgroups only? Is it possible to find them in different forums? Can they exist in co-located CoPs?

Another idea with great potential for research is the possibility of nurturing TCMs. Is that possible? Can the rules applied to common core members be applied to Transient Core Members? If such nurturing is considered possible, can the same rules be applied to different forums?

Questions regarding the necessary strategies for their discovery and use, in addition to the requirements for their existence, are still unanswered.

Everything that has already been discussed over the years about CoPs can be checked against RCoPs. Certainly it is important to know if the rules applied for typical CoPs are still valid in RCoPs. Moreover, questions relating to the nurturing and maintenance of these RCoPs have great importance for their future use in companies and institutions. If sometimes it is difficult to find the typical CoP, with Recurrent CoPs the process might be even more challenging. This alone represents a source of opportunities for new research and case studies.

Regarding the RCoPs within electronic networks, the work could not find any of them in the studied newsgroups. However, different studies in different Virtual CoPs might find them. In these days, with the increased use and spread of social networks, the potential for discovery of Recurrent CoPs has increased immensely.

Even considering only the cases of study of co-located RCoPs, more knowledge is still necessary to understand how they behave and how different they might be from regular Communities of Practice. Questions related to their use by companies and institutions need to be answered before any practical use can be implemented. Such questions are: Do they exist in every co-located CoP? Imagining that they exist in electronic networks, how can they be nurtured? Is this possible? If so, how? Can RCoPs be used to expand the range of services and products a company has, in a similar way to a regular CoP? If so, then how?

Another important aspect discussed in this thesis that might generate new studies is the temporal aspect of CoPs. This is usually seen as an intrinsic component of the community's functioning. However, this study showed a glimpse of how much is still hidden. It is more common to find literature that discusses Communities of Practice seen through a single snapshot in time than through slices of it. Time can be a useful tool to nurture CoPs, since its role in the internal structure of a CoP is known. Consequently, much more can still be done to shed light on this area.

A. Material related to the studies

A.1. First study at the Psychology Network

A.1.1. Questions used during the interview

Date:
1. Name: 2. Gender: 3. Age: 4. Education level: 5. Occupation:
6. Do you have a constant relationship with your colleagues? 7. When you have a work problem do you ask a colleague for help? 8. Is information propagated quickly? 9. Do you need to explain your work's activities before engaging in a conversation with a colleague? 10. Is it easy to introduce a problem that requires a discussion among your colleagues? 11. Do you know your colleagues' skills and how these can be used to achieve a common enterprise? 12. Can you assess the appropriateness of an action or product for the organisation? 13. Do you remember any shared representation or tool? 14. Do you know any story, case or joke shared with your colleagues? 15. Do you know any jargon or shortcut shared with your colleagues? 16. Can you define a characteristic of your work shared with your colleagues? 17. Do you have any question for me?

Table A.1.: Questions used during the first study at the Psychology Network

A.1.2. Indicators of a CoP and their relationship with questions used during the interview (first study continued)

Indicators of CoP	**Questions**
(1) Sustained mutual relationship – Mutual Engagement	6. Do you have a constant relationship with your colleagues?
(2) Shared ways of engaging in doing things together – Shared Repertoire	7. When you have a work problem do you ask a colleague for help?
(3) Rapid flow of information and propagation of innovation – Shared Repertoire	8. Is information propagated quickly?
(4) Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process – Joint Enterprise	9. Do you need to explain your work's activities before engaging in a conversation with a colleague?
(5) Very quick setup of a problem to be discussed – Joint Enterprise	10. Is it easy to introduce a problem that requires a discussion among your colleagues?
(6) Substantial overlap in participants' descriptions of who belongs -Ű Mutual Engagement	
(7) Knowing what others know, what they can do, and how they can contribute to an enterprise – Mutual Engagement	11. Do you know your colleagues' skills and how these can be used to achieve a common enterprise?
(8) Mutually defining identities – Mutual Engagement	
(9) The ability to assess the appropriateness of actions and products – Mutual Engagement	12. Can you assess the appropriateness of an action or product for the organisation?
(10) Specific tools, representations, and other artifacts – Shared Repertoire	13. Do you remember any shared representation or tool?
(11) Local lore, shared stories, inside jokes, knowing laughter – Shared Repertoire	14. Do you know any story, case or joke shared with your colleagues?
(12) Jargon and shortcuts to communication as well as the ease of producing new ones – Shared Repertoire	15. Do you know any jargon or shortcut shared with your colleagues?
(13) Certain styles recognised as displaying membership – Mutual Engagement	16. Can you define a characteristic of your work shared with your colleagues?
(14) A shared discourse reflecting a certain perspective on the world – Mutual Engagement	

Table A.2.: Indicators of Communities of Practice (Wenger, 1998b, pp. 125–126)

Note: Questions (6), (8) and (14) from the table above have not been used during the interviews as they are not applicable to a workplace.

A.2. Second study at the Psychology Network

A.2.1. Written consent

Informed Consent Form

Before you participate in this study, please complete Section A, printing your name in the first space and then sign at the end.

Once the study is over and you have been debriefed, you will be asked to initial the three statements in Section B, to indicate your agreement.

Section A

I, ________________________, voluntarily give my consent to participate in this study as part of Richard Ribeiro's PhD Project.

I have been informed about, and feel that I understand, the basic nature of the project. I realize that I will be interviewed by Richard and asked about my work and my working relationships.

I give my permission for the study to be recorded. I understand that all the information collected, including the audio, is confidential. Only Richard Ribeiro and his PhD supervisors, Chris Kimble and Paul Cairns, will have access to the data collected today in its original format and it will only be made public in an anonymised format. The audio will not be made public without prior explicit permission from me.

I understand that I may withdraw from the study at any time without prejudice, simply by saying that I would like to stop now.

Signature of Research Participant Date

Section B

Please initial each of the following statements when the study has been completed and you have been debriefed.

I have been adequately debriefed	Your initials:
I was not forced to complete the study	Your initials:
All my questions have been answered	Your initials:

A.2.2. Introduction scripts

Ethics information: introduction scripts[1]

The introduction script that is used at the start of the experiment must:

- state the general aim of the experiment
- explain why you need the involvement of other people
- describe what will happen in the experiment
- describe what data will be collected
- explain what interaction the participant may have with you during the experiment
- reassure the participant that this is not a test of ability
- state that the participant may withdraw at any time
- seek explicit consent
- allow the participant to ask questions

[1]Based on the original version from Department of Computing Science, University of Glasgow

A.2.3. Questions used during the interview (first phase)

Questionnaire (participant 1)

Questions based on Wenger's concept of *reification*:

1. *Sustained mutual relationships – harmonious or conflictual*
   - Can you describe a situation where a colleague was helpful or where you were helpful?
   - Have you had any problem with a colleague? How did you resolve it?
   - (*Long term collaborations*)
2. *Shared ways of engaging in doing things together*
   - Have you been in a situation that as a team member you have not been able to address? What did you do? How was the problem solved?
   - Can you describe a situation where you worked as a team? What were the goals? In what context did that happen? Did it include everyone? Who was excluded/included? Why?
   - (*Lost track of time / extra 1/2 mile*)
3. *The rapid flow of information and propagation of innovation*
   - When was the last time you received helpful advice from a colleague? And before that? Can you describe it? What was the impact of that? Was it good advice?
   - Is it easy to pass information to your colleagues? How is this done? Is it easy to pass new ideas to your colleagues?
   - How quickly do people adopt new practices? When somebody has an idea, how quickly does the team pick up on it?
   - (*Knowing something without needing to say it*)
4. *Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process*
   - Can you say if your relationship with your colleagues is formal or informal? Why?
   - Do people in your workplace engage in regular conversations? Are the subjects always related to the work?
   - Do conversations have pre-ambles?
5. *Very quick setup of a problem to be discussed*
   - When you have a problem and need help, what are the procedures to discuss a solution?

- Do you remember one example of that?

6. *Substantial overlap in participants' descriptions of who belongs*
    - How do you know when a person belongs to your workplace? Is there any another way to identify that?
    - And when the person doesn't belong. Can you identify that?
    - Who is a member of your group?
7. *Knowing what others know, what they can do, and how they can contribute to an enterprise*
    - In a case where you receive a task to do and need help, who do you ask for help? And if help is not available?
    - Who determines the responsibilities in a common enterprise? How?
8. *Mutually defining identities* (**Be alert!**)
    - What is the typical behaviour of a member of your workplace? Who defined this?
    - Can you describe some example of that?
9. *The ability to assess the appropriateness of actions and products*
    - Who is the person in charge of defining what is appropriate as part of your job (action or product)? And who decides in cases where this person is not present?
    - Have you been present in a typical situation where the above has happened?
    - Who is the expert/guru (un-official)
10. *Specific tools, representations, and other artefacts*
    - Can you list programs, manuals or guides common to all in your workplace?
    - From these which one(s) can be found elsewhere? In other organisations?
    - Un-official guides/lists/etc.
11. *Local lore, shared stories, inside jokes, knowing laughter*
    - Do you remember any funny story that happened in your workplace? And jokes that are related to your workplace?
    - Do you remember anything funny that one of your colleagues has done as a consequence of being naïve in your workplace? What?
12. *Jargon and shortcuts to communication as well as the ease of producing new ones*
    - Tell me about any jargon or acronym used in your work? Which one(s)?

- Do you remember any jargon or acronym that somebody in your workplace has used and that you could not understand?

13. *Certain styles recognized as displaying membership* (**Be alert!**)
    - Can you list some characteristics common to everybody in your workplace?
    - Are these characteristics present in any situation outside your workplace?

14. *A shared discourse reflecting a certain perspective on the world*
    - What is the common opinion in your workplace about the Higher Education Academy? The University?

15. *Common opinions within your workplace?* (**Listen for this!**)

A.2.4. Questions used during the interview (second phase)

A. *Identifying the CoPs' components*:

A.1. Practice

- What is your job?
- What do you actually do (on a day-to-day basis, on a typical day, what do you do)? Can you give me an example of ...? (What are your activities?)

A.2. Community

A.3. Identity

1. *Sustained mutual relationships – harmonious or conflictual*
   - Can you describe a situation where a colleague was helpful or where you were helpful?
   - Have you had any problem with a colleague? How did you resolve it?
   - (*Questions about long term collaborations/relationships – people that worked over a period/built up relations with*)
2. *Shared ways of engaging in doing things together*
   - Have you been in a situation that as a team member you have not been able to address? What did you do? How was the problem solved?
   - Can you describe a situation where you worked as a team? What were the goals? In which context did that happen? Did it include every one? Who was excluded/included? Why?
   - (*Lost track of time /extra 1/2 mile*)
3. *The rapid flow of information and propagation of innovation*
   - When was the last time you received helpful advice from a colleague? And before that? Can you describe it? What was the impact of that? Was it good advice?
   - Is it easy to pass information to your colleagues? How is this done? Is it easy to pass new ideas to your colleagues?
   - How quickly do people adopt new practices? When somebody has an idea, how quickly does the team pick up upon it?
   - (*Knowing something without needing to say it*)
4. *Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process*

- Can you say if your relationship with your colleagues is formal or informal? Why?
- Do people in your workplace engage in regular conversations? Are the subjects always related to the work?
- Do conversations have pre-ambles?

5. *Very quick setup of a problem to be discussed*
    - When you have a problem and need help, what are the procedures to discuss a solution?
    - Do you remember one example of that?
6. *Substantial overlap in participants' descriptions of who belongs*
    - How do you know when a person belongs to your workplace? Is there any another way to notice that?
    - And when the person doesn't belong. Can you notice that?
    - Who is a member of your group?
7. *Knowing what others know, what they can do, and how they can contribute to an enterprise*
    - In a case where you receive a task to do and need help, who do you ask for help? And if help is not available?
    - Who determines the responsibilities in a common enterprise? How?
8. *Mutually defining identities* (**Be alert!**)
    - What is the typical behaviour of a member of your workplace? Who defined this?
    - Can you describe some example of that?
9. *The ability to assess the appropriateness of actions and products*
    - Who is the person in charge of defining what is appropriate as part of your job (action or product)? And who decides in cases where this person is not present?
    - Have you been present in a typical situation where the above has happened?
    - Who is the expert/guru (un-official)
10. *Specific tools, representations, and other artefacts*
    - Can you list programs, manuals or guides common to all in your workplace?
    - From these which one(s) can be found elsewhere? In other organisations?
    - Un-official guides/lists/etc.

11. *Local lore, shared stories, inside jokes, knowing laughter*
    - Do you remember any funny story that happened in your workplace? And jokes that are related to your workplace?
    - Do you remember anything funny that one of your colleagues has done as a consequence of being naïve in your workplace? What?
12. *Jargon and shortcuts to communication as well as the ease of producing new ones*
    - Tell me about any jargon or acronym used in your work? Which one(s)?
    - Do you remember any jargon or acronym that somebody in your workplace has used and that you could not understand?
13. *Certain styles recognized as displaying membership* (**Be alert!**)
    - Can you list some characteristics common to everybody in your workplace?
    - Are these characteristics present in any situation outside your workplace?
14. *A shared discourse reflecting a certain perspective on the world*
    - What is the common opinion in your workplace about the Higher Education Academy? The University?
15. *Common opinions within your workplace?* (**Listen for this!**)

A.2.5. Questions used during the interview (final phase)

Questionnaire (participant 5)

A. *Identifying the CoPs' components*:

A.1. Practice

- What is your job?
- What do you actually do (on a day-to-day basis, on a typical day, what do you do)?
- Can you give me an example of . . . ?
- What are your activities?
- Are these activities the same all the time?

A.2. Community

- Do you work alone?
- How many people belong to your community?
  - Are all of them located here, at the same workplace as you?
  - Are they always the same group of people?
- Does your community change over time?
  - Change in the number of members?
  - How about Novices and Old-timers?

A.3. Identity

- How do you describe your community at your workplace?
- Which similarities do all the members share?
- Do those similarities change with time? How?
- Do you believe that people external to your community can recognise those similarities? Why?

B. *Structural component of a CoP*:

B.1. Mutual Engagement

B.2. Shared Repertoire

B.3. Joint Enterprise

1. Sustained mutual relationships – harmonious or conflictual
   - Can you describe a situation where a colleague was helpful or where you were helpful?

- Have you had any problem with a colleague? How did you resolve it?
- Questions about long term collaborations/relationships (people that you worked with over a period/built up relations with)

[. . .]

[The rest of the questionnaire is the same as the one used in the first phase]

B. Exchange of messages in CoPs

B.1. Spreadsheet of communications in CoP *xtrprg*

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
130	7	23	11	6	11	9	10	24	12	6	1	6	10	8	13	3	6	11	2	1	6	1	2	1	8	10	20	1	7	9
571	14	17	9		11	20	17	35	33	23	10	8	8	20	15	2	5	9	7	2	4	7	3	1	6	9	1	11	19	14
604		14	3	12	18	21	3	21	4	6	5	1	6	6	8	13		11	3	1	2		1		1	6	4		17	17
478	6	14	10	3	4	11		3		8	1	2		8	3	1		5	5	2		1				5	3	2	5	6
260	3	5	7		5	21	10	19	23	17	11	4	1	5	15	2	3		5	5						1			4	
104	1	4	1		3	2		2	1					1	1	1					2	1	1		4	5		1	2	3
426		1	1	2						1	21	6	2	9	22	4	3	1	1	5	7	2		1	1					4
447	1	6		5	4	5	1	1	2	2	3	4						4					2		4	1	1	1		3
139	5	7	1		2	1		6			1	1		1	3							1					2		1	2
662					3				7	6	8		1	1	1	3		3	2											
222		4	2		5	3	1	4	1	1	3	5	2	5	5	2		1												
477	1	2				1		1	3		1	1	2			2	3	1								1	1			
551		4	3		2		3	5	6	6	4	1		3	2	1	1		1						1				1	1
416				3	8	5	2			1	1		1					1							4	1		1	1	
619									29	2				2	1	10	4	3	14	9								18	12	
598		1	1	2				12	6	4	1							3	7		3									1
583				1		1																	1			2	11	1		
525		1	4				1				12			1	1			1		5		1								
500								3			7	1	2	1					2	1	1					1		4	4	
485								14	21	11	12	12	2				1	2				1		1			2	3		
450											1	1			3	3		1	1						1	15		1	1	
317	1									1			1				1	2	2		3							1		
65																														
405																									4	4			2	3
554									4																					
673										1																				
646									3	1						1	2													
479						7	3	2																						1
567									2					6		1		2		1	1				3					1
657						1	2		6	1																				
196																														
486																1										9			2	1
529																			8	2					4			8		
342								9	1	2	1	2																	3	
615	2		1											4	3								1					1		
442	1					1																						1		
232																														
190																											1			
555																														
251																	2	5			1				1					
27	4	2	1																											
463								1	3	3	1	1																		
481		1	2						1							1														
634																														
209																						5	3		2			4		
127																3	4	4	2	1										
226																														
353														1			2	3			1	3								
372																										1				1
167					5								1				1	1												1
219								1																						
253	2	1																												
404									1	1	2	1		1																
394			1		1					1			1																	
57	1	6	1																							3				
71					5	2	2																			1				
535																													2	6
562	3		2		2								2																	
407																			4	1	2	2								
47																														
4																														
18				1																			1							
565							1						2		1															
511					2																		1			1	1			
391					1																					1				
358					1																1									
667									1	1																		1		
356														1	1														1	
312									2																					
346																														
644					5																	2	1							
690																														1
201			2																								3		1	
649										1																				
368										2		3							1											
96																														
412				2									1			2														
158													1		1													3		
614																1			1											
254																														
182			1						1	2																				
113									1	1					2															
381														2	1			1												
466															2											1			1	
93																														
517					1										1	1														
77							1	1	1																					
231												1	1			1														
62					3	16	5	3	18	3	18	6	7	7	17	9	7	8	2	2	1		2		11	4	14	4	8	11

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
130	8	11	10	9	5	1	4	1	1	4	5	4	2	1		5	9	4	2	5	6		342	50	6.8
571	9	13	25	12	8		5	2	8	7	7	12	2		5	6	11	7	8	14	6	13	520	49	10.6
604	7	30	8	17	14				2	2	3	5	3	1					3	1			300	38	7.9
478	6	12	10	7	6			2	4	6	4	3	1	1	3	6		3	2				184	38	4.8
260		2			9						6	10	2							17	6	31	249	28	8.9
104	1	1	1													1	1		2		5	3	51	26	2.0
426	5	1	1		2																		103	23	4.5
447						1		1											4	3		1	60	23	2.6
139		2		4	1				1			2	2				5	1	1				53	23	2.3
662							2	1	2	1	4	3	1				5	7	2	2		1	66	22	3.0
222		3		4	1				1			1	1				2						57	22	2.6
477		3	2	2	2	1			1		1									1		1	34	22	1.5
551	1	2	2														1						51	21	2.4
416					1				1		1		1					2	2	8	2		47	20	2.4
619	4	21	12	18	18														1	4			182	18	10.1
598	2	12		1						1							1			2	1		61	18	3.4
583	6	7	4	2													2	3			7	13	61	14	4.4
525										1						4				11	12	1	56	14	4.0
500	1		2																	1			31	14	2.2
485																		1					83	13	6.4
450		4		1								1											34	13	2.6
317				2											2	1				4			21	12	1.8
65				3				2				1	2	1			3	2	5	22	8	3	52	11	4.7
405			5					1	2	1	2				3								27	10	2.7
554	4	3	5	1	1		1		1			1	1										22	10	2.2
673	1	2	2	3	2					4			1							3	2		21	10	2.1
646																	11	5			5	6	34	8	4.3
479											4				1						2	1	21	8	2.6
567																							17	8	2.1
657			1	1																1	1		14	8	1.8
196		11	8	5	1						1						1				2		29	7	4.1
486		3			3																	7	26	7	3.7
529										1									1			1	25	7	3.6
342		4																					22	7	3.1
615											2												14	7	2.0
442	4	1									5						1						14	7	2.0
232	1	2													1	3	1		1	1			10	7	1.4
190	1	1	13	9	1																		26	6	4.3
555									5	11	2	4			1						2		25	6	4.2
251							1				1												11	6	1.8
27										1	1							1					10	6	1.7
463	1																						10	6	1.7
481	1						1																7	6	1.2
634				6			1				6	2			1								16	5	3.2
209					1																		15	5	3.0
127																							14	5	2.8
226		2	8		1															1	1		13	5	2.6
353																							10	5	2.0
372		1															1			6			10	5	2.0
167																							9	5	1.8
219			1								1	1								4			8	5	1.6
253					1	1															1		6	5	1.2
404																							6	5	1.2
394		1																					5	5	1.0
57																							11	4	2.8
71																							10	4	2.5
535		1	1																				10	4	2.5
562																							9	4	2.3
407																							9	4	2.3
47													2					1		2		4	9	4	2.3
4																		1		2	3	3	9	4	2.3
18															2							2	6	4	1.5
565											2												6	4	1.5
511																							5	4	1.3
391									1												1		4	4	1.0
358																				1	1		4	4	1.0
667	1																						4	4	1.0
356			1																				4	4	1.0
312																			2	9			13	3	4.3
346																			4	2	5		11	3	3.7
644																							8	3	2.7
690																				3	4		8	3	2.7
201																							6	3	2.0
649																			3	2			6	3	2.0
368																							6	3	2.0
96		4			1																	1	6	3	2.0
412																							5	3	1.7
158																							5	3	1.7
614																	3						5	3	1.7
254								1												1	3		5	3	1.7
182																							4	3	1.3
113																							4	3	1.3
381																							4	3	1.3
466																							4	3	1.3
93										2						1	1						4	3	1.3
517																							3	3	1.0
77																							3	3	1.0
231																							3	3	1.0
62	4	4	12																				206	27	7.6

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
522						1	1	25	19	15	8	3																		
68		32	15	1	3	1																								
633									15	1	1	3																		
45																														
653																														
53																														
97																											9	5		
248														5	7															
301						9								2																
502																														
334															7	2														
225																											7	2		
292				2																										
178							7	1																						
491									2																					
610																														
44			6	1																										
321					4	3																								
85																												1		6
326																														
528																														
340																														
558					4	2																								
504									5																					
415																														
128																														
162	3	2																												
198		3	2																											
64						4						1																		
449																			4	1										
616																						1								
352																													2	3
218																														
58																														
489			1		3																									
187				2		2																								
142							1						3																	
455																2	2													
679																		3	1											
681																										2	2			
5																														
327																														
403		2				1																								
437			2																											
617			2																											
348			2		1																									
29				1	2																									
11						2							1																	
157											1	2																		
411																1														
375																									2	1				
119																											2		1	
628																													1	2
84																														
35																														
643	1																													
475		1										1																		
70					1	1																								
296					1									1																
684					1	1																								
553						1			1																					
510												1	1																	
591													1												1					
266															1	1														
460																1														
632																1		1												
311																1	1													
137																	1													
376																			1	1										
337																			1	1										
124																					1	1								
621																							1		1					
574																									1			1		
240																											1			
131																														
257																														
361																														
325																														
229																														
338																														
298									9																					
126																														8
61																														
213																														
618										5																				
32															5															
378															5															
288																													5	
169																														
132																														
584		4																												
310					4																									
389															4															
33															4															
20			3																											

wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
																						72	7	10.3
																						52	5	10.4
																						20	4	5.0
						4			5	6	3											18	4	4.5
	5	8		2																		15	3	5.0
				1				5	6													12	3	4.0
																						14	2	7.0
																						12	2	6.0
																						11	2	5.5
																1	9					10	2	5.0
																						9	2	4.5
																						9	2	4.5
																				6		8	2	4.0
																						8	2	4.0
												6										8	2	4.0
																				1	7	8	2	4.0
																						7	2	3.5
																						7	2	3.5
																						7	2	3.5
			4	3																		7	2	3.5
										1	6											7	2	3.5
																			6	1		7	2	3.5
																						6	2	3.0
			1																			6	2	3.0
																			3	3		6	2	3.0
																				2	4	6	2	3.0
																						5	2	2.5
																						5	2	2.5
																						5	2	2.5
																						5	2	2.5
																4						5	2	2.5
																						5	2	2.5
		1	4																			5	2	2.5
				4			1															5	2	2.5
																						4	2	2.0
																						4	2	2.0
																						4	2	2.0
																						4	2	2.0
																						4	2	2.0
																						4	2	2.0
								3											1			4	2	2.0
															1					3		4	2	2.0
																						3	2	1.5
														1								3	2	1.5
			1																			3	2	1.5
																						3	2	1.5
																						3	2	1.5
																						3	2	1.5
																						3	2	1.5
				2																		3	2	1.5
																						3	2	1.5
																						3	2	1.5
																						3	2	1.5
															1		2					3	2	1.5
															2	1						3	2	1.5
											1											2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																1						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																			1			2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
																						2	2	1.0
		1																				2	2	1.0
		1																			1	2	2	1.0
			1											1								2	2	1.0
								1	1													2	2	1.0
											1				1							2	2	1.0
											1						1					2	2	1.0
												1		1								2	2	1.0
																						9	1	9.0
																						8	1	8.0
				6																		6	1	6.0
																					6	6	1	6.0
																						5	1	5.0
																						5	1	5.0
																						5	1	5.0
																						5	1	5.0
				5																		5	1	5.0
																			5			5	1	5.0
																						4	1	4.0
																						4	1	4.0
																						4	1	4.0
																						4	1	4.0
																						3	1	3.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
658			3																											
544					3																									
392								3																						
546															3															
406																							3							
433																											3			
322																													3	
242																														
52																														
432	2																													
329	2																													
264		2																												
647			2																											
159			2																											
323					2																									
15					2																									
515							2																							
418									2																					
473									2																					
410									2																					
393										2																				
287										2																				
336										2																				
172												2																		
208															2															
210															2															
341																		2												
458																		2												
88																					2									
683																										2				
238																														
514																														
200																														
149																														
651																														
640																														
397																														
7																														
669																														
161	1																													
345	1																													
177	1																													
185	1																													
457	1																													
160	1																													
6		1																												
585		1																												
413		1																												
263		1																												
652		1																												
259		1																												
527			1																											
452			1																											
192			1																											
31			1																											
625			1																											
469			1																											
189			1																											
448			1																											
363			1																											
570				1																										
37				1																										
556				1																										
59				1																										
233				1																										
156				1																										
602				1																										
258				1																										
98				1																										
237					1																									
465					1																									
67					1																									
25					1																									
543					1																									
300						1																								
174							1																							
22							1																							
332							1																							
270								1																						
390								1																						
659								1																						
92								1																						
507									1																					
319									1																					
620									1																					
688									1																					
24									1																					
462										1																				
86										1																				
534										1																				
216										1																				
168										1																				
464										1																				
294											1																			
666											1																			

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
658																							3	1	3.0
544																							3	1	3.0
392																							3	1	3.0
546																							3	1	3.0
406																							3	1	3.0
433																							3	1	3.0
322																							3	1	3.0
242																3							3	1	3.0
52																				3			3	1	3.0
432																							2	1	2.0
329																							2	1	2.0
264																							2	1	2.0
647																							2	1	2.0
159																							2	1	2.0
323																							2	1	2.0
15																							2	1	2.0
515																							2	1	2.0
418																							2	1	2.0
473																							2	1	2.0
410																							2	1	2.0
393																							2	1	2.0
287																							2	1	2.0
336																							2	1	2.0
172																							2	1	2.0
208																							2	1	2.0
210																							2	1	2.0
341																							2	1	2.0
458																							2	1	2.0
88																							2	1	2.0
683																							2	1	2.0
238		2																					2	1	2.0
514						2																	2	1	2.0
200												2											2	1	2.0
149													2										2	1	2.0
651															2								2	1	2.0
640																		2					2	1	2.0
397																			2				2	1	2.0
7																				2			2	1	2.0
669																				2			2	1	2.0
161																							1	1	1.0
345																							1	1	1.0
177																							1	1	1.0
185																							1	1	1.0
457																							1	1	1.0
160																							1	1	1.0
6																							1	1	1.0
585																							1	1	1.0
413																							1	1	1.0
263																							1	1	1.0
652																							1	1	1.0
259																							1	1	1.0
527																							1	1	1.0
452																							1	1	1.0
192																							1	1	1.0
31																							1	1	1.0
625																							1	1	1.0
469																							1	1	1.0
189																							1	1	1.0
448																							1	1	1.0
363																							1	1	1.0
570																							1	1	1.0
37																							1	1	1.0
556																							1	1	1.0
59																							1	1	1.0
233																							1	1	1.0
156																							1	1	1.0
602																							1	1	1.0
258																							1	1	1.0
98																							1	1	1.0
237																							1	1	1.0
465																							1	1	1.0
67																							1	1	1.0
25																							1	1	1.0
543																							1	1	1.0
300																							1	1	1.0
174																							1	1	1.0
22																							1	1	1.0
332																							1	1	1.0
270																							1	1	1.0
390																							1	1	1.0
659																							1	1	1.0
92																							1	1	1.0
507																							1	1	1.0
319																							1	1	1.0
620																							1	1	1.0
688																							1	1	1.0
24																							1	1	1.0
462																							1	1	1.0
86																							1	1	1.0
534																							1	1	1.0
216																							1	1	1.0
168																							1	1	1.0
464																							1	1	1.0
294																							1	1	1.0
666																							1	1	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
318												1																		
195												1																		
351												1																		
211												1																		
269												1																		
10												1																		
575													1																	
608													1																	
508													1																	
194													1																	
693													1																	
576														1																
366														1																
605														1																
115															1															
116															1															
246															1															
581															1															
654															1															
671															1															
678															1															
520															1															
150															1															
609																1														
624																1														
220																	1													
540																		1												
151																				1										
506																					1									
69																					1									
639																					1									
408																						1								
661																							1							
227																								1						
309																									1					
315																										1				
454																										1				
459																											1			
215																											1			
256																												1		
308																												1		
217																												1		
498																												1		
8																												1		
655																													1	
441																													1	
42																														1
136																														
214																														
335																														
80																														
682																														
286																														
249																														
423																														
374																														
592																														
400																														
133																														
691																														
472																														
606																														
355																														
384																														
663																														
117																														
121																														
17																														
542																														
420																														
76																														
613																														
536																														
349																														
550																														
221																														
343																														
439																														
438																														
38																														
569																														
483																														
111																														
14																														
146																														
493																														
451																														
141																														
262																														
623																														
611																														
289																														
83																														
635																														
436																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
318																							1	1	1.0
195																							1	1	1.0
351																							1	1	1.0
211																							1	1	1.0
269																							1	1	1.0
10																							1	1	1.0
575																							1	1	1.0
608																							1	1	1.0
508																							1	1	1.0
194																							1	1	1.0
693																							1	1	1.0
576																							1	1	1.0
366																							1	1	1.0
605																							1	1	1.0
115																							1	1	1.0
116																							1	1	1.0
246																							1	1	1.0
581																							1	1	1.0
654																							1	1	1.0
671																							1	1	1.0
678																							1	1	1.0
520																							1	1	1.0
150																							1	1	1.0
609																							1	1	1.0
624																							1	1	1.0
220																							1	1	1.0
540																							1	1	1.0
151																							1	1	1.0
506																							1	1	1.0
69																							1	1	1.0
639																							1	1	1.0
408																							1	1	1.0
661																							1	1	1.0
227																							1	1	1.0
309																							1	1	1.0
315																							1	1	1.0
454																							1	1	1.0
459																							1	1	1.0
215																							1	1	1.0
256																							1	1	1.0
308																							1	1	1.0
217																							1	1	1.0
498																							1	1	1.0
8																							1	1	1.0
655																							1	1	1.0
441																							1	1	1.0
42																							1	1	1.0
136	1																						1	1	1.0
214	1																						1	1	1.0
335	1																						1	1	1.0
80	1																						1	1	1.0
682		1																					1	1	1.0
286		1																					1	1	1.0
249		1																					1	1	1.0
423		1																					1	1	1.0
374			1																				1	1	1.0
592			1																				1	1	1.0
400			1																				1	1	1.0
133			1																				1	1	1.0
691				1																			1	1	1.0
472				1																			1	1	1.0
606				1																			1	1	1.0
355				1																			1	1	1.0
384				1																			1	1	1.0
663				1																			1	1	1.0
117				1																			1	1	1.0
121					1																		1	1	1.0
17					1																		1	1	1.0
542					1																		1	1	1.0
420					1																		1	1	1.0
76					1																		1	1	1.0
613					1																		1	1	1.0
536							1																1	1	1.0
349							1																1	1	1.0
550								1															1	1	1.0
221										1													1	1	1.0
343										1													1	1	1.0
439											1												1	1	1.0
438											1												1	1	1.0
38											1												1	1	1.0
569												1											1	1	1.0
483												1											1	1	1.0
111												1											1	1	1.0
14													1										1	1	1.0
146													1										1	1	1.0
493													1										1	1	1.0
451													1										1	1	1.0
141														1									1	1	1.0
262														1									1	1	1.0
623															1								1	1	1.0
611															1								1	1	1.0
289															1								1	1	1.0
83															1								1	1	1.0
635															1								1	1	1.0
436																1							1	1	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
87																														
590																														
422																														
398																														
299																														
434																														
91																														
446																														
601																														
645																														
228																														
328																														
331																														
680																														
670																														
577																														
290																														
55																														
595																														
476																														
34																														
509																														
537																														
347																														
330																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
87																1							1	1	1.0
590																	1						1	1	1.0
422																	1						1	1	1.0
398																	1						1	1	1.0
299																	1						1	1	1.0
434																		1					1	1	1.0
91																		1					1	1	1.0
446																			1				1	1	1.0
601																			1				1	1	1.0
645																			1				1	1	1.0
228																			1				1	1	1.0
328																				1			1	1	1.0
331																				1			1	1	1.0
680																				1			1	1	1.0
670																				1			1	1	1.0
577																				1			1	1	1.0
290																					1		1	1	1.0
55																						1	1	1	1.0
595																						1	1	1	1.0
476																						1	1	1	1.0
34																						1	1	1	1.0
509																						1	1	1	1.0
537																						1	1	1	1.0
347																						1	1	1	1.0
330																						1	1	1	1.0

B.2. Spreadsheet of communications in CoP *taxes*

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
190																											60	30	31	60
1183	1	1	2	15	8	9	5	22	8	3	10	3	14	7	10	9	3	7	41	13	23	15	27	6	13	14	30	13	11	3
242	10	14	1	17	4		8	22		6											3									
1883	4	5		1	7		1			5	10	9	11	2	1	1	2	4	7	6	6	10	12	1	4	18	28	17		
2118								3	11	4	4	6	5	3	2	7	8	9	11	2	8	6	20	5	4	14	20	8	16	11
1705	3	1		18	7	6	2	9	7	5	10	5	8	9	8	12	12	4	19	9	30	17	11	7	8	6	23	12	7	10
174	3	5		12	4	2	1	7	2	3	9	11	8	11	8	9	11	4	27	11	6	8	14	7	7	6	16	14	7	18
592																		10	19	12	19	10	7	12	17	8	5	11		7
14	1	1	2	1				4			4		15	2		3	1	3	2	1	2	6	6	3	1	11	23	9	17	11
1519	3	1		13	3	1		10	5	1	1	5	11	2	3	6	3	3	4	5	6	13	19	6	1	4	41	4	6	12
731																														7
1301	2	4	1	6	1	4		12	6		6	1	8	5	5	2	5	6	2	5		6	6	5	7	7	20	7	2	2
2238	3	1	2	11	2	3	1	4	2			6	5	8	1		2	4	4	5	1	7	13	2	8	7	7	4		
1525			1	1																								2	14	11
1116		1	2		3	2	2	5	6	3	7	5	11	2	6	11	2	10	3	4	2	5	2	1	1	2	18	11	4	10
372				3	2					1	3	1	2			1	1		2		4	3	2			2	4	3	3	6
2344		6	1	14	2			4	1	2	2	6	12	8	3	5	3	6	17	6	6	9	7	6	3	1	2	3	9	2
257	4	2	2	16	12		2	6	3	2	3	5	11	8	7	8	4	6	1			4	3		3	1	1	1	1	11
1212	3	5	2																				4		3	1	10	7	6	2
1985	3	3		4				8	6	1	3	6	3	1	2	2	3	2	6	3	5	9	4	1	1	4	9	5	3	14
436						2		4		1		2			1			4	1			3	9	3		2	13	9	3	
2215	3	4		8	1			8	3		5	7	3	5	6	4	7	1	3	1	1	2	6	6	4	3	12			
1290								2	6			1	7	3		1														
478	3	2		4		2		1				5			2	3		1	2	1	2	1	1	1		7	7	5	5	4
65		1	1	2	4			11	4	2	7	5		1	2	2	2				2	1	3				7	6	8	8
2114								1				4				2			6			5	4							
2007	2	1	2	1			2	1	2	4	4	6	2	5	4		3	1	3		4	4	3			6	4	4	2	2
1777				2		1	1	9	1	3	2	6	1			1	1		1						2	1	1	1	8	4
945	1			3	4			4			2	1	3	2	1	7	2	8	3	3	7	3	3		1		3	2	1	1
1881																												2	1	
519		3	1					5	5	1	3				2				1		4	5	6	1	4	1	1	4		
1113		2		1	2	1	3	5	2		1		1	1		1	3	1			1		2	1	7	3	13	2	2	6
175					2				1	1	1	1					1					1	2		1		2	1	4	9
247				2	1		1	4	2	2	5	1	5		1	1	4	3	2	1	4	4								
1947	5	1	2	3		1		3			2	1	4	2		2	4	6	7	2		3			2	1	4	1	2	1
210		1	1	1	2	1			1	1		4			2	2	2	1	1	2	3	1	2		1	3	4	4	7	1
2295															2					2		2	3		1	5	6	2	3	
480											4	1		1	2				1	1		1		1		3	4	6	2	3
929																														
784			1	1																		2		2	2		8	2		2
2006						1				1				1				1	1	1			1							8
2343												1	7				1	2			1									
1014																											5	4	2	1
1884				4	1	2		1																						
2218						2			3	2	3	3		1																
1142				1									1		1	2		1		1	4						1	1		1
1625			1		2			1	1	1	1					2	2	1	1	3				3	1	3	7	5	3	3
1373																					2			2		1	5	1		
1227												2	1	1			1					2	4	1		4	3	3		
393																		1			1	1		1	1	1	11	1		2
647	2	2		4	1	1		3		1	3	4	1	4	2		1	2	2		1		1			1	3			2
1079															1	2		1			1		2			1	1	1	3	
844																						2	2			1	2	1		
682											1	1	1		2	4	2		3											
1106			2	4	3	1		1	1																					
479		1	1	3				3		2																				
1470			1	1				3														4	1							
1405																										2	4	1	1	
1669				1	4			1			2	1	1				2	1	2	1	3					1	3	1	2	
1672			1	1	1						1		2	1				3	4	1		1	1				3		1	3
319							1	2	1		1	2	4		3		1		2				1	2		1	1	1	1	
1543																														
941				1					2													1		2	1	1		2		
220									1										1				3							2
1986																														
278			1	1	1			1			1					2	1	4		3	2		4		1	2	4	2		2
1241				2			1	3		1			1	1	3	1	1			1		3	1	1		1		4		
2171																														
2337			1	1	1	1		3	1		1			1	1	2		1						2	1		4	1		2
637	1	4	2	3	2	1		2					2	1				1	4	1	1	2	2			2	1	1	1	1
476										1		2		1			1	3	2	1	2									
807																														1
1583																														
1939								1						2		1			2	1			3							
1689								2						1									1				3	1		2
1029	2	1		1		1		1	1	2	2	1	1	2		1		2	1	2		2	2	1	1		2	1	1	
1604				1			1		1			1				2					4	1	5		1	1			1	1
882		1		1				2	2		1	1	1	2	3		2	1				1					2	1	1	
2003			1									1	1									1				1		1		
2200			1						2		1		1								1									
267																						2					2			
1209																														
962	2			2				1								1														
53																			1				1	1	3					
2320				1	1			1						2		1				1			1		1					1
385		2							1			1																1		
1075			2	1	1															1			4				1	1	1	1
121				3																		1	1			1	2			1
1145								1		1										1								1		1
914					1						1				1				1	1	1		2	1		1		2	2	1
1976			1	1		1	1				1							1	1	1			1			1	4			
2165	1	1			2	2			1			2				1	2													
987		1						2																						

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Active weeks	Rate msg/wk
190	37	12	7	5	1	42	8	37	25	23	36	6	28	22	15	22	25	16	13	2	19	8	590	26	22.7
1183	11	7	4	3		8	4	2					2	9	7	16	14	19	15	27	15	6	515	47	11.0
242			28	18		3	4				4												142	14	10.1
1883		8	37	49	8	19	9	17	17	16	16	1			3	8	3	10	5	11	4	7	420	43	9.8
2118	19	8	18	20	5	16	17	20	2	7	24	1	4	5	7	5	8	6		11	15	3	408	44	9.3
1705	8	7	11	11	3	9	7	5	8	7	7		9	2	5	17	7	10	6	18	7		449	49	9.2
174	15	12	9	10	6	11	6	11	13	18	11		8	6	1	12	7	20	7	13	6	2	455	50	9.1
592	12	6	4	22	1				3		4	4	2	22	2	6	5	9	9	15	6	3	272	30	9.1
14	28	20	32	24	1	20	3	25	22	15	11	3	2	7	2	3	12	2	5	6	6	2	380	45	8.4
1519	12	11	24	13	6	14	3	7	3		8	1	6		5	12	6	8	7	3	3		344	47	7.3
731	14	3	21	14	3	12	6	6	6	3				4		2	3				3	1	108	16	6.8
1301	10	6	6	9	7	16	4	7	6	5	12	2	6	6	8	4	7	2	4	2	2	3	277	49	5.7
2238	11	6	7	11	9	11	2	23	2	2	3		5					3					208	38	5.5
1525	6	3	5	8		2		4	2		2	4	9	4			11	6	6		6	1	108	21	5.1
1116	5	2	7	6	15	6	3	12		2	7	2	3	7	1	5	1	3		9	3	2	242	48	5.0
372	11	7	8	18	10	12	6	10	9	4	2												140	28	5.0
2344	8	5			2						4		1		3	1		3	1	2		7	183	38	4.8
257	14	4	1	4	2	6	1	12	8	4			1	2	1		2	4	6	8	2		209	44	4.8
1212	10	2	5	7	4	5	4	10	5	1	3		4	3	2	6	1		5	10	3		133	29	4.6
1985	9	4	6	13	5	5	4	7	3	4	4	1	4	1	2	4	1	1		2			191	45	4.2
436	15		2	2	1								4					6		1		1	89	22	4.0
2215			1	1		1		1			2		3	6	1	8		1	8	2	9	1	148	37	4.0
1290																		3	13	5	1	2	44	11	4.0
478	14	4	17	10		8	5	10	3		1	1	2	1	2	2	2	2	1	8	3		155	39	4.0
65	5	6	2	2		11		3		5	2				2		1	1	3	2	2		126	34	3.7
2114																							22	6	3.7
2007	2	11	3		3	7		10	2		6	1	2	3	2	7	3	4	3	6	3	2	152	43	3.5
1777	7	4	2		3	6	2	3	6														79	26	3.0
945	5	8	10	2	2	2	1	3	1		1		4	1				1	1	4	3		114	38	3.0
1881	4						5																12	4	3.0
519																							47	16	2.9
1113	5	3		4		3	1	2		1	1	2	7	2	1	6	2	1	4				106	38	2.8
175	2	2	13	6	2	3	2	1	3	4				1		3	1	3					73	27	2.7
247																							43	17	2.5
1947		1	2	3			1	2	1	1			2		4	2	3	2	2	3	4	3	95	38	2.5
210	3	5	4			1	3	3	6	2	6	1						4		2	2		90	36	2.5
2295		4	3	6	1	1		2	3		1		1			1			1				50	20	2.5
480	2	3	2		4						4		1	3	2	5		2	3			1	62	25	2.5
929		3	2	4	3	5	2			1	2		2			1				2	2		29	12	2.4
784	4	2	3	3		3	1	1	2	4	3		3			2	1				1		53	22	2.4
2006	8	1	3	2		2																	31	13	2.4
2343			4	2								1											19	8	2.4
1014	4	1	2	4	1	1		2	3		3	2		2				2				1	40	17	2.4
1884											1		3	7		1					1		21	9	2.3
2218																							14	6	2.3
1142		2	4	1			1	3	8	2	1		2			7	4	1	4	1			55	24	2.3
1625		1	4		3	3	2	3	2	1	1		3			1							65	29	2.2
1373			2			2		3	1	6	1	2	3				1	1					33	15	2.2
1227	9	3	1	3	1		1	1		1	2		1	1									46	21	2.2
393	2		4		1	1		5		2	2		2	1						1	1		42	20	2.1
647	1		3	4					1		4	1	3		1	1					2	2	64	31	2.1
1079	1		3	3	1	2		6	2		3			2	1	2				2	3		44	22	2.0
844		2		1			1	2	4	2	4												24	12	2.0
682																							14	7	2.0
1106																							12	6	2.0
479																							10	5	2.0
1470																							10	5	2.0
1405																							8	4	2.0
1669	1	3	5	3	1	3		1		2				2		1	2			1			51	27	1.9
1672	1		4	4	2						1			3		1	1	4	2	1	1		49	26	1.9
319	1		6	3	3		1	1		1	1		2				2		1	2	3		51	28	1.8
1543	1	2	4			1					1												9	5	1.8
941			2	1		1		4	3	3	2	1						1	1	1	4		34	19	1.8
220																2	2	1					12	7	1.7
1986	1	3		2				1	2	1	2												12	7	1.7
278		1	2					1		1	1	1	1	1	2	1							44	26	1.7
1241																							25	15	1.7
2171								1	1	1	2					3	2						10	6	1.7
2337	3		2	1	1	2	1	4				1	1	1		5		1		1			48	29	1.7
637	1											1		1					1				39	24	1.6
476																							13	8	1.6
807	3		1	2													1						8	5	1.6
1583																	2	1	2	1	2		8	5	1.6
1939						1																	11	7	1.6
1689	1																						11	7	1.6
1029	2		1	2				2	4														42	27	1.6
1604				1					1		1		1							2			26	17	1.5
882	3	2	2	1				1		1							1		2	1	2		38	25	1.5
2003	1	3	4	2			1		1	2	1												21	14	1.5
2200		2				3					1												12	8	1.5
267	1	1		2						1													9	6	1.5
1209						1					1		2					1	2	2			9	6	1.5
962																							6	4	1.5
53																							6	4	1.5
2320		2	3	1		2	2	1		3	2	2	1			1					1		31	21	1.5
385	1	2	2	1		2				2			1										16	11	1.5
1075	1	2	2	2		1		1	1	2	1									1	2		29	20	1.5
121		1	1	3		1								1						1			17	12	1.4
1145							1	3	1		2					3		1				1	17	12	1.4
914	2	3	1	1		1	1		1	2	2			2									31	22	1.4
1976	1	1	1		1	1		4		3	2			2			1	1	1	1		1	35	25	1.4
2165																1	1						14	10	1.4
987															2		1					1	7	5	1.4

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
95																														
1419											1			1									2			1		2		
1173																							1			1	2			
430				1						1	1									4										
1640					1							1		1							1				2	1	3			
1844					2				1				1							2										
801																							1	2						
1379																									1	1				
113		3					2		1								1	1										1		1
539													1				1			1								1		
531													1		1	1									1			2		2
1342												1	1	1										1		1			1	
599				1									1							2		1	1	1	1			2	1	1
501				2																									1	
537														1		1	2		1											
306																		1	2	1										
870																														
1327																														
1611			1	2					1		1				1	1	2							1				1		
645																									1	1	1		1	2
392	1	1						2							1	1														
1008	1							2					1			1				1										
803														1		1														
2252														1			1		2						1					
408																										1			1	
977				1			1		1		1	1				1	1													
492								1										1		2	2				1					
320		1									1	2																	1	
349		1																	1		1						1			
1606																		1					1	1		1	2			1
1422		1		1										1	1															
794								2			1	1	1		1	1	1				1		1	1	1					
2035																1	1			1	1		1	1			1			
376																	1												1	
1674																					1	1	1	1	1					
1137							1																							
1870																								1				1		
1372		1					1			1				1						1										
151																												1		
733		1		1																										
158			1	1																						1	1			
380				1								1																		
2300												1																		1
198																														

390																														29
1182	14	18	4	20	13		8	32	15	8	23	15	17	16	15	5	7	12												
559																											9		5	1
1648																														1
562														2	1		3	1	13	7	5	3	7	6	8					
1767																														
2113																										3	1	1		4
1311																														
369																														
2296																														
90																										4	7	2	3	2
2240																														7
2243																														3
228																														
2040																												1	10	1
2046																													2	
1726										2																				
2068																														
326																														
2070																														
137																												5	5	2
1570																														2
1768				1																1							2	2	2	3
633																														
955	1																													
2213	1																													
532																														
330																									7					
590					5																									
1284																											5			
433																														
248										4																				
1309																							4							
2212																											4			
1042																														4
2214																														
219																														
564													6	1																
1969																												7		2
626														3	3															
2053																											1	5		
606																											5	1		

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Active weeks	Rate msg/wk
95	1									1	1						1			3			7	5	1.4
1419			1							1										2			11	8	1.4
1173	3		1	1	1											1							11	8	1.4
430	1		1	1	1	1			2	1	2	1		1									19	14	1.4
1640		1		1	1	1	1				1	3	1	1	1		3	1	1				27	20	1.4
1844				1		1																	8	6	1.3
801								2			1	1										1	8	6	1.3
1379		1	3								1					1							8	6	1.3
113	1					1							1										13	10	1.3
539						1	2	2															9	7	1.3
531												1											9	7	1.3
1342	2		1	1	1	2								3		1			1	1			19	15	1.3
599	1	1				1	1			1	1						1			4	1		24	19	1.3
501															1	1							5	4	1.3
537																							5	4	1.3
306																			1				5	4	1.3
870				1			1	2												1			5	4	1.3
1327								2		1								1		1			5	4	1.3
1611				1																			12	10	1.2
645		2	1			1	1				1												12	10	1.2
392																							6	5	1.2
1008																							6	5	1.2
803						2						1					1						6	5	1.2
2252																					1		6	5	1.2
408	1			2		1																	6	5	1.2
977	1		3		1		1																13	11	1.2
492	1		1		1		1	1		1													13	11	1.2
320									1				1										7	6	1.2
349													1							2			7	6	1.2
1606	1																						8	7	1.1
1422	2		1	1		1			1														10	9	1.1
794																							12	11	1.1
2035		1				1			1														10	10	1.0
376	1							1	1		1	1											7	7	1.0
1674	1					1																	7	7	1.0
1137				1					1							1			1	1			6	6	1.0
1870			1			1		1				1											6	6	1.0
1372																							5	5	1.0
151							1			1			1	1									5	5	1.0
733					1									1									4	4	1.0
158																							4	4	1.0
380						1		1															4	4	1.0
2300	1													1									4	4	1.0
198				1									1			1	1						4	4	1.0
390	8	7	11	19																			74	5	14.8
1182																							242	17	14.2
559	4																						19	4	4.8
1648	4	7	5	31	12	25	2	2	18	2													109	11	9.9
562																							56	11	5.1
1767			1			2	5	6															14	4	3.5
2113	13	12		3	10	1	3	6		3													60	12	5.0
1311											3	3	6	7		3	6						28	6	4.7
369													1	5	3	7	1		1	6			24	7	3.4
2296				1	1			6	7	3	5	1	1										25	8	3.1
90	5		1	3						1													28	9	3.1
2240	2	2	2	2	1	2	2	3	1	2	11												37	12	3.1
2243	2		2	4	2	1	5	3			4												26	9	2.9
228			1	3	1	2		8	3		2												20	7	2.9
2040	1	1																					14	5	2.8
2046	1	1		8	2				2														16	6	2.7
1726								6		5	1	1	4	1					1				21	8	2.6
2068	4	4	4	5	1	1	2	3	1		1												26	10	2.6
326		1	1	6	3				2														13	5	2.6
2070																	2	3	1	4	3		13	5	2.6
137				1				1		1													15	6	2.5
1570	2							1			5												10	4	2.5
1768	10	1	3																				25	9	2.8
633								1	4	5	1	2	4	4	1	5	1	2	5	2		1	38	14	2.7
955																2			4	3	1		11	5	2.2
2213					2									1							4		8	4	2.0
532				8																			8	1	8.0
330																							7	1	7.0
590																							5	1	5.0
1284																							5	1	5.0
433	11		1	1																			13	3	4.3
248																							4	1	4.0
1309																							4	1	4.0
2212																							4	1	4.0
1042																							4	1	4.0
2214			4																				4	1	4.0
219									4														4	1	4.0
564																							7	2	3.5
1969						1																	10	3	3.3
626																							6	2	3.0
2053																							6	2	3.0
606																							6	2	3.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
953																														
226																														
895													3																	
192																					3									
1063																											3			
1502																												3		
1936																														3
2061																														
1328																														
38																														
2073																														
2086																														
449																														
34																														
72																														
261																														
2060		5		1				2																						
1143																										5			2	1
629														4	1															
482																											3	2		
485																														4
1879																														
769																									1					
1954																														
2236																														
1591								1														3								
910																														
1554													1	3																
2095																3						1								
818																1	3													
1811																			2								2			
1887																											2			2
82	2																													
1450		2																												
307		2																												
1873				2																										
755								2																						
1341									2																					
415													2																	
625													2																	
968													2																	
560														2																
270														2																
1805																2														
1882																						2								
1635																							2							
374																							2							
1750																								2						
1453																											2			
26																												2		
1178																												2		
348																												2		
1893																													2	
1477																													2	
409																														
869																														
1560																														
332																														
891																														
2144																														
1090																														
1668																														
1293																														
585																														
709																														
1348																														
873																														
446																														
896																														
518																														
1944		3					1						1																	
701		1														1					3									
2103								1				3																		
2032																					1	3			1					
1733																														
1032																														
1306	2	1																												
1190				2						1																				
1152				2							1																			
529				2								1																		
1270					1			2																						
2260									2																					1
419												1	2																	
654												1															2			
574																	1		2											
2234																			2										1	
2161																				2	1									
2164																					2	1								
85																								1						
1809																									1		2			
1978																										2		1		
438																										2	1			
792																										1				
1281																											2	1		

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Active weeks	Rate msg/wk
953		2	4																				6	2	3.0
226			2	4																			6	2	3.0
895																							3	1	3.0
192																							3	1	3.0
1063																							3	1	3.0
1502																							3	1	3.0
1936																							3	1	3.0
2061	3																						3	1	3.0
1328				3																			3	1	3.0
38								3															3	1	3.0
2073										3													3	1	3.0
2086																3							3	1	3.0
449																	3						3	1	3.0
34																		3					3	1	3.0
72																		3					3	1	3.0
261																			3				3	1	3.0
2060																							8	3	2.7
1143																							8	3	2.7
629																							5	2	2.5
482																							5	2	2.5
485	1																						5	2	2.5
1879				3	2																		5	2	2.5
769											3			3									7	3	2.3
1954	1	5						1															7	3	2.3
2236		1		4	2																		7	3	2.3
1591																	2						6	3	2.0
910	2		3	1																			6	3	2.0
1554																							4	2	2.0
2095																							4	2	2.0
818																							4	2	2.0
1811																							4	2	2.0
1887																							4	2	2.0
82																							2	1	2.0
1450																							2	1	2.0
307																							2	1	2.0
1873																							2	1	2.0
755																							2	1	2.0
1341																							2	1	2.0
415																							2	1	2.0
625																							2	1	2.0
968																							2	1	2.0
560																							2	1	2.0
270																							2	1	2.0
1805																							2	1	2.0
1882																							2	1	2.0
1635																							2	1	2.0
374																							2	1	2.0
1750																							2	1	2.0
1453																							2	1	2.0
26																							2	1	2.0
1178																							2	1	2.0
348																							2	1	2.0
1893																							2	1	2.0
1477																							2	1	2.0
409		2																					2	1	2.0
869		2																					2	1	2.0
1560				2																			2	1	2.0
332				2																			2	1	2.0
891				2																			2	1	2.0
2144				2																			2	1	2.0
1090				2																			2	1	2.0
1668					2																		2	1	2.0
1293							2																2	1	2.0
585								2															2	1	2.0
709											2												2	1	2.0
1348													2										2	1	2.0
873													2										2	1	2.0
446															2								2	1	2.0
896																2							2	1	2.0
518																			2				2	1	2.0
1944																							5	3	1.7
701																							5	3	1.7
2103														1									5	3	1.7
2032																							5	3	1.7
1733									1		3				1								5	3	1.7
1032										2	1					2							5	3	1.7
1306																							3	2	1.5
1190																							3	2	1.5
1152																							3	2	1.5
529																							3	2	1.5
1270																							3	2	1.5
2260																							3	2	1.5
419																							3	2	1.5
654																							3	2	1.5
574																							3	2	1.5
2234																							3	2	1.5
2161																							3	2	1.5
2164																							3	2	1.5
85				2																			3	2	1.5
1809																							3	2	1.5
1978																							3	2	1.5
438																							3	2	1.5
792	2																						3	2	1.5
1281																							3	2	1.5

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
1715																											2	1		
1876																												1		
484																												1		
2111																													2	
2163																													1	2
1621																													1	
1700																														1
318																														
173																														
642																														
235																														
106																														
217																														
444																														
1374																														
799		2							1																					
681								1															1							
483																1		2										1		
1280																1						1							2	
77																					1	2								1
825																										1	1			
1927	1					1		1																						
782	1												1														1			
1878		1																						1						
530		1																												1
1603								1									1				1									
334								1																		1				
66								1																						
144									1	1																				1
88											1	1															1			
1344											1	1	1																	
1033											1																			
2207											1																1			
876													1																	
80														1																
1959																			1			1								
94																								1	1	1				
849																									1					1
754																											1		1	
1829																												1		
823																														1
638																														
1663																														
1479																														
211																														
1633	1																1													
516	1																													
716	1		1																											
2227	1	1																												
1960			1	1																										
1206			1	1																										
1489				1			1																							
145					1																					1				
821					1																				1					
1386						1																	1							
1632								1								1														
238											1															1				
1431													1		1															
2226													1																	
1039															1			1												
2317																			1											
1984																				1									1	
283																				1							1			
1316																				1	1									
2130																					1					1				
1381																						1	1							
583																						1			1					
1949																							1			1				
1413																										1	1			
98																										1	1			
389																										1	1			
155																											1			
1048																											1			
981																											1			
1346																											1			
1412																												1	1	
1664																													1	1
1983																													1	
1095																													1	1
2131																														1
160																														1
1691																														
1695																														
49																														
2117																														
1853																														
2168																														
969																														
1107																														
2014																														
877																														
1568																														
2052																														
1218																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Active weeks	Rate msg/wk
1715																							3	2	1.5
1876							2																3	2	1.5
484	2																						3	2	1.5
2111																		1					3	2	1.5
2163																							3	2	1.5
1621		2																					3	2	1.5
1700	2																						3	2	1.5
318		1	2																				3	2	1.5
173			2			1																	3	2	1.5
642				2		1																	3	2	1.5
235					2	1																	3	2	1.5
106											2		1										3	2	1.5
217													1	2									3	2	1.5
444														2		1							3	2	1.5
1374																					1	2	3	2	1.5
799															1								4	3	1.3
681											2												4	3	1.3
483																							4	3	1.3
1280																							4	3	1.3
77																							4	3	1.3
825				2																			4	3	1.3
1927																							3	3	1.0
782																							3	3	1.0
1878																				1			3	3	1.0
530			1																				3	3	1.0
1603																							3	3	1.0
334													1										3	3	1.0
66																	1			1			3	3	1.0
144																							3	3	1.0
88																							3	3	1.0
1344																							3	3	1.0
1033						1										1							3	3	1.0
2207				1																			3	3	1.0
876															1		1						3	3	1.0
80		1	1																				3	3	1.0
1959				1																			3	3	1.0
94																							3	3	1.0
849				1																			3	3	1.0
754						1																	3	3	1.0
1829			1			1																	3	3	1.0
823			1					1															3	3	1.0
638		1	1					1															3	3	1.0
1663						1						1	1										3	3	1.0
1479																		1	1	1			3	3	1.0
211																			1	1	1		3	3	1.0
1633																							2	2	1.0
516																					1		2	2	1.0
716																							2	2	1.0
2227																							2	2	1.0
1960																							2	2	1.0
1206																							2	2	1.0
1489																							2	2	1.0
145																							2	2	1.0
821																							2	2	1.0
1386																							2	2	1.0
1632																							2	2	1.0
238																							2	2	1.0
1431																							2	2	1.0
2226								1															2	2	1.0
1039																							2	2	1.0
2317															1								2	2	1.0
1984																							2	2	1.0
283																							2	2	1.0
1316																							2	2	1.0
2130																							2	2	1.0
1381																							2	2	1.0
583																							2	2	1.0
1949																							2	2	1.0
1413																							2	2	1.0
98																							2	2	1.0
389																							2	2	1.0
155		1																					2	2	1.0
1048			1																				2	2	1.0
981				1																			2	2	1.0
1346	1																						2	2	1.0
1412																							2	2	1.0
1664																							2	2	1.0
1983						1																	2	2	1.0
1095																							2	2	1.0
2131	1																						2	2	1.0
160			1																				2	2	1.0
1691	1	1																					2	2	1.0
1695	1		1																				2	2	1.0
49		1					1																2	2	1.0
2117		1			1																		2	2	1.0
1853			1	1																			2	2	1.0
2168			1	1																			2	2	1.0
969			1	1																			2	2	1.0
1107			1	1																			2	2	1.0
2014			1	1																			2	2	1.0
877				1		1																	2	2	1.0
1568				1	1																		2	2	1.0
2052								1	1														2	2	1.0
1218								1		1													2	2	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
554																														
176																														
826																														
761																														
347																														
1131																														
957																														
513																														
1704																														
1168																														
2196																														
2149	1																													
1230	1																													
1773	1																													
2199		1																												
840		1																												
233		1																												
1784			1																											
1933			1																											
2169			1																											
1370			1																											
19				1																										
12				1																										
925				1																										
948				1																										
284					1																									
185					1																									
1314					1																									
432						1																								
2017						1																								
288							1																							
1831							1																							
215							1																							
1409								1																						
107								1																						
1333								1																						
934									1																					
286									1																					
552										1																				
1151										1																				
453										1																				
463										1																				
1661											1																			
856												1																		
424												1																		
867													1																	
383													1																	
1843													1																	
1363													1																	
1645														1																
1999														1																
1757														1																
1514															1															
1308																1														
1558																1														
1055																1														
371																1														
143																1														
1105																	1													
1955																	1													
355																	1													
2011																	1													
351																		1												
48																		1												
102																		1												
224																		1												
489																		1												
1765																		1												
1288																		1												
7																		1												
2246																			1											
1102																			1											
1735																			1											
275																			1											
1310																			1											
2036																			1											
1720																			1											
1987																				1										
919																				1										
427																				1										
536																				1										
1956																				1										
768																				1										
337																				1										
45																				1										
205																				1										
78																					1									
1257																					1									
1658																						1								
1977																						1								
1448																						1								
988																						1								
377																						1								
1894																						1								

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Active weeks	Rate msg/wk
554									1		1												2	2	1.0
176										1						1							2	2	1.0
826											1				1								2	2	1.0
761													1		1								2	2	1.0
347													1					1					2	2	1.0
1131														1		1							2	2	1.0
957																	1	1					2	2	1.0
513																		1		1			2	2	1.0
1704																			1	1			2	2	1.0
1168																			1	1			2	2	1.0
2196																				1	1		2	2	1.0
2149																							1	1	1.0
1230																							1	1	1.0
1773																							1	1	1.0
2199																							1	1	1.0
840																							1	1	1.0
233																							1	1	1.0
1784																							1	1	1.0
1933																							1	1	1.0
2169																							1	1	1.0
1370																							1	1	1.0
19																							1	1	1.0
12																							1	1	1.0
925																							1	1	1.0
948																							1	1	1.0
284																							1	1	1.0
185																							1	1	1.0
1314																							1	1	1.0
432																							1	1	1.0
2017																							1	1	1.0
288																							1	1	1.0
1831																							1	1	1.0
215																							1	1	1.0
1409																							1	1	1.0
107																							1	1	1.0
1333																							1	1	1.0
934																							1	1	1.0
286																							1	1	1.0
552																							1	1	1.0
1151																							1	1	1.0
453																							1	1	1.0
463																							1	1	1.0
1661																							1	1	1.0
856																							1	1	1.0
424																							1	1	1.0
867																							1	1	1.0
383																							1	1	1.0
1843																							1	1	1.0
1363																							1	1	1.0
1645																							1	1	1.0
1999																							1	1	1.0
1757																							1	1	1.0
1514																							1	1	1.0
1308																							1	1	1.0
1558																							1	1	1.0
1055																							1	1	1.0
371																							1	1	1.0
143																							1	1	1.0
1105																							1	1	1.0
1955																							1	1	1.0
355																							1	1	1.0
2011																							1	1	1.0
351																							1	1	1.0
48																							1	1	1.0
102																							1	1	1.0
224																							1	1	1.0
489																							1	1	1.0
1765																							1	1	1.0
1288																							1	1	1.0
7																							1	1	1.0
2246																							1	1	1.0
1102																							1	1	1.0
1735																							1	1	1.0
275																							1	1	1.0
1310																							1	1	1.0
2036																							1	1	1.0
1720																							1	1	1.0
1987																							1	1	1.0
919																							1	1	1.0
427																							1	1	1.0
536																							1	1	1.0
1956																							1	1	1.0
768																							1	1	1.0
337																							1	1	1.0
45																							1	1	1.0
205																							1	1	1.0
78																							1	1	1.0
1257																							1	1	1.0
1658																							1	1	1.0
1977																							1	1	1.0
1448																							1	1	1.0
988																							1	1	1.0
377																							1	1	1.0
1894																							1	1	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
1439																						1								
317																						1								
333																						1								
310																						1								
1794																						1								
2209																							1							
940																							1							
1321																							1							
1144																							1							
277																							1							
1807																							1							
1522																							1							
1239																								1						
1023																								1						
1759																									1					
793																									1					
2116																									1					
1121																									1					
815																									1					
2319																									1					
2																									1					
168																									1					
2223																										1				
1743																										1				
1585																										1				
338																										1				
225																										1				
1771																										1				
291																										1				
428																										1				
1424																										1				
2358																										1				
422																											1			
1762																											1			
548																											1			
1331																											1			
51																											1			
1495																											1			
1249																											1			
1837																											1			
126																											1			
1100																											1			
2190																											1			
1481																											1			
2283																											1			
1725																											1			
1601																											1			
41																											1			
2309																											1			
511																											1			
1065																												1		
705																												1		
494																												1		
138																												1		
2306																												1		
31																												1		
1286																												1		
197																												1		
1874																												1		
1437																												1		
1266																												1		
252																												1		
673																												1		
2279																												1		
1068																												1		
1231																												1		
1776																													1	
245																													1	
1070																													1	
1085																													1	
820																													1	
1780																													1	
2329																													1	
591																													1	
1208																														1
928																														1
1512																														1
724																														1
853																														1
1736																														1
396																														1
157																														1
1426																														1
1323																														1
736																														1
1641																														1
2027																														1
1941																														1
2102																														1
1445																														1
1403																														
1367																														
111																														
1989																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Active weeks	Rate msg/wk
1439																							1	1	1.0
317																							1	1	1.0
333																							1	1	1.0
310																							1	1	1.0
1794																							1	1	1.0
2209																							1	1	1.0
940																							1	1	1.0
1321																							1	1	1.0
1144																							1	1	1.0
277																							1	1	1.0
1807																							1	1	1.0
1522																							1	1	1.0
1239																							1	1	1.0
1023																							1	1	1.0
1759																							1	1	1.0
793																							1	1	1.0
2116																							1	1	1.0
1121																							1	1	1.0
815																							1	1	1.0
2319																							1	1	1.0
2																							1	1	1.0
168																							1	1	1.0
2223																							1	1	1.0
1743																							1	1	1.0
1585																							1	1	1.0
338																							1	1	1.0
225																							1	1	1.0
1771																							1	1	1.0
291																							1	1	1.0
428																							1	1	1.0
1424																							1	1	1.0
2358																							1	1	1.0
422																							1	1	1.0
1762																							1	1	1.0
548																							1	1	1.0
1331																							1	1	1.0
51																							1	1	1.0
1495																							1	1	1.0
1249																							1	1	1.0
1837																							1	1	1.0
126																							1	1	1.0
1100																							1	1	1.0
2190																							1	1	1.0
1481																							1	1	1.0
2283																							1	1	1.0
1725																							1	1	1.0
1601																							1	1	1.0
41																							1	1	1.0
2309																							1	1	1.0
511																							1	1	1.0
1065																							1	1	1.0
705																							1	1	1.0
494																							1	1	1.0
138																							1	1	1.0
2306																							1	1	1.0
31																							1	1	1.0
1286																							1	1	1.0
197																							1	1	1.0
1874																							1	1	1.0
1437																							1	1	1.0
1266																							1	1	1.0
252																							1	1	1.0
673																							1	1	1.0
2279																							1	1	1.0
1068																							1	1	1.0
1231																							1	1	1.0
1776																							1	1	1.0
245																							1	1	1.0
1070																							1	1	1.0
1085																							1	1	1.0
820																							1	1	1.0
1780																							1	1	1.0
2329																							1	1	1.0
591																							1	1	1.0
1208																							1	1	1.0
928																							1	1	1.0
1512																							1	1	1.0
724																							1	1	1.0
853																							1	1	1.0
1736																							1	1	1.0
396																							1	1	1.0
157																							1	1	1.0
1426																							1	1	1.0
1323																							1	1	1.0
736																							1	1	1.0
1641																							1	1	1.0
2027																							1	1	1.0
1941																							1	1	1.0
2102																							1	1	1.0
1445																							1	1	1.0
1403	1																						1	1	1.0
1367	1																						1	1	1.0
111	1																						1	1	1.0
1989	1																						1	1	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
842																														
566																														
44																														
2063																														
545																														
1599																														
1252																														
156																														
1506																														
920																														
17																														
901																														
1465																														
1764																														
584																														
1993																														
2127																														
622																														
904																														
720																														
11																														
473																														
746																														
575																														
298																														
1800																														
1378																														
131																														
356																														
1644																														
2064																														
1030																														
2141																														
180																														
1650																														
2020																														
2331																														
234																														
418																														
2031																														
991																														
1295																														
2299																														
2183																														
311																														
1036																														
1259																														
1166																														
1501																														
462																														
354																														
1157																														
758																														
723																														
1786																														
1890																														
1922																														
1005																														
576																														
1995																														
58																														
1626																														
2220																														
946																														
618																														
28																														
1104																														
1343																														
57																														
87																														
1315																														
1616																														
903																														
2120																														
1041																														
1351																														
2083																														
665																														
451																														
200																														
1533																														
1250																														
894																														
368																														
1253																														
1670																														
1109																														
710																														
33																														
2048																														
1892																														
1935																														
1220																														
1469																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Active weeks	Rate msg/wk
842	1																						1	1	1.0
566	1																						1	1	1.0
44	1																						1	1	1.0
2063	1																						1	1	1.0
545	1																						1	1	1.0
1599	1																						1	1	1.0
1252	1																						1	1	1.0
156	1																						1	1	1.0
1506	1																						1	1	1.0
920	1																						1	1	1.0
17	1																						1	1	1.0
901	1																						1	1	1.0
1465	1																						1	1	1.0
1764	1																						1	1	1.0
584	1																						1	1	1.0
1993	1																						1	1	1.0
2127	1																						1	1	1.0
622	1																						1	1	1.0
904	1																						1	1	1.0
720	1																						1	1	1.0
11		1																					1	1	1.0
473		1																					1	1	1.0
746		1																					1	1	1.0
575		1																					1	1	1.0
298		1																					1	1	1.0
1800		1																					1	1	1.0
1378		1																					1	1	1.0
131		1																					1	1	1.0
356		1																					1	1	1.0
1644		1																					1	1	1.0
2064		1																					1	1	1.0
1030		1																					1	1	1.0
2141		1																					1	1	1.0
180			1																				1	1	1.0
1650			1																				1	1	1.0
2020			1																				1	1	1.0
2331			1																				1	1	1.0
234			1																				1	1	1.0
418			1																				1	1	1.0
2031			1																				1	1	1.0
991			1																				1	1	1.0
1295			1																				1	1	1.0
2299			1																				1	1	1.0
2183			1																				1	1	1.0
311			1																				1	1	1.0
1036				1																			1	1	1.0
1259				1																			1	1	1.0
1166				1																			1	1	1.0
1501				1																			1	1	1.0
462				1																			1	1	1.0
354				1																			1	1	1.0
1157				1																			1	1	1.0
758				1																			1	1	1.0
723				1																			1	1	1.0
1786				1																			1	1	1.0
1890				1																			1	1	1.0
1922				1																			1	1	1.0
1005				1																			1	1	1.0
576				1																			1	1	1.0
1995				1																			1	1	1.0
58				1																			1	1	1.0
1626				1																			1	1	1.0
2220				1																			1	1	1.0
946				1																			1	1	1.0
618				1																			1	1	1.0
28					1																		1	1	1.0
1104					1																		1	1	1.0
1343					1																		1	1	1.0
57					1																		1	1	1.0
87					1																		1	1	1.0
1315					1																		1	1	1.0
1616					1																		1	1	1.0
903						1																	1	1	1.0
2120						1																	1	1	1.0
1041						1																	1	1	1.0
1351						1																	1	1	1.0
2083						1																	1	1	1.0
665						1																	1	1	1.0
451						1																	1	1	1.0
200						1																	1	1	1.0
1533						1																	1	1	1.0
1250						1																	1	1	1.0
894						1																	1	1	1.0
368						1																	1	1	1.0
1253						1																	1	1	1.0
1670							1																1	1	1.0
1109							1																1	1	1.0
710							1																1	1	1.0
33								1															1	1	1.0
2048								1															1	1	1.0
1892								1															1	1	1.0
1935								1															1	1	1.0
1220								1															1	1	1.0
1469								1															1	1	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
1868																														
213																														
1888																														
5																														
752																														
1545																														
1827																														
1329																														
1459																														
688																														
832																														
1272																														
659																														
1900																														
587																														
2191																														
1268																														
340																														
2069																														
2034																														
1687																														
966																														
1526																														
527																														
1610																														
2336																														
1205																														
2305																														
2134																														
279																														
1077																														
2175																														
1974																														
735																														
440																														
802																														
542																														
69																														
2250																														
1801																														
1869																														
2342																														
206																														
1637																														
1330																														
1651																														
2347																														
1972																														
1287																														
1864																														
1371																														
1245																														
641																														
588																														
684																														
2255																														
1754																														
2071																														
443																														
1659																														
871																														
555																														
442																														
1595																														
628																														
52																														
1507																														
561																														
1475																														
2192																														
1499																														
135																														
791																														
2322																														
1536																														
1247																														
297																														
1471																														
341																														
382																														
1734																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Active weeks	Rate msg/wk
1868								1															1	1	1.0
213								1															1	1	1.0
1888								1															1	1	1.0
5								1															1	1	1.0
752									1														1	1	1.0
1545									1														1	1	1.0
1827									1														1	1	1.0
1329									1														1	1	1.0
1459									1														1	1	1.0
688									1														1	1	1.0
832									1														1	1	1.0
1272									1														1	1	1.0
659									1														1	1	1.0
1900									1														1	1	1.0
587									1														1	1	1.0
2191									1														1	1	1.0
1268									1														1	1	1.0
340									1														1	1	1.0
2069										1													1	1	1.0
2034										1													1	1	1.0
1687										1													1	1	1.0
966										1													1	1	1.0
1526										1													1	1	1.0
527										1													1	1	1.0
1610											1												1	1	1.0
2336											1												1	1	1.0
1205											1												1	1	1.0
2305												1											1	1	1.0
2134													1										1	1	1.0
279													1										1	1	1.0
1077													1										1	1	1.0
2175													1										1	1	1.0
1974													1										1	1	1.0
735														1									1	1	1.0
440														1									1	1	1.0
802														1									1	1	1.0
542														1									1	1	1.0
69														1									1	1	1.0
2250														1									1	1	1.0
1801															1								1	1	1.0
1869															1								1	1	1.0
2342															1								1	1	1.0
206															1								1	1	1.0
1637															1								1	1	1.0
1330															1								1	1	1.0
1651																1							1	1	1.0
2347																1							1	1	1.0
1972																1							1	1	1.0
1287																1							1	1	1.0
1864																1							1	1	1.0
1371																1							1	1	1.0
1245																1							1	1	1.0
641																	1						1	1	1.0
588																		1					1	1	1.0
684																		1					1	1	1.0
2255																		1					1	1	1.0
1754																		1					1	1	1.0
2071																		1					1	1	1.0
443																		1					1	1	1.0
1659																		1					1	1	1.0
871																		1					1	1	1.0
555																		1					1	1	1.0
442																			1				1	1	1.0
1595																			1				1	1	1.0
628																			1				1	1	1.0
52																			1				1	1	1.0
1507																				1			1	1	1.0
561																				1			1	1	1.0
1475																				1			1	1	1.0
2192																				1			1	1	1.0
1499																				1			1	1	1.0
135																				1			1	1	1.0
791																					1		1	1	1.0
2322																					1		1	1	1.0
1536																					1		1	1	1.0
1247																					1		1	1	1.0
297																					1		1	1	1.0
1471																					1		1	1	1.0
341																					1		1	1	1.0
382																					1		1	1	1.0
1734																						1	1	1	1.0

B.3. Spreadsheet of communications in CoP *physres*

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
878			13	18	3		9	16	10	9	17	24	15	20	31	30	12	10	11	11	30	15	8	15	5	13	21	20	1	16
1101										1	3	7	6	12	10	10	6	8	7	9	6	5	12	1	4	3	7	15	9	3
451																													1	3
542			2	4		3	3	4	9	16	6	5	9	5	4				9	7	7	2	5	1	3	4	10	26	5	12
696			1	4	2	2	7	3	7										5	9	5		13	5	5	7	3	6	8	12
450		1						4	5	5	2	3	1	6	3	9	6	13	10	15	16	3	11		2	1				
1363		1	4	10	2	1			2	3		5	7	5	5	8	4	7	2	3	2		1		1	2	4	6		8
664										1	1	4	9	8	12	4	2	8	6	2	7	3			2	3	2	1	1	2
1360			1	6	1		8	3	1	8	1	8	7	4	3	9	3	2	4	5	3		5	3			10	5	2	4
1395				1		1																	13			11	6	4	4	2
401			3	4		1	2	5	4	4	5	4	11	2	1	5	4	4	1	2	6	1				2	1	1	1	1
589			2	2		1	3	3	3	1	4	5	11	5	10	11	2	7	4	4	2	1	1		4	2	3	1		
1429							8	5	3	2	1	4	2								9	5	13	1	2	2	1	1	3	1
927				2	1				1	2	2	1	4	1	9	5	3	6	3	2	4	3	8		2	3	2	2	4	
1335				2	1		3	1	3	4	3	6	2	3	2	3	3	11	5			2	2				1			
724				1	2		1			5	1	3		4	6	6	1	2	1		3			2		3	2			
1084				2							2			4	6	7	4			2			4		3	5	5		1	2
890			2	3	1	1	2	2			2	2	9	9	5	3	2		1	5		2	5	2				3	6	3
1177				1		1					1	1	2		4	4	3	4	1	2	6	1	6			2		2	1	2
89				4		2	7	1	7	3	1	1			4	8	5	3			4	1					1			
751				2			1	1	1		1	4	5	5	2	4	6	3	1		5	1	2							
231																								1					1	
13				1	1				1	3	3	5	4				1	4	5	2	1	4	4	2	3	5		2	1	1
801				3	1	2		1		1		5	3	2	2				1		2	2	4				1	1	2	2
844				1		1	3	1					1		1	2	1	2				1					1		1	1
1303			1					2		1	2			1	1	1					1									
304				2	1		3	2	7	2		2	1		2	4		2	5	2	2	4	1				2	4	1	2
214																7	2	3							1	1				
791																			1		2	2	5		1	3		2		2
1323				5			1	1	1	2	2	3	2	1	4	2	2	2	3	2		1	3		1	2		2	1	4
1394			1	1		3	2	2	2					1		1		3	3					2						
137			1			1	2	1		1	1					7		3	3											
1035							1		1	2	3	3	2				1			1	1		1			1	2	5	4	3
237							2	2	1	1		2	4	2	1	2		2		1										
1123												1				1			2		1									1
1164												3	1		2	5	2	1	4		1	3	1					1		
1285				2			1					2											1		1	2	3		3	1
1369				5	1		3	1	1					1	2				1	2	4	3	7		2	2			1	1
776											1	1	2	4		1	1				1	1							2	1
1135									1			1	3	2	3	2	3	3		1										1
770																														
660												1									2	3	1	1	1	1	5			1
669										1													3		1		1	1		1
1290				3	2	2	3		2	2		2	1	1	1	3	4	3	1	2	3	2	4	1			1	2		1
1057									1	2					4	1	2													
729																											1	1	1	3
47				3	2		1	1		1	2												3			3	3	2	1	1
230				1	1	1	1	2					1	3	1	1	2	1		1					3	3	1	2	2	3
987				1							2	2				1				1	2		1							
452														1	6	1	1	3					1			2	1			
620			1	2		1		1	1			3			3	2			4			4	2	1			2		1	1
1069												1	2					1			5	1	3	1	1					
1104							1	1		2	3		4	1	1	1	1	5	1	1		1	1					1		
1210				2	2	1	1	1	1	1		2			3		1								1			1		1
858							2									2	2		1											
1281																									1	2	1	2	1	1
7				3			1	1	1	1	4	3	2		1	3	1	1	4								1			
1171			1	3					1	1	1	3		1																
1327					2		1	1	1			1			2	4	1					1	1						1	1
1048				1			1		2	1		1				3		2	2											1
1202					2				1							1														
704																														2
408									1	1				1						1							1	4		
1252													2	2	1															
449																3	1						2	1		1				
804																				1									3	
587						1	1																			1		3		
781																														
912			1	2		2									1	1	2									1				
895														1		1			2		2									
540									2	2	1																			
668													1	1		2							3			1				
117																	3			1							2		1	1
740																										2			1	1
1357																										1	3	1		1
1206					1		2	4		1	1	1		1	2	1		2	1				1			1	2	1	1	
1047				1	1	3			2													1		1		1			2	
1410										3	1	1	1					1												
1087										1		1	1			3														
1266												1			1	1	1				3									
1420																														
1359				1	2		1			1	2		1	1	3	2	1	1		1	3	1	1				1			
918			2	1		1		1															2	1		1	1	1	1	
389					1	2									2		1	2	1		1	1								
1024										2	2	1	1														1			
1302																						2	2		1	1	1	1	2	
1188								1						2	1						1				1	3	3	2	1	
481																							1				2	1	2	1
431																														1
827															1		1								1	1	2		2	
786																1														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
878	17	32	19	28	16	19	16	3	7	19	15	13	19	22	3	3	18		19	13	5	4	713	48	14.9
1101	5	16	10	19	19	9	5	8	7	3	1	2	7	8	4	6	16	3	12		17	10	331	42	7.9
451	5	7	5	8	6	5	10	8	4	7	5	8	13	14	4	7	11	5	16	10	14	5	181	24	7.5
542	13	3	11	15	14	11	6	10	5	6	4	16	12	5	1	4	12	1	9	10	2		331	45	7.4
696	9	21	9	8	8	7	16	7	5	7	6	5	4	7	4	3	6	3	4	3	2	4	252	40	6.3
450													3	8	5	3	3	1	4	4	4	3	154	29	5.3
1363		9	5	5	7	9	10	6	8	3	3		1	2	3	3	1						168	38	4.4
664	6	6	7	10	5	1	2	3		6	2	4		3	2		5	1	6	1	3	6	157	38	4.1
1360	4	2	2	3	6	8	4	3	4	2	3	2	3	5	3	2	7	4	5	2	2		182	45	4.0
1395	5	2			1			5	4	1	4	3	3	3	2	4	3	1	1	2	7	1	94	26	3.6
401	2	1	1	1	4	1	10	7	5	1	6	5	5	9	2	5							140	40	3.5
589		1	1	3	2	1	3					1		1									105	32	3.3
1429	1	4	2	1							2	1											74	23	3.2
927	3	2		1	1	3	8	8	8	4	2	3	4	1	1	2	2	3				2	128	40	3.2
1335																							57	18	3.2
724			1						17	4	3	2	5	1	1	1							78	25	3.1
1084	1	4	4	4	1		4	3								1	2	1	1	1			74	25	3.0
890	2	3		1	3		2	2	4	5			3	3	1	1	4	1	2	1			108	37	2.9
1177	1	1	1		2	5	6	7	4	6	1	4	3	1		3	2	4	4		1		100	36	2.8
89		3	2	1	1	1	3	1			4	2	1	1	1	3	1						77	29	2.7
751					1																		45	17	2.6
231	2	2		2	2	1	2	3	7							1	5	5	6	1	1		42	16	2.6
13			1	4	3	1	1	1															64	26	2.5
801	3		2	3	1	7	4	3	5	4	1	2	2					1					73	30	2.4
844	3		3	2	9	3	4	4		1	1	4	1	1	1		2	4	5	3	3	5	76	32	2.4
1303			2	6	3	4	1	1			2	2	4	4	1	2	6	1	2	1	2		54	25	2.2
304	3		1		1	2	1		2		1	2	1		2		1		1	2		1	72	34	2.1
214					1	1			2						1								19	9	2.1
791	1	1	2	3		2	2	4	1	4	1		1										40	19	2.1
1323		2	1	1	2		4	1	2	3		1	3	5	1	2	1	1	1	1			79	39	2.0
1394									3														24	12	2.0
137			1				1																22	11	2.0
1035		1	3	1	1	2	4	1				2		3	1		2	2		1			55	28	2.0
237		2	4	3	2			1		2	1	2											37	19	1.9
1123			1		1	2	1		5	5	2	1	1	2			3		3				33	17	1.9
1164															1	1	2	2		1			31	16	1.9
1285		1												1					1	5	4	1	29	15	1.9
1369		1								1	1	1	3	3	1	1	1		1	1	2		54	28	1.9
776		1	1	3	4	2	4	4		1				2					3	1		1	42	22	1.9
1135						2		3	2	1	2	3		1	1	2			1				38	20	1.9
770												1	2	2	1		4		1	3		1	15	8	1.9
660	1					2	3	1	1	1	3	4	3	4	1	1	1					1	43	23	1.9
669	1							3	3	3	3	2		1									24	13	1.8
1290	2		1	1	1	1	2									1		1		1			57	31	1.8
1057									1														11	6	1.8
729	2	3		2	1	2	3	1	2	3	3	2		1	1	1			1				34	19	1.8
47			1													1	1	1	1			4	32	18	1.8
230	4	2					2							1									39	22	1.8
987							3	3		2			1	1								3	23	13	1.8
452										1				1	1		2		1				22	13	1.7
620	1		1				2					1	1				1		1	1			38	23	1.7
1069		1	1				1	2			1	1	2	2		1	2			2	2		33	20	1.7
1104														2	2	1			1				31	19	1.6
1210					7	1	3	1		1		1						1		1			34	21	1.6
858																	1						8	5	1.6
1281		3		1	1							1	1	1	2	1	2		2			4	27	17	1.6
7			1	1	1	2		1		1	1		1	1				1					38	24	1.6
1171																							11	7	1.6
1327	1	2	1			2	1			3		1		2	2	1			2				35	23	1.5
1048	1	1		2																			18	12	1.5
1202	2	2	1	1	3	1				1										2	1		18	12	1.5
704	1	2	3									1	1		1	2	1	1			1	2	18	12	1.5
408																							9	6	1.5
1252							1	2						1									9	6	1.5
449		1																					9	6	1.5
804									1			1		2	1								9	6	1.5
587																							6	4	1.5
781							1	2								2	1						6	4	1.5
912									1	2				2								1	16	11	1.5
895				1				1			1									2	2		13	9	1.4
540																1	1		2	1			10	7	1.4
668																				1	1		10	7	1.4
117		1										1											10	7	1.4
740	1	3	1				1																10	7	1.4
1357	1	1									1	1	2		1		3	1					17	12	1.4
1206		1																					24	17	1.4
1047										1	1												14	10	1.4
1410																							7	5	1.4
1087											1												7	5	1.4
1266																							7	5	1.4
1420														1			2		2		1	1	7	5	1.4
1359		1			2		1			1	1	1	2	1			2	1					36	26	1.4
918	1	1	1		1		1	5		1	1	2		1		3			1	1	1		33	24	1.4
389																							11	8	1.4
1024				2						1				1									11	8	1.4
1302	1																						11	8	1.4
1188		1	2				1				1	1	1		1		1		1			1	26	19	1.4
481											1	1		2	1								12	9	1.3
431	1						1					2	1	1	1	2	2						12	9	1.3
827																							8	6	1.3
786																		1	1	1	2	2	8	6	1.3

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
525																												2	1	2
1379																														
509																		1	3	1	1		1	1	2			1	2	1
908									1		1		1	3						1	1	2			1					
1347									1	3	1		1			2				1	1		2		1	1		1	2	2
734				2																										
116				2	1					1		1	2	1	1															
911																		1		1										
741																						1	2							
1292				1					1		1		1	1			1				1	1							1	1
151				2								2										1	1		1	1				
825																											3		1	
600			1											1						3	1		1				1	1	1	1
921																														
1328				1	1																1		2							
1111															2		1					1								
1332																	1													
1094																														1
967																														
360																														
260					1					1	1				2															
1233																		1							1					
594					2													1		2	1									
1262											1	1		1		1					1		3	1						
1403						1	2	1																			1			
1175															1	1	2													
649																									1					
496																	1										1	2	1	
944																													1	
1054			2	1														1					1	1						
1193									2									1							1	1				
1139											1	1		1	2							1	1							
607																				1			1	1		2				
351																								1	2	1				
1283																														
1278																			1	1										
1005																				1	1	1	1				1			1
976																									1	2	1	1		
285																														1
195							2							1							1	1				1				
725				1		1	2		1	1						1						1								
1004													2	1	1	1					1									
1331													1																	
529				1			1	1			1			1								2	1			1				
1142										1	1	1	1		2	1			1						1					
1214																		1	1				1						1	1
469																														
1148								1	1						1	1			1						1					
1150									1													1	1							
81				1					1																1	1				
1401						1							1		1						1									
138							1																							
1023				1			1						1		1					1	1									
1040					1															1				1		1		1		
939																1			1	1		1	1							
577							1														1								1	1
534							1	1	1	1																				
325							1			1	1			1						1										
605												1	1												1			1		
1299															1															1
168																			1	1		1								
1169																									1	1	1			
1239				1											1		1													
484				1	1		1	1																						
760					1								1							1		1								
701							1				1																			
973									1										1											
1399									1						1															
948									1					1																1
1386												1																		
756												1							1											
994														1									1			1				
1029														1			1													
462															1	1	1				1									
672															1	1							1							
850																1						1								
528																		1			1						1			1
992																			1									1		
1089																					1									
718																					1	1			1	1				
1019																										1			1	
538																													1	
712																														
547																														
77																														
1163																														
687																														
1116																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
525	1	1				1																	8	6	1.3
1379				1								1		2		1	1		2				8	6	1.3
509		1		1			2							1						1	1		21	16	1.3
908	1				1																		13	10	1.3
1347		1	1	1					2	1		1				1	1		1	1	1		31	24	1.3
734			1												2		1		1	1		1	9	7	1.3
116																							9	7	1.3
911			2	1	1			2												1			9	7	1.3
741			2	1				1							1	1							9	7	1.3
1292	1				2	2	1					3	1				2					1	23	18	1.3
151					2	1				1	1		1										14	11	1.3
825				1				1				2	1	1			1	1	1			1	14	11	1.3
600			2																		1	1	15	12	1.3
921	2	1	1	2			1		1										1	1			10	8	1.3
1328																							5	4	1.3
1111							1																5	4	1.3
1332	1	1											2										5	4	1.3
1094			1				2	1															5	4	1.3
967		2	1														1		1				5	4	1.3
360						2			1		1	1											5	4	1.3
260	1				1					2						1			1				11	9	1.2
1233							1		1		2	2	1							1	1		11	9	1.2
594					1	1	1				1		1								1		12	10	1.2
1262		1			1		1																12	10	1.2
1403																	1						6	5	1.2
1175				1													1						6	5	1.2
649						1								2		1	1						6	5	1.2
496	1		2	1			1					1	1						1				13	11	1.2
944		1						1	1	2	1		1	2		1		1		1		1	14	12	1.2
1054																						1	7	6	1.2
1193	1						1																7	6	1.2
1139																							7	6	1.2
607							1				1												7	6	1.2
351		1	1		1																		7	6	1.2
1283	1			1	1			2	1				1										7	6	1.2
1278	1					1	2											1	1				8	7	1.1
1005		2																					8	7	1.1
976	1		1						1														8	7	1.1
285	1	1										1		2					1	1			8	7	1.1
195	1				1	1	1	1						1		1	1		1		2	1	18	16	1.1
725				1																			9	8	1.1
1004		1	1														1						9	8	1.1
1331							1	2	1			1		1			1	1					9	8	1.1
529			1																				10	9	1.1
1142									1			1											11	10	1.1
1214		1				1		1		2	1												11	10	1.1
469							1	1	1			1	2		1	1			1		1	1	11	10	1.1
1148	1		1	1																			9	9	1.0
1150					1		1				1	1		1						1			9	9	1.0
81	1				1		1												1				8	8	1.0
1401							1			1			1				1						8	8	1.0
138									1		1	1	1		1				1				7	7	1.0
1023																							6	6	1.0
1040	1																						6	6	1.0
939						1																	6	6	1.0
577				1																			5	5	1.0
534																	1						5	5	1.0
325																							5	5	1.0
605								1															5	5	1.0
1299												1	1			1							5	5	1.0
168							1		1														5	5	1.0
1169		1	1																				5	5	1.0
1239							1																4	4	1.0
484																							4	4	1.0
760																							4	4	1.0
701		1																		1			4	4	1.0
973																				1		1	4	4	1.0
1399			1	1																			4	4	1.0
948	1																						4	4	1.0
1386																	1			1		1	4	4	1.0
756			1						1														4	4	1.0
994																1							4	4	1.0
1029			1	1																			4	4	1.0
462																							4	4	1.0
672				1																			4	4	1.0
850									1							1							4	4	1.0
528																							4	4	1.0
992	1						1																4	4	1.0
1089				1	1				1														4	4	1.0
718																							4	4	1.0
1019													1									1	4	4	1.0
538	1	1								1													4	4	1.0
712		1										1		1								1	4	4	1.0
547			1						1	1		1											4	4	1.0
77				1	1								1				1						4	4	1.0
1163					1		1							1	1								4	4	1.0
687						1		1								1			1				4	4	1.0
1116												1	1	1			1						4	4	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
1318																														
66																														
551		1	7	11	4	1	2																							
797																2	8	8	2	1	2	3	9	1	1	3				
809																														
780			1	7			2		1																					
33							2													3	1									
817			1	1			3			4																				
1367																														1
716																														
722																														
1368									1	2	4	3	2	1				1												
966																												5		
659																														
708																											3	2		
1190																														
1308																			2											
1158																														
121												1	1			1				1							5			
1186																	1	1												
435				2	2		1		1			1	4	2			1													
494					3				1																1					
1319								1			1	2											3							
483																												2		2
300																														
1287				2																			1							
1255														2	1					1	3		3				1			
1353																					2		1							
59																					1	2	5				1	1		
853														1												2		1	1	
234															2				2	2	1					1	2			
1114																			1							1	3	2	1	2
1373																									1	1	2	1		3
1028																											2		1	1
434																														
521																														
1218																														
1197							1	1					1	4									2							
755								1	2			1			1	2														
175										1		1					2	1			2		3		1					
1166																	2	4			1		1			1				
134														1			1		2		1		3			2				
1237										1							1		4		1	2								1
1077									1	2	1	2	2	2	2	1	1			1	1	1	4	2		1	1	1		
682																														
1045													4																	
368								1																						
750																														
1102																					2									
1213													3																	
1307																							3							
412																														
1381												1	4																	
466																													4	1
224																														
810																														
1276																3							2							
381																			2		4							1		
335																					2	1	4							
179																						4	2							
447																		2	2	2										
1185				3																										
584										3																				
558												1	3																	
340															3															
1126															1	3														
833																										1	3			
1157																											3	1		
867																														
1145																														
499																														
840				2																										
1358				2																										
812				2																										
1230							2																							
313							2																							
1222							2																							
570										2																				
580											2																			
863														2																
1020														2																
880															2															
917															2															
1161															2															
965																2														
1097																2														
1154																2														
790																2														
1195																2														
366																			2											

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
1318				6	2	7	6	4	7	4	5	4											45	9	5.0
66												4	5	5	2	5	10	1					32	7	4.6
551																							26	6	4.3
797																							40	11	3.6
809																4	5	2	2				13	4	3.3
780									3	1													15	6	2.5
33														2		3	4						15	6	2.5
817																							9	4	2.3
1367			3	4	1																		9	4	2.3
716																2	3	3	3	1	1		13	6	2.2
722					1	6	3	1		2			1	1						1			16	8	2.0
1368																							14	7	2.0
966								1	1	3	1			1									12	6	2.0
659														1	4	1	3	1					10	5	2.0
708	2				1																		8	4	2.0
1190																			1	3	1	3	8	4	2.0
1308										1						3	2	1	2				11	6	1.8
1158							1	1					1	5		2	1						11	6	1.8
121																							9	5	1.8
1186				2	3	2																	9	5	1.8
435																							14	8	1.8
494																	2						7	4	1.8
1319																							7	4	1.8
483	1	2																					7	4	1.8
300																			1	4	1	1	7	4	1.8
1287						3	2												1	2	1		12	7	1.7
1255																				1			12	7	1.7
1353							3	3			1	1	1										12	7	1.7
59															1				1	1	1	3	17	10	1.7
853							3			2													10	6	1.7
234																							10	6	1.7
1114																							10	6	1.7
1373				2																			10	6	1.7
1028										3	2	1											10	6	1.7
434		1		2		2	2														1		8	5	1.6
521		1		2	2					2							1						8	5	1.6
1218									1	1	1	4		1									8	5	1.6
1197																		1	1				11	7	1.6
755																					2	2	11	7	1.6
175																							11	7	1.6
1166		1		1																			11	7	1.6
134	1			1			2		1					2									17	11	1.5
1237							1	1	2			1	3				1			1			20	13	1.5
1077																							26	17	1.5
682												5											5	1	5.0
1045																							4	1	4.0
368												7	2										10	3	3.3
750							4	4	2														10	3	3.3
1102				4																			6	2	3.0
1213																							3	1	3.0
1307																							3	1	3.0
412		3																					3	1	3.0
1381																							5	2	2.5
466																							5	2	2.5
224																				2	3		5	2	2.5
810																					1	4	5	2	2.5
1276						2																	7	3	2.3
381																							7	3	2.3
335																							7	3	2.3
179	1																						7	3	2.3
447																							6	3	2.0
1185					1																		4	2	2.0
584													1										4	2	2.0
558																							4	2	2.0
340																				1			4	2	2.0
1126																							4	2	2.0
833																							4	2	2.0
1157																							4	2	2.0
867											3	1											4	2	2.0
1145											3	1											4	2	2.0
499																			2	2			4	2	2.0
840																							2	1	2.0
1358																							2	1	2.0
812																							2	1	2.0
1230																							2	1	2.0
313																							2	1	2.0
1222																							2	1	2.0
570																							2	1	2.0
580																							2	1	2.0
863																							2	1	2.0
1020																							2	1	2.0
880																							2	1	2.0
917																							2	1	2.0
1161																							2	1	2.0
965																							2	1	2.0
1097																							2	1	2.0
1154																							2	1	2.0
790																							2	1	2.0
1195																							2	1	2.0
366																							2	1	2.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
426																				2										
1397																				2										
765																					2									
838																											2			
851																											2			
1417																											2			
31																														
504																														
427																														
227																														
871																														
779																														
1309																														
753																														
1343																														
348																														
1092																														
662																														
299																														
282																														
1338																														
680		1	2					2																						
1339									1	3		1																		
658												2				1	2													
377												1								2			2							
1059													1																	
1014																3	1													1
170																				2	2									
238																											1	2	2	
220																													1	
615																														
1205					1	2																								
588											2	1																		
866												1							2											
92												1	2																	
1326															2	1														
1141															1	2														
582															1			2												
1113																	2		1											
1316																		2												
887																		2												
209																		2		1										
616																							1	2						
1407																											2	1		
286																													1	
1271																													2	1
455																														
557																														
41																														
969																														
1159																														
957																														
1219																														
904			1	1																	2									
894					1	1		2																						
144							1	2																						
1125								2	1																					
1120								2	1	1																				
870																1														
215																	1	2	1											
1348																		2	1								1			
951																					2	1								
1003																					2	1	1							
604																								1				1		2
738																									2	1	1			
1016																											2			
993																														
956																														
48																														
265																														
864			1						1						1															
983				1			1		1																					
112				1		1	1																							
526					1	1	1																							
933					1				1		1																			
743						1										1														
1070						1	1	1																						
322									1	1							1													
1216									1	1	1																			
1346										1																				
180											1									1								1		
99												1								1										
683												1	1							1										
585												1																		
1259													1																	
1251													1									1				1				
910													1			1														
1007													1	1				1												
104														1																
1324														1			1													
1355															1													1		1
273																1														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
426																							2	1	2.0
1397																							2	1	2.0
765																							2	1	2.0
838																							2	1	2.0
851																							2	1	2.0
1417																							2	1	2.0
31			2																				2	1	2.0
504				2																			2	1	2.0
427					2																		2	1	2.0
227						2																	2	1	2.0
871						2																	2	1	2.0
779							2																2	1	2.0
1309								2															2	1	2.0
753											2												2	1	2.0
1343												2											2	1	2.0
348																	2						2	1	2.0
1092																	2						2	1	2.0
662																			2				2	1	2.0
299																				2			2	1	2.0
282																					2		2	1	2.0
1338																					2		2	1	2.0
680																							5	3	1.7
1339																							5	3	1.7
658																							5	3	1.7
377																							5	3	1.7
1059										1	3												5	3	1.7
1014																							5	3	1.7
170																		1					5	3	1.7
238																							5	3	1.7
220		3																			1		5	3	1.7
615																				1	1	3	5	3	1.7
1205																							3	2	1.5
588																							3	2	1.5
866																							3	2	1.5
92																							3	2	1.5
1326																							3	2	1.5
1141																							3	2	1.5
582																							3	2	1.5
1113																							3	2	1.5
1316						1																	3	2	1.5
887			1																				3	2	1.5
209																							3	2	1.5
616																							3	2	1.5
1407																							3	2	1.5
286	2																						3	2	1.5
1271																							3	2	1.5
455	2											1											3	2	1.5
557							1							2									3	2	1.5
41							1	2															3	2	1.5
969											1	2											3	2	1.5
1159																	1	2					3	2	1.5
957																	2			1			3	2	1.5
1219																				1	2		3	2	1.5
904																							4	3	1.3
894																							4	3	1.3
144													1										4	3	1.3
1125					1																		4	3	1.3
1120																							4	3	1.3
870																2	1						4	3	1.3
215																							4	3	1.3
1348																							4	3	1.3
951					1																		4	3	1.3
1003																							4	3	1.3
604																							4	3	1.3
738																							4	3	1.3
1016				1															1				4	3	1.3
993		2	1	1																			4	3	1.3
956							1		2						1								4	3	1.3
48											1	1				2							4	3	1.3
265																		1	2		1		4	3	1.3
864																							3	3	1.0
983																							3	3	1.0
112																							3	3	1.0
526																							3	3	1.0
933																							3	3	1.0
743															1								3	3	1.0
1070																							3	3	1.0
322																							3	3	1.0
1216																							3	3	1.0
1346																1			1				3	3	1.0
180																							3	3	1.0
99													1										3	3	1.0
683																							3	3	1.0
585				1											1								3	3	1.0
1259																	1			1			3	3	1.0
1251																							3	3	1.0
910													1										3	3	1.0
1007																							3	3	1.0
104			1											1									3	3	1.0
1324																1							3	3	1.0
1355																							3	3	1.0
273																	1	1					3	3	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
235																1					1									
211																	1													1
274																	1													
391																		1		1	1									
700																			1		1									
221																					1									
517																					1									
565																					1									
306																							1			1		1		
1249																									1					
1209																										1				1
1119																														
857																														
11																														
21																														
1274																														
418																														
778																														
1191																														
444																														
63																														
201			1	1																										
673			1	1																										
236			1																											
328				1											1															
127				1																		1								
901				1	1																									
309					1	1																								
1075						1													1											
926							1													1										
57							1			1																				
736								1		1																				
885								1																						
942										1		1																		
1009										1		1																		
920											1																			
902											1																			
679											1	1																		
935												1																		
310												1																		
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721														1	1															
1277														1					1											
1165															1				1											
1342															1															
1356																1			1											
1109																1	1													
1387																1	1													
294																1				1										
1351																	1	1												
764																		1	1											
703																		1				1								
575																		1											1	
232																			1											
1062																				1		1								
185																					1									
1375																						1	1							
808																							1			1				
1012																									1			1		
963																										1				1
442																										1				
453																											1			
374																											1	1		
1008																											1	1		
603																													1	
748																														
429																														
1000																														
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923																														
1267																														
955																														
272																														
1282																														
346																														
846																														
1117																														
1017																														
980																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
235																				1			3	3	1.0
211			1																				3	3	1.0
274								1			1												3	3	1.0
391																							3	3	1.0
700										1													3	3	1.0
221															1							1	3	3	1.0
517																					1	1	3	3	1.0
565												1	1										3	3	1.0
306																							3	3	1.0
1249							1	1															3	3	1.0
1209			1																				3	3	1.0
1119	1											1							1				3	3	1.0
857		1		1																	1		3	3	1.0
11		1	1		1																		3	3	1.0
21					1		1			1													3	3	1.0
1274						1				1		1											3	3	1.0
418										1			1			1							3	3	1.0
778											1	1						1					3	3	1.0
1191													1							1		1	3	3	1.0
444																			1	1	1		3	3	1.0
63																			1	1		1	3	3	1.0
201																							2	2	1.0
673																							2	2	1.0
236																	1						2	2	1.0
328																							2	2	1.0
127																							2	2	1.0
901																							2	2	1.0
309																							2	2	1.0
1075																							2	2	1.0
926																							2	2	1.0
57																							2	2	1.0
736																							2	2	1.0
885													1										2	2	1.0
942																							2	2	1.0
1009																							2	2	1.0
920						1																	2	2	1.0
902			1																				2	2	1.0
679																							2	2	1.0
935		1																					2	2	1.0
310						1																	2	2	1.0
813																							2	2	1.0
681															1								2	2	1.0
721																							2	2	1.0
1277																							2	2	1.0
1165																							2	2	1.0
1342												1											2	2	1.0
1356																							2	2	1.0
1109																							2	2	1.0
1387																							2	2	1.0
294																							2	2	1.0
1351																							2	2	1.0
764																							2	2	1.0
703																							2	2	1.0
575																							2	2	1.0
232	1																						2	2	1.0
1062																							2	2	1.0
185																					1		2	2	1.0
1375																							2	2	1.0
808																							2	2	1.0
1012																							2	2	1.0
963																							2	2	1.0
442																						1	2	2	1.0
453						1																	2	2	1.0
374																							2	2	1.0
1008																							2	2	1.0
603					1																		2	2	1.0
748		1															1						2	2	1.0
429		1										1											2	2	1.0
1000		1	1																				2	2	1.0
1314			1																	1			2	2	1.0
546			1	1																			2	2	1.0
1263				1						1													2	2	1.0
684					1	1																	2	2	1.0
336						1															1		2	2	1.0
1074						1													1				2	2	1.0
932						1	1																2	2	1.0
859								1														1	2	2	1.0
548										1											1		2	2	1.0
1044											1	1											2	2	1.0
512												1	1										2	2	1.0
312													1	1									2	2	1.0
388													1	1									2	2	1.0
923													1		1								2	2	1.0
1267														1							1		2	2	1.0
955														1	1								2	2	1.0
272														1			1						2	2	1.0
1282														1	1								2	2	1.0
346															1	1							2	2	1.0
846																1	1						2	2	1.0
1117																			1	1			2	2	1.0
1017																			1	1			2	2	1.0
980																				1		1	2	2	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
379			1																											
1414			1																											
334			1																											
737				1																										
217				1																										
1081				1																										
229				1																										
1080				1																										
1162				1																										
754				1																										
651				1																										
824				1																										
78				1																										
96				1																										
365				1																										
1204				1																										
1221				1																										
914				1																										
663					1																									
1155					1																									
94					1																									
1006						1																								
268						1																								
80							1																							
728							1																							
256							1																							
68							1																							
95								1																						
136								1																						
111								1																						
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1032								1																						
631								1																						
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553									1																					
1248									1																					
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446										1																				
692											1																			
757											1																			
122											1																			
492											1																			
1128											1																			
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953														1																
1261														1																
269														1																
293														1																
316														1																
301														1																
903														1																
305															1															
695															1															
998															1															
1320															1															
592															1															
818															1															
88															1															
1295															1															
689															1															
1236															1															
568															1															

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
379																							1	1	1.0
1414																							1	1	1.0
334																							1	1	1.0
737																							1	1	1.0
217																							1	1	1.0
1081																							1	1	1.0
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1080																							1	1	1.0
1162																							1	1	1.0
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824																							1	1	1.0
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365																							1	1	1.0
1204																							1	1	1.0
1221																							1	1	1.0
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663																							1	1	1.0
1155																							1	1	1.0
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1006																							1	1	1.0
268																							1	1	1.0
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728																							1	1	1.0
256																							1	1	1.0
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1128																							1	1	1.0
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222																							1	1	1.0
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1199																							1	1	1.0
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818																							1	1	1.0
88																							1	1	1.0
1295																							1	1	1.0
689																							1	1	1.0
1236																							1	1	1.0
568																							1	1	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
979															1															
591															1															
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177																1														
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1194																1														
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1107																							1							
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1384																							1							
277																							1							
317																									1					
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1322																									1					
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1184																										1				
152																										1				
191																										1				
839																										1				
555																										1				
648																											1			
465																											1			

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
979																							1	1	1.0
591																							1	1	1.0
1350																							1	1	1.0
177																							1	1	1.0
1039																							1	1	1.0
404																							1	1	1.0
782																							1	1	1.0
601																							1	1	1.0
1194																							1	1	1.0
212																							1	1	1.0
888																							1	1	1.0
1269																							1	1	1.0
1082																							1	1	1.0
1090																							1	1	1.0
699																							1	1	1.0
187																							1	1	1.0
952																							1	1	1.0
233																							1	1	1.0
865																							1	1	1.0
413																							1	1	1.0
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364																							1	1	1.0
102																							1	1	1.0
1140																							1	1	1.0
114																							1	1	1.0
341																							1	1	1.0
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421																							1	1	1.0
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1153																							1	1	1.0
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667																							1	1	1.0
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464																							1	1	1.0
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611																							1	1	1.0
1149																							1	1	1.0
1310																							1	1	1.0
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819																							1	1	1.0
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1345																							1	1	1.0
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1322																							1	1	1.0
666																							1	1	1.0
1184																							1	1	1.0
152																							1	1	1.0
191																							1	1	1.0
839																							1	1	1.0
555																							1	1	1.0
648																							1	1	1.0
465																							1	1	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
433																											1			
924																											1			
1227																											1			
409																											1			
493																											1			
1001																											1			
488																											1			
436																											1			
178																												1		
425																												1		
1241																												1		
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1176																														
508																														
1258																														
974																														
169																														
805																														
1372																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
433																							1	1	1.0
924																							1	1	1.0
1227																							1	1	1.0
409																							1	1	1.0
493																							1	1	1.0
1001																							1	1	1.0
488																							1	1	1.0
436																							1	1	1.0
178																							1	1	1.0
425																							1	1	1.0
1241																							1	1	1.0
10																							1	1	1.0
539																							1	1	1.0
536																							1	1	1.0
344																							1	1	1.0
199																							1	1	1.0
44																							1	1	1.0
1203																							1	1	1.0
524																							1	1	1.0
254																							1	1	1.0
717																							1	1	1.0
386																							1	1	1.0
467																							1	1	1.0
219																							1	1	1.0
735																							1	1	1.0
1297																							1	1	1.0
502																							1	1	1.0
652	1																						1	1	1.0
868	1																						1	1	1.0
1217	1																						1	1	1.0
141	1																						1	1	1.0
950	1																						1	1	1.0
1311	1																						1	1	1.0
1026		1																					1	1	1.0
552		1																					1	1	1.0
253		1																					1	1	1.0
1329		1																					1	1	1.0
1086		1																					1	1	1.0
1		1																					1	1	1.0
610			1																				1	1	1.0
1365			1																				1	1	1.0
678			1																				1	1	1.0
115			1																				1	1	1.0
1272			1																				1	1	1.0
343				1																			1	1	1.0
852				1																			1	1	1.0
459				1																			1	1	1.0
1180				1																			1	1	1.0
146				1																			1	1	1.0
596					1																		1	1	1.0
826					1																		1	1	1.0
1393					1																		1	1	1.0
1076					1																		1	1	1.0
337					1																		1	1	1.0
1132					1																		1	1	1.0
954					1																		1	1	1.0
1124					1																		1	1	1.0
64						1																	1	1	1.0
602						1																	1	1	1.0
133						1																	1	1	1.0
855						1																	1	1	1.0
51						1																	1	1	1.0
278						1																	1	1	1.0
363							1																1	1	1.0
291							1																1	1	1.0
110							1																1	1	1.0
1215								1															1	1	1.0
997									1														1	1	1.0
707									1														1	1	1.0
571									1														1	1	1.0
486									1														1	1	1.0
1229										1													1	1	1.0
883										1													1	1	1.0
1402										1													1	1	1.0
530											1												1	1	1.0
1228											1												1	1	1.0
40											1												1	1	1.0
978											1												1	1	1.0
768												1											1	1	1.0
1333												1											1	1	1.0
255												1											1	1	1.0
207												1											1	1	1.0
1234												1											1	1	1.0
414												1											1	1	1.0
288												1											1	1	1.0
1176												1											1	1	1.0
508												1											1	1	1.0
1258												1											1	1	1.0
974													1										1	1	1.0
169													1										1	1	1.0
805													1										1	1	1.0
1372													1										1	1	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29	wk30
1265																														
503																														
1022																														
160																														
1250																														
1041																														
609																														
1046																														
406																														
937																														
627																														
292																														
1428																														
240																														
742																														
416																														
1137																														
1064																														
1243																														
72																														
1181																														
514																														
560																														
84																														
733																														
1160																														
564																														
176																														
1240																														
1257																														
495																														
1122																														
632																														
1207																														
203																														
280																														
829																														
1334																														
686																														
307																														
630																														
400																														
1051																														
1021																														
986																														
1247																														

Node	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
1265													1										1	1	1.0
503													1										1	1	1.0
1022													1										1	1	1.0
160													1										1	1	1.0
1250													1										1	1	1.0
1041														1									1	1	1.0
609														1									1	1	1.0
1046														1									1	1	1.0
406														1									1	1	1.0
937														1									1	1	1.0
627															1								1	1	1.0
292															1								1	1	1.0
1428															1								1	1	1.0
240															1								1	1	1.0
742															1								1	1	1.0
416																	1						1	1	1.0
1137																	1						1	1	1.0
1064																	1						1	1	1.0
1243																	1						1	1	1.0
72																	1						1	1	1.0
1181																		1					1	1	1.0
514																		1					1	1	1.0
560																			1				1	1	1.0
84																			1				1	1	1.0
733																			1				1	1	1.0
1160																			1				1	1	1.0
564																			1				1	1	1.0
176																			1				1	1	1.0
1240																			1				1	1	1.0
1257																			1				1	1	1.0
495																			1				1	1	1.0
1122																				1			1	1	1.0
632																				1			1	1	1.0
1207																				1			1	1	1.0
203																				1			1	1	1.0
280																				1			1	1	1.0
829																				1			1	1	1.0
1334																				1			1	1	1.0
686																					1		1	1	1.0
307																					1		1	1	1.0
630																					1		1	1	1.0
400																					1		1	1	1.0
1051																					1		1	1	1.0
1021																						1	1	1	1.0
986																						1	1	1	1.0
1247																						1	1	1	1.0

B.4. Spreadsheet of communications in CoP *cplus*

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
1483	16	13	22	40	38	24	30	31	27	44	46	30	12			2	21	14	19	21	25	12	28	19	28	26	20	16	36
1830	6	15	37	25	11	24	21	29	21	37	45	46	14	35	22	11	28	31	15	23	32	27	19	7	30	39	28	30	34
1805			2		24	28	15	32	13	4	12	10	19	15	24	17	15	12	5	7	3	2	13	8	19	27	17	13	20
1919											3	1			2	4	10	1	1	1	18	13	19	8	21	16	12	18	23
1009											2	30	19	27	36	16	25												
1067			4	10	7	18	27	43	9	15		1							2	11									
2489	3	2						1																	5	1			
1626		1	4	6	7	11	7	8	15	15	26	12	14	6	8	3	15	3	12	8	13	5	12	9	3	2	2	5	4
588														1		5	8	3			24	15	5					1	16
1312													1	3			3	2	1	3	2	24	20	12	12	15	9	5	4
1140		1	9	7	9		3	8	4	3	8	13	2	6	11	11	8	1			2	1	3	19	26	11	6	9	11
2740								6	5	2	12	12	5		6				1		1						1	3	20
713									1	2	1	3	2	7	8	6	12	14	5	3	7	2	2		3				
2754																												1	6
44									2		1			1	14	7	6	2		4	6	4	14	8	12	3	2		7
965	6	9	1	4	2	9	2	15	15	17	21	8	10	1	3	4	5	11	2		2	2	1						
2474		2		1	5			1	5	5	12	8	11	10	16	10	18	9	6	1	2	7	8	2	6	16	5	3	10
1504	1	7	8	7	6		2	12	1		2	7	7	2	1	4	7	8	2	1	6	2	6	13	21	7	1	2	1
1557	1	3	15	4		3									1				5	3	5	7	12	1		6	7	3	
2323				3	3	8	6	4	4	5	6	7	14	3	7	4	10	3	6				1	1	1		2	2	1
1525	6	7	4	3	8	7	3	2	3	5	15	5	1	11	8	2	2	5											
974		1	2	5	2	14	8	2	1	3		4	2	7	1	17	2	2			5	1	6	8	10	6	2	7	1
127	10	6	7	7	8	7	3	8	1	7	9	2	4	3	3		2	6	1	2	3	10	8		7	6	8		3
2689	6	1		3	1	1	2	3	1	2	6	5	5	5		7	9	5	5	3	5	1	1	12	4	12	2	6	4
2246	1	6	11	8	2	12	5	11	4	11	2	1	2	7		2	7	5	3	2	12	2				3	2	1	4
627			1	2	2		1	10	4	14	20	6	9	9	1	4	11	13		1	5	2	3	1		2		2	6
2360					7	11	4	1	2		1	5	1	1	2	6	4	5	1	3	6	9	11				3		3
2598								3	3	6	2	13	7	3	6	4	4	3	2	5		2	4	3	15	2	2	4	6
2062	6	6	6	7	6	7		3	3	5	3				2		4	1	4	6		5				5	3	1	
692	1	4	3	1	9	3	1	2	4	8	2					1	2	4	10	7	3	2	7				5	3	2
1294													5			1	9	4	1	1	2		2			4	5	1	2
655																						2	9	5	6	2	1	4	3
341			2	2	2	1	2	3	8	3	1				4	9	3	2	2	5		1	1	3	1	1	4		4
2520		6	3	6	3	2																							1
2615		3	3									2	17	7			1		2					2		4	1	2	1
960	6	9		2	2	3	13	10	4	6	8	8	4	2	2	3	2	1	5	4	5	6	1	4		1	1		2
986	1	2	9	5	4		2		1			3	2		2	2	4		2	1	11	8	5	2	9	8	5	4	2
948		1		1	3		2	6	5	7					10					3		3	1						
1188	1	8	3	6	3	1	2	7	4	5	3		4	4	2	3	8	2		3	4	7	1	7	3	1	5	3	2
1028	7	2	1	3	4	1	7	6	4	4	9	5				2	6	5	5	6			1		5	2	2		7
1623	2								3							5	6	1	2	4	3	6	13	9	8	8	1	3	1
1948	6	4	5		5	3		4	1	1			1	2	4		4	2	1	5	4	3	4	1	7	6	5	5	1
1992	1	7	6	6	5				6	3	10	11	3	3	1	2	1	4	2		1	1				1	1	1	
1838	2	8	7	3		6	8		3	4	2		4	1	4	2	2		1	2	3	2	8	2	4	3	8	2	6
118																												2	6
2322	2	1	2			6	4	11	7	5	3	1	3		2		2				1		4	2					
2355								3	1	8		9	4	1			3	4			3		4		6	1			
1533	1		1	4	2	5	5			2	2			14			1	3	2	4	8	7	2						3
192															1	4	1	1		9	7	6	4		2	3	11	2	1
807						5	4	5	4											1	3				1	9	4	4	11
738	11	2	4	6	3	7	2	4	1				1	6	1													2	1
1092		1	2	2	2	4	4	9	8	7	1	3	1	1									4			1	1		
2041		2	3	12	3		1	2	4	1																			
2653		1	1	1	2	3	2	1			1		1			1	4	4	6	4	4	1		4	4	3	1	2	7
2241		6	4	7	4	10	5	4	5	1	1		4	1	2						3	2	2			6	8	1	2
2111																		2	1	3	1	3	3	2	9	5	3	4	5
2725										2			2	9	2	3	5	1	2										
2331											4	6	2	5		4	9	7	1	1			2			1	3		1
2649			1	9	5				2	2			3	2	4	2	3	3	2	2	4	3	1						
1669	1	1	1																										1
1725	4		5	1										5					2		3					2			
266	2	9	5	4	2		1	1		1							4			2	2	2	4		2	3	2		
2585		1		1				3																					
2440									2					1							1	4						1	
2121																1				4	1	3	2	2	4	4	1	5	3
277																		1	2	2							2	2	1
743		1	3	6	1	4	9			2	3			1	3						1		1						
2458			1							13	1	4			4	2		1	1	2	1							1	
2600	1		1		2	1		1		3	1	2				2	5	1	2			2	2		7	2	3	1	2
518																	9	5	1	1		1	2						
1559		1													1	1	2	1	2	1	3	2	2	1	15	1	5	1	5
1443		1	3	4	1	8	2	2	4	6	3	2	4	2	4			5	3	3	2	5	2	2	2	1	1	1	3
2146						9	3	1	12	4		1	4	1	1	1		2			2		1		2	1	1	5	
2373								3	11	2	1			3		1	2		1			6	4			1			
1814						1					9									3	4		2						
1796																		2	4	1			7		1				
2328										2	1			7	4	4	5	2	2					1					
1378		1	2	2		6	1	6	4		4	2						1	1	7			1	1					1
106				2			1	1	1	1		2			1		2						1					1	
2595	2			3			1	1	2			1					4		1										
1032																													
1604		4		3	9	1	1	3	1	1	2	1	4	3	2		4	3			2	1	1	3	4	2	1		
1372			1						1	1	3	1	1	3			1			1	2	1	2		1	1	1	1	10
1970																		2											
515																					1	6							1
1192	4		1		2	1	1	2		2	4				6		1	1	2	7		1				2	1	3	2
969	4	1	2	2	1		1	3	3	8	2	6	2	1	3	1	1			3	1	1							2
145					1											2													6
1532							3	4	1	4	2	8			1	1	1	1	1	1	1	4							
1726				2				3	1	3	3	5		5		1	3	4			3	4					1		
2250																							2	2	2	1	3	2	2
289											5	3	1	1			1					3							
2579																		2	1		6		1						
1071																													

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
1483	32	20	11	19	32	26	14	27	2	15	24	9	24	32	7	41	41	12	23	32	24	37	33	1197	50	23.9
1830	36	27	30	18	30	29	26	11	9	16	22	10	26	36	43	15			2	9	2	7	10	1156	50	23.1
1805	27	17	9	7	14	17	12	5		9	22	14	11	13	35	16	17	19	12	25	43	32	13	765	48	15.9
1919	38	25	15	11	26	8	6	5	2	18	15	4	11	24	19	32	31	26	14	16	9	34	30	590	40	14.8
1009														7	1	4	20	9	1	14	6	5	10	232	17	13.6
1067	2	3	2																					154	14	11.0
2489					1	4	5	3	7	15	16	11	10	18	14	7	27	12	13	8	18	22	21	244	24	10.2
1626	16	21	3	13	5	4	11	15	8	13	7	8	5	4	15	4	6	5	8	6	1	2	2	418	51	8.2
588	5	7				1					2		3	2							4	10	28	140	18	7.8
1312	2	3	8	5	16	18	4	2			2	9	2	3	11	9	2	8	8	4	1		22	255	35	7.3
1140	7	2	5	1	2		1	2			3	3	6	12	9	9	13	10	9	6	11	15	2	320	45	7.1
2740	9	8	1	25	2			3																122	18	6.8
713				19	7	2	9	11	5	4	7	8	10	15	6	2	5	11	4	5	7	4	14	233	36	6.5
2754	24	15	1	4	11	2		1			1			10	15		2	1				1		95	15	6.3
44	1	5	3		1	10	2		1	2	2	2	3	1	4	1	9	26	5	3	24	19	10	227	37	6.1
965									1	10	3	1	9	2	3								3	182	30	6.1
2474	3			7	3	3	2	1		11	5	4				1	2	1		1		3		226	39	5.8
1504	5	2	2	2		2				2	1			14	3	5	6	8	6			8	1	211	42	5.0
1557	1	2			4	5		8			1	5	9	11	6	1	3	2		1		1	4	140	31	4.5
2323	5	9	2	6	2	4	9	7		5			5	6	1		1	3	1					167	37	4.5
1525															1	1	1	2	3	2				107	24	4.5
974	3	1					1					3	5	3										135	31	4.4
127	4		4		5	1	4			1	2			3	2	1	3	3		1		1	1	177	41	4.3
2689	8	8	6	2	1	4	3	3	3	2	1		4	9	4	7	4		2	1	1			190	46	4.1
2246	2	2	1	2	1	2			1	1	1			5	3	3	4	1	4	3	4	12	3	181	44	4.1
627	1	1	2			1	1	1		1	3		1		1	1	5	3	2				1	154	38	4.1
2360	10	6	3	7	2	4			3	2	4	1	4	2	2	1	6	2	4				2	151	38	4.0
2598	3	3					1			2	3	1	4	4	5		2		1	4	6	4	1	143	36	4.0
2062			1			4	6	6	5		1					1	3	6	3	2	1	2	7	131	33	4.0
692		1	2	1	9	2	5	5	3	12	4	3	7	6	4	3	4		2	1	2	8	2	170	43	4.0
1294	3	4	2	4	7	6	2	5		3	6	3	2	7	2	4	4	4	1	5	5	9	7	132	34	3.9
655	1	6	10	11	13	3		1		1	1			4	1	1	1	3	2			5	1	97	25	3.9
341	3	8	7	2	10	8	4	5	4	2	3	9	4		6	2								141	37	3.8
2520	1	9	10	8		1	2	1				3									1			57	15	3.8
2615																								45	12	3.8
960	1		4	1	1	1	7	3	1				2	1	2	3	7	7	2			1	2	160	43	3.7
986	5	6	4	4	1	2	1		1	1	3	2	9	2	1	1	12	7	1	1	2			160	43	3.7
948	2	4	2																	6		5	2	63	17	3.7
1188	5	13	8	1			1			3	6	2	2	2		1	1	1	1					149	41	3.6
1028	1		2	2		2	2		1	2	1					6				2			2	117	33	3.5
1623	3	1	3	2	2		1	1	1	2	1													92	26	3.5
1948	9	2	2	9	4	5	5	2	2			2	1	3	5	2	1	2	6	2	5		2	155	44	3.5
1992	4			4	1	2		4	4	1	3		1	5		1	3		1	5	3	8	7	133	38	3.5
1838	4	6	1	6	2	2	4	2			1	2	2	3	3		2						2	139	40	3.5
118	10	5	3	1	5	3	1		1		2	1		2			10	2		4		1		59	17	3.5
2322		1	3	2		1							3	10	3		1							80	24	3.3
2355	2			2	1		1																	53	16	3.3
1533	1	2	3	3			1	2		1														79	24	3.3
192	2	3	1	3	5	1		1											1					69	21	3.3
807	3		1		1					1			1		1	1	1		2					63	20	3.2
738	2	1	1	1	1	3	1		1		5	1	3	3		3	4		1	4	5	9	3	103	33	3.1
1092				2		1	1			1								2	3	3		6	8	78	25	3.1
2041													2	1										31	10	3.1
2653	9	6	4	1		1	3	8	3	3	7			1	6	2	2	2	2	5	2		2	127	41	3.1
2241		2	1		2			1						2	2	2	2		1	1	4	3	1	102	33	3.1
2111	2		1				2		1	1		5	2	2	3	2	6	4	3	1	5	2		83	28	3.0
2725						1		4	3	3	1	6	1	2										47	16	2.9
2331	4			3		1			1	1	1					5	3					1	1	67	23	2.9
2649								3	3		3	5	1	1										64	22	2.9
1669	12	9	3	3	7	2	1	3	1	1	2	2		2		3		1					2	58	20	2.9
1725																	3		1					26	9	2.9
266																								46	16	2.9
2585		4	8	1			1			2	1	8			1									31	11	2.8
2440		1									1	2	1	1	3	7	11							36	13	2.8
2121	2	1	3	1	10	6	1				1						2	1						58	21	2.8
277	5	1		5	1	3	1	2	5		1	1	7		4		5	6			2	3	1	63	23	2.7
743										2	2		2											41	15	2.7
2458			2		1					5	2													41	15	2.7
2600	2	2	6	1	3		8	1	1	3		1	4	2	3	3	4	4	6	1	3	3	5	107	40	2.7
518						1												1						21	8	2.6
1559	3	4	1													2				1				55	21	2.6
1443	4	4	2	2	1	3	1			3	2	1				1	1						1	102	39	2.6
2146	4	1			1	2	2	2														1	1	65	25	2.6
2373	3	1		2	2				1	2	1	2							3					52	20	2.6
1814								1		1		5								2	1	1	1	31	12	2.6
1796	1						2	2	1	1				5	4									31	12	2.6
2328	1																1		2	1				33	13	2.5
1378		1																			2	2		45	18	2.5
106	1			2	1	1	1		3	7	4	1	4	2	1		7	2		6	5	4	4	69	28	2.5
2595	1		1		1				3			3	4	5	3	1	4	2	2	4	3	2	5	59	24	2.5
1032	5	4	2	6		1			1		1				1		2					1	3	27	11	2.5
1604																1	2	1			2	4	2	68	28	2.4
1372	1	8	1		1		2						5		3	2	8						2	65	27	2.4
1970				2	1													5			2			12	5	2.4
515															3			1						12	5	2.4
1192	3			2				3	2	2	6	1	1		2		4			2	1	2		74	31	2.4
969			2												5	1			1					57	24	2.4
145	3					3	1		3	1				4	1				1					26	11	2.4
1532																								33	14	2.4
1726		2			2							1	2	3		1	1		1			1	1	53	23	2.3
2250				4		5	1	4		2	1	1												32	14	2.3
289							2																	16	7	2.3
2579		1			3	2																		16	7	2.3
1071													7		1			3	1	1	1	2		16	7	2.3

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
1657		6	2	3	1	2		2		3				4		1		1		1			3				1		
38												1											4		7			1	2
2701	2	3		2	2																								
15	1	4	1	3																									
1388	1	2																											
1634		2	4	2		1																							
558								2			4																	2	1
303								2	4																				2
1236																													
1934																													
2396														3	1			1		1			2		1	1	4		1
2580		1			1	1		4	7			1	2		2	2							1						
2716											1		2				1	1				2	5		1				
2050																													
1709					2	1																				1	1		
650			2								3	1										2							
1949																		2	2	1		4				1			
1665				2		4		1	3									1			2	2							
308		4	4	2	1	2	2				3		1		1								1			1			
1766													1								2		1		1			2	2
2665																4	4			2	2				1	1			2
2681																			2	1	7	1				1			
897	4						2				2				1				1	1	1	3				1			
1403																											1	2	3
1041			1			3	1	1		3				1	2				1	3	1	3	3	1	1	5		1	4
2150						1			1	3		2	5	2	1	2	2			2						4	3	2	1
463		1				1		3	1	2		3	2	1			1		3		4	5	1			1			
1289							1	1	2	2								4		1						3	4	1	1
482														1			2			1		1							
938						2	1		4		2					1					2	2			1				
1636									1	1				2		1	1									2	1		
2320		1																					1		1	2		1	1
1722					1			2	4	2	3	3	1																
2216									5	1	3		4	1	1			1	1	1									
2338			1	6		1						1		1	4	1													
1819						1								7		3							1	1		1	1		
1842		2	3	4		2																							
2744					1			4	4	2	1							1				1							
99				1	4	1			2	2																			
2230							2	1																1	2			4	
247												1								1						1	3		4
580																		1	2	3			2	2					
1110																													
2275																													
1637					2		1			3	2																		
537																													
138																													
2020																													
2015	3						1							1	2		1	2	1	1	1	1	3	2	1	1	1	2	
2721																									1			1	3
2277			2		2	3				4	3	1	1						1						2	1	2	2	1
489	2		2	4	3									1		1													
2154		1	3	1		2	1			3	2		1		1	2	5	1	1		1	1	1	3					
918		2					2	1			2				1					2				1	4				
1887								1	1	2	2		1	3	5	1												3	1
1512																										3	1	3	
181		1								1	4	4	2	3	5	5	1	1	2					1					
1698						2		3		3	2	2				2			1	2	1		2		1				
1655		3	4	1											1			1	2										
2589																		6		1	1	2							
784		1												7	2												1	1	1
2465		1	2																	1	1					4			1
274	1	4	1		2	2				1																			
936		6						3		2	1						2							1		1			
632			6	1							1				1	1					1	2			2				
1617		1								3	1	1	1	3			2			1			2						
1000				2	1	1	1				1		3	1			1	2	1	3	2				1			2	4
1157		1																	1	2	1						1		
775							1						2	1					4	1			1			3			3
2175	1	1	6	4	1	1	1	1	1									1											
88	2														1														
2375			1										1																
955															1							1							1
1609																				1	1								
1546																								2		2	1	3	
2393																								1					
2388			1	2						1	4	2	2			1	1												
678													1													2	2		
2441																													
612		1							2			2		1		1	4			2			1						
2736					2			2		1		1	1	1	3						1								
2228									1	1	3	1								3			1						3
2391								2		1			2												3				
1775												3						2			1	1	1	1			4		
225								1																					
1089																1		1											
1908																		2	1			2	2						
1316																									3			1	
2587																											2	3	1
744																												4	
1753																													
2071																													
1205	2	2									2	4	2			2	2	1	1						1	1	3		1
1337													1	3	2	1	3	1											1
1897															1		1	2							5	1			

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
1657	1	2	2	4	1		1	2	2	2	5	6	1		2	1			1		3	2	2	70	31	2.3
38				1	1							1	3	3	1	2								27	12	2.3
2701																								9	4	2.3
15																								9	4	2.3
1388																					5	1		9	4	2.3
1634																								9	4	2.3
558																								9	4	2.3
303																			1					9	4	2.3
1236								1		3	3									2				9	4	2.3
1934										5	1	1		1	5	2	2	2			1			20	9	2.2
2396	2		2	4	11	1		1	1			2	1		1		2	2	2			1	5	53	24	2.2
2580																								22	10	2.2
2716													3	3	3									22	10	2.2
2050							2	5	2										1		1			11	5	2.2
1709						1			4	3	2	5	3							1				24	11	2.2
650		1									1			1	1		3	3	7	1				26	12	2.2
1949		6	1			1	2	2	2	2									2					28	13	2.2
1665																								15	7	2.1
308		1			1					2	7				1									34	16	2.1
1766	5	3																						17	8	2.1
2665	1																							17	8	2.1
2681								1											3	1				17	8	2.1
897	2			2		1	2				3	1		1		1	3					7	3	42	20	2.1
1403		2	2	1		2	3		3		1	3	2	1	2	1	4	3	1	2	3	2		44	21	2.1
1041	5		1		2	3				1			1			3			1					52	25	2.1
2150				1	3							1									1			37	18	2.1
463	2	2	2		1		1		1	1	2	2	2		1			3			3	4	2	58	29	2.0
1289	2	4	2	1	1	3					2		3	1	1			2						42	21	2.0
482		1	3	2		1	1	3	2					2		4	1		2		5		2	34	17	2.0
938												1		1		1					4	3	3	28	14	2.0
1636			7	2				1			1				1							3	4	28	14	2.0
2320	1	10	2	1			1																	22	11	2.0
1722															1		1							18	9	2.0
2216																								18	9	2.0
2338		1																						16	8	2.0
1819						1																		16	8	2.0
1842																			1	1	1			14	7	2.0
2744																								14	7	2.0
99																								10	5	2.0
2230																								10	5	2.0
247																								10	5	2.0
580																								10	5	2.0
1110		2	1		1		5	1																10	5	2.0
2275															4	2	1	1					2	10	5	2.0
1637																								8	4	2.0
537	3				2	2	1																	8	4	2.0
138										3			2	2		1								8	4	2.0
2020																				2	3	2	1	8	4	2.0
2015	4	2		2	7	3	1		3	1	1	1	4			2		1	1		2	4	2	65	33	2.0
2721	5	1	2	2		2	1	2		1					2			2		2	2	2		31	16	1.9
2277	4		3	3	4			1	2		2	1	1	1				1	1	2		1		52	27	1.9
489		2	2	3	2	1								1				1						25	13	1.9
2154	1	1		1	2	1	8	3														1		48	25	1.9
918						1							2					3						21	11	1.9
1887		1	2			1	1				1	1		2		1		1	2	7				40	21	1.9
1512		1	1		2			1								3	2	2						19	10	1.9
181		1		1	1	1			1		1		1	1	1									39	21	1.9
1698				1		1								2	5	1	1	2			2	1	2	39	21	1.9
1655																1								13	7	1.9
2589							1									1	1							13	7	1.9
784		1		1													4	1		1	1			22	12	1.8
2465	2	2									1					1	5	1						22	12	1.8
274																								11	6	1.8
936			1							1					1	1								20	11	1.8
632		1			2					2														20	11	1.8
1617	1	2	1	3			1												1				5	29	16	1.8
1000	1	6		4	2						1				1	2	1	1	1	1				47	26	1.8
1157	1	2	1	1	9			2		1						1						2	1	27	15	1.8
775	3			1						1						2		2	1		1			27	15	1.8
2175																								18	10	1.8
88																3	2				1			9	5	1.8
2375				3		3									1									9	5	1.8
955																3				3				9	5	1.8
1609															3			1					3	9	5	1.8
1546	1																							9	5	1.8
2393								2									1					2	3	9	5	1.8
2388		2																						16	9	1.8
678					1	2	1		2		2				3									16	9	1.8
2441	3	1	1		4	1			1	2		2	1											16	9	1.8
612						2		1			1				3									21	12	1.8
2736									2	2		3								2				21	12	1.8
2228										1	1		2	3	1									21	12	1.8
2391	1									1	1						3							14	8	1.8
1775						1																		14	8	1.8
225																					2	3	1	7	4	1.8
1089				2	3																			7	4	1.8
1908																								7	4	1.8
1316	1	2																						7	4	1.8
2587																			1					7	4	1.8
744		1		1			1																	7	4	1.8
1753							3	2	1	1														7	4	1.8
2071													1	4	1	1								7	4	1.8
1205						1	1																	26	15	1.7
1337																								12	7	1.7
1897				1		1																		12	7	1.7

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
2380																							1	2	2		3		2
2711	3	1			3	3	1		1	2		1		1	1				1				3						
2349			2	1							2			2															
360					1		1	2	2	1	3																		
1946					1		1																	4		1			1
2487																									1				5
2236				1					1	1						1	1				2					1	3	5	
1563						1		2				1	3	1	1						1	3				1	2		
112			1				1															3	2				1		
971							2						2	1			2									1			
174											2	3	1		1											1			
2726												1	1		2					2	2								
2659																		1		1									
2576																										3		1	
2106																													
2597	3		2																					1	1			1	1
2442	2			2	1										1											1	1		1
896																										1		1	
2628			1	2															1										1
2201																						1			2				
2200																											1		2
377			1		1					1							1				1				2				1
1290						2	1	2			1						1	2				1	2		1				1
1986				1				1	1					1		2	2	2			1	4	2			2	1		
2483			1			1			1	2								2										1	
215		1	3	2	1	3	1	1									1		1										
1288												2				1										1		3	1
2379																				1	1				2	1	1	2	
1287																													
2438														1	4	1				2									
2136					1								1																
234															1							1							
2232																												1	2
416		3												1											1	1			
2537			1	1									3																
2262							2		1																				
1631																1			3		1		1						
1176																				1									
2336																						3	1						
2673																													
698		2		3		1			1			1					1	3	1				1						
1266											1							3			1	2	1		2	1			
1760		1		1	1	1	1	1	2				2		1						1	1						1	1
1717										1									1				1				1	1	2
751																							1	1	1	1	2	3	1
774						3										1			2										1
964														1				1						2					3
988											1	1	2				1								1	2	2		
1246																2			1	1					1	1			
945	1	2		2	2				1	2											1	1	1			2			
2001	4			2									1	1													1	1	
2791					1				1	2	1						1			1	3					1			
2363																		1							2				
179								1														1	2		2	1			
1585																					1	1		3	1				
1917		2	2		1		1				1		1										1						
834		2		2				2			1				1														
569														1					1							1		2	
1345																											1		
1053			2	1	2	1		1						2					1										
1943			2	2							1		1		2					1		1	1						
2611													1	2			1		2	1	1					3		1	
600		1	1						1								1								2			2	
2494					2			1						1						2					1				
2456																													
2761		1									1	1											2						
2660					1																	1	1						
1896													1	1	1	1	3		1										
2613																				1			2						
43																					1	1							
1930																													
954		2	1	1	1		1	1		2	1			1													1	1	
2014	2	1		1		1		1	2	1																			
1841				1		2							1														2		
900																		1											
2021																						2	1	2	1	1			
2381	1			1		1			1					3				1						1					
260											1				2	1	2		1	1	1		2						
2251		1			1	1			1		1										1	3			1				
1063			2			1		1	1																				
338			2							1		1			1														
1044			2										1																1
2679				1	2	1	1																						
2174					1																					1			
2651					1																								
2273							1				1																		
848										1		2												1		1			
1210											1														1				
160												1	2																
952																			2	1									
2240																			1	1				2					
565																										1			
658																											1	1	2
374																											2		
1882																													

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
2380			1	1																				12	7	1.7
2711	1																							22	13	1.7
2349				1	2																			10	6	1.7
360																								10	6	1.7
1946	2																							10	6	1.7
2487	1	1											1							1				10	6	1.7
2236	2		2	1	2		1				2		3	1		1			1		1	1		34	21	1.6
1563																								16	10	1.6
112																								8	5	1.6
971																								8	5	1.6
174																								8	5	1.6
2726																								8	5	1.6
2659						4											1						1	8	5	1.6
2576	2																		1		1			8	5	1.6
2106							1	1	3	2	1													8	5	1.6
2597											3					1		1	3		1	1		19	12	1.6
2442	1					1	1	4	2						3						1			22	14	1.6
896						2	4	1		1								1						11	7	1.6
2628											3			2					1	2	1			14	9	1.6
2201	1			1			1	3				2	1			2								14	9	1.6
2200									2	2		2	1								2	1	1	14	9	1.6
377							2			1					2	1	2				4			20	13	1.5
1290	4						1								1									20	13	1.5
1986	1	1	1																					23	15	1.5
2483	1					1		3						2								2	1	18	12	1.5
215																	1							15	10	1.5
1288	1													3	1			1	1					15	10	1.5
2379		1			1							3						2						15	10	1.5
1287			1	3	1	1	2			1		2						1			1		2	15	10	1.5
2438						1				1					1		1							12	8	1.5
2136							1									1		3					2	9	6	1.5
234									1	4					1						1			9	6	1.5
2232	3									1	1				1									9	6	1.5
416																								6	4	1.5
2537	1																							6	4	1.5
2262													1				2							6	4	1.5
1631																								6	4	1.5
1176								1	1	3														6	4	1.5
2336																	1	1						6	4	1.5
2673																	1	2		2	1			6	4	1.5
698												1											1	16	11	1.5
1266		2	1							1	1													16	11	1.5
1760		1			1									2	3	2						2	3	29	20	1.5
1717									3		1				2									13	9	1.4
751						2								1										13	9	1.4
774		1	1	1									1		1	3	1	1	2				1	20	14	1.4
964	1	1	1	1	1	1				1							3	1		2				20	14	1.4
988																								10	7	1.4
1246	1	3																						10	7	1.4
945	1																						1	17	12	1.4
2001						1				1	1										1			14	10	1.4
2791																	2					1		14	10	1.4
2363							1	1	1		2			1	2				1	2				14	10	1.4
179																								7	5	1.4
1585																					1			7	5	1.4
1917		2																						11	8	1.4
834														1				1				1		11	8	1.4
569	2							1			2			1										11	8	1.4
1345	1				2		2		1	1			2			1								11	8	1.4
1053										2	1			1			1							15	11	1.4
1943		1			2																		1	15	11	1.4
2611		1			1																1			15	11	1.4
600		1		1					2															12	9	1.3
2494				1										1		2			1					12	9	1.3
2456							1		1			3	1	2		1	1				1	1		12	9	1.3
2761	2	1																						8	6	1.3
2660																				1	2	2		8	6	1.3
1896																								8	6	1.3
2613					1		2													1	1			8	6	1.3
43			1							1	3	1												8	6	1.3
1930						1	2		1		1	2			1									8	6	1.3
954	2		1	3			1	1																21	16	1.3
2014																								9	7	1.3
1841	1	1					1																	9	7	1.3
900			1				2		2									1				1	1	9	7	1.3
2021		1															1							9	7	1.3
2381												1		1	1					2				14	11	1.3
260							1				1				1	1								15	12	1.3
2251																								10	8	1.3
1063																								5	4	1.3
338																								5	4	1.3
1044									1															5	4	1.3
2679																								5	4	1.3
2174																				1			2	5	4	1.3
2651	1										1					2								5	4	1.3
2273		1											2											5	4	1.3
848																								5	4	1.3
1210				2	1																			5	4	1.3
160												1									1			5	4	1.3
952	1									1														5	4	1.3
2240							1																	5	4	1.3
565			1																		1	2		5	4	1.3
658	1																							5	4	1.3
374											1	1											1	5	4	1.3
1882			1		1			1		2														5	4	1.3

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
1993																													
1616																													
1214																													
1461																													
963																													
689															1	2	1	1		1	1		1						
102	1		1												2	1	1												
616			1	1		1	2								1														
1123				1											2											1			
2205										2																		1	
628																		2		1	1		1		1				
1710			3		1														1	1		1			1		1	1	1
2075						1			1	1		1																	
1739																				1			1	1			1		1
1812									1		1												1		1		1	1	1
859	2					1	1					1											1		1				
1430	1		1		1						2												1						
1662					1	1		2				1	1				1												
1425																		1											
1651																													
335						1								1						2					1				
1048																													
2635																													
571	1		1					1							1		1												
1005									1						1					1					1		1		
981													1					1			1	1					1		2
405							1								1		1	1										1	
1358	1					1						1				1						1						1	
1080					1		1	1	1					1				1	1										
2247															1	1	1												
1727																								1	1	1			1
1234										1		1		1												1			
1922											1				1			1								1			1
2720					1	1																							
1612	1																										1		
1644	1		1																						1				
1383		1			1	1	1			1																			
1834		1									1					1						1							
1218		1		1	1		1			1																			
25				1	1	1									1										1				
536															1													1	
91																							1			1	1		1
1462																							1						
1109																									1		1		
1782																											1		
2384																													
2667																													
1265																													
200				1		1																			1		1		
1542				1				1	1						1														
2784					1	1					1																	1	
2132						1	1																						
2122							1	1																					
1166								1	1		1																		
8									1						1													1	
1124										1			1								1								
2202										1	1						1												
1535											1															1			
445												1														1			1
2089													1																
1802															1						1								
2545																1	1						1		1				
1448																1		1	1										
1885																			1	1									
422																				1	1				1	1			
1677																							1						
2385																													

10			1						1	1	5	3		1	6				2		2								
1854																													
598	1		5	3	1		1																						
643																						1	6	3	1	1		2	
296		1	2			4	3																						
1215																							1	4	2	3			
398																											2	4	2
355																													
2042	1																												
1963																							2	2	5		3		2
2181								6	3	3																			
1392									3	9	1								2	2	3								
819																													
2519		3	5	4													3	1		2									
1156														1			1	2	1	4	9	6							1
110															1						3	5	3						
1191	3			4														3	6						1				
1672																													
1007													5	2			1												
144														3		2													7
2460		1																											
1942																											8	4	5
221							1																	1	15	1	1		
1923	2	9	3	2	3			2	4	16	4	2		1	1	1	3												

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
1993						1			1									1	2					5	4	1.3
1616							1	1		1	2													5	4	1.3
1214								2					1						1	1				5	4	1.3
1461												1	1			2					1			5	4	1.3
963												1	1	1					2					5	4	1.3
689	2	2		1				1							1	1			1					17	14	1.2
102																								6	5	1.2
616																								6	5	1.2
1123																		1		1				6	5	1.2
2205	1									1						1								6	5	1.2
628																								6	5	1.2
1710	1																					1		13	11	1.2
2075									2	1	1	2	1								1		1	13	11	1.2
1739				2	1							2		1	1			1						13	11	1.2
1812					1			3			1					1			1					14	12	1.2
859																								7	6	1.2
1430																			1					7	6	1.2
1662																								7	6	1.2
1425				1							1		2		1						1			7	6	1.2
1651		1							1					1	1		1				2			7	6	1.2
335											1				1			1						8	7	1.1
1048			1	1	1		2		1	1													1	8	7	1.1
2635													1	1		1	1		1	2	1			8	7	1.1
571		1					2		1															9	8	1.1
1005		2	1				1																	9	8	1.1
981				1			1																	9	8	1.1
405												1	2					1		1				10	9	1.1
1358						2						1	1		1	1		1		1				14	13	1.1
1080																						1	1	9	9	1.0
2247	1			1									1								1	1		8	8	1.0
1727	1		1	1	1																			8	8	1.0
1234			1			1									1									7	7	1.0
1922																	1					1		7	7	1.0
2720	1	1		1	1																			6	6	1.0
1612															1					1	1			5	5	1.0
1644		1																					1	5	5	1.0
1383																								5	5	1.0
1834		1																						5	5	1.0
1218																								5	5	1.0
25																								5	5	1.0
536		1														1						1		5	5	1.0
91	1																							5	5	1.0
1462				1						1						1	1							5	5	1.0
1109	1																1			1				5	5	1.0
1782															1	1	1				1			5	5	1.0
2384				1					1					1					1	1				5	5	1.0
2667						1	1						1			1	1							5	5	1.0
1265																1	1				1	1	1	5	5	1.0
200																								4	4	1.0
1542																								4	4	1.0
2784																								4	4	1.0
2132										1						1								4	4	1.0
2122															1				1					4	4	1.0
1166																1								4	4	1.0
8																				1				4	4	1.0
1124			1																					4	4	1.0
2202									1															4	4	1.0
1535	1		1																					4	4	1.0
445	1																							4	4	1.0
2089				1	1																		1	4	4	1.0
1802			1	1																				4	4	1.0
2545																								4	4	1.0
1448																	1							4	4	1.0
1885	1										1													4	4	1.0
422																								4	4	1.0
1677	1					1	1																	4	4	1.0
2385	1		1	1	1																			4	4	1.0

10																								22	9	2.4
1854									3	1	1	2				1	3	1	6	3				21	9	2.3
598													3											14	6	2.3
643																								14	6	2.3
296																								10	4	2.5
1215																								10	4	2.5
398	3	1							3															15	6	2.5
355													2	7			1	3	3	2	2	1		21	8	2.6
2042					3		6	1																11	4	2.8
1963																								14	5	2.8
2181										1		1	5		3	3								25	8	3.1
1392			3	2																				25	8	3.1
819						7	5	2	1									1			6	6	3	31	8	3.9
2519																								18	6	3.0
1156																								25	8	3.1
110			4	4																				20	6	3.3
1191																								17	5	3.4
1672																			8	5	2	1	1	17	5	3.4
1007																			1	4	8			21	6	3.5
144	7	1	1																					21	6	3.5
2460																		5	4		1	6	4	21	6	3.5
1942	4	1	2		1																			25	7	3.6
221											3													22	6	3.7
1923																								53	14	3.8

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
2590											2		2		2		2		1	1	10		5	6	2	7	7	2	
2565	2	8	4	6	7	1	2	3	1	4	2	5	2	2	10	6	3	1											
1328	7	17	4	8	6	2	1	1	1	5	3	3	1				1												
2685										2																1			
2527					7	5		2																					
2782																					5		6	1	3				
1600																													
911																													
2346			9	14	2							1							3										
2684																											4	12	12
1712								8	3	4	9	3	7		6	13	4	3	11	7									
799																													3
1397						1	8	14	2																				
400	2	7	8	15	5		5	10	4	6	3	7	3	5	3	3	5	4	1										
535																													
1776																													2
1096																													
152													11	7	25	13	2			1	4								
1407																													
2362																					1	2	8		40	13	12	7	31
1832																													
2052																						7							
83						2		1	1	7	3				1														
1257											1																		
1428																													
1368																													
794																													
466														24	3														
2691																													
1537												6																	
531																													
1260																													
1576		6	8	2																									
943																												3	10
1607																													
1238																						5							
2506																													
1212																												6	3
697														5	4	4													
586																													
2448							1	2																					
1754											2	5	5																
2269																													
436																4	4												
1344																													
2737																													
2143																													
1547																													
302									4																				
2501											4																		
2482																4													
634																					4								
1406																										4			
2295																												4	
344																												4	
50																													
2408																													
35																													
352																													
854																													
1253																													3
380																													
2536																										1			
534		4	4		1																								
1936				2	3								4																
135					1								1	7															
468		1	5																										
2264																			3						3				
1790																													
1862																													
977																													
1903		3																											
2387					3																								
793									3																				
920												3																	
2229													3																
929													3																
465														3															
1733																	3												
881																	3												
2044																		3											
1396																			3										
2594																				3									
2562																							3						
1583																									3				
785																										3			
2446																										3			
2278																										3			
2110																												3	
737																													3
2652																													3

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
2590	7	5			2									1										64	17	3.8
2565																								69	18	3.8
1328	1																							61	15	4.1
2685													13	10	3	7	8	6	1	2	3	14	8	78	13	6.0
2527				1																				15	4	3.8
2782																								15	4	3.8
1600																		1			6	5	3	15	4	3.8
911																	15	25	20	24	5	5		94	6	15.7
2346																						2	12	43	7	6.1
2684	17	8	8	4	8	4	4	15	8	6	7	1	8	7	2	5	1	11	3	5	2	6	5	173	26	6.7
1712														2								1		81	14	5.8
799	9	7	4																					23	4	5.8
1397							3																	28	5	5.6
400																								96	18	5.3
535											6	8	12	9	7				4	6	13	4	1	70	10	7.0
1776	3	2		4	4	4	11	13	9	14	25	13	3	14	6	2	6	3	3	1			2	144	21	6.9
1096														1		1	6	21	14	11	6	6	16	82	9	9.1
152																								63	7	9.0
1407																1	7	7	13	25	16	24	8	101	8	12.6
2362	24	3	2	2	3																			148	13	11.4
1832																	24	22	20	33	24	64	49	236	7	33.7
2052																			7	2			1	17	4	4.3
83									2	4	3	2	1	12	18	9	5	3	2	2	1		5	84	20	4.2
1257							11	11	1	1							3						1	29	7	4.1
1428														7	12	5	5	14	13	3	2	3	1	65	10	6.5
1368																	7	1	7	10	7	11	6	49	7	7.0
794															16	26	10							52	3	17.3
466																								27	2	13.5
2691																				7				7	1	7.0
1537																								6	1	6.0
531																			1	10				11	2	5.5
1260																				3	8			11	2	5.5
1576																								16	3	5.3
943	2																							15	3	5.0
1607																				8			2	10	2	5.0
1238																								5	1	5.0
2506	5																							5	1	5.0
1212																								9	2	4.5
697																								13	3	4.3
586																				2	10	1		13	3	4.3
2448														9										12	3	4.0
1754																								12	3	4.0
2269																5	3	4						12	3	4.0
436																								8	2	4.0
1344				2	6																			8	2	4.0
2737																			4	4				8	2	4.0
2143																					6	2		8	2	4.0
1547																						2	6	8	2	4.0
302																								4	1	4.0
2501																								4	1	4.0
2482																								4	1	4.0
634																								4	1	4.0
1406																								4	1	4.0
2295																								4	1	4.0
344																								4	1	4.0
50	4																							4	1	4.0
2408	4																							4	1	4.0
35				4																				4	1	4.0
352																	4							4	1	4.0
854																							4	4	1	4.0
1253	4																							7	2	3.5
380													1	6										7	2	3.5
2536															6	3								10	3	3.3
534																								9	3	3.0
1936																								9	3	3.0
135																								9	3	3.0
468																								6	2	3.0
2264																								6	2	3.0
1790						2				4														6	2	3.0
1862												5	1											6	2	3.0
977																			4	2				6	2	3.0
1903																								3	1	3.0
2387																								3	1	3.0
793																								3	1	3.0
920																								3	1	3.0
2229																								3	1	3.0
929																								3	1	3.0
465																								3	1	3.0
1733																								3	1	3.0
881																								3	1	3.0
2044																								3	1	3.0
1396																								3	1	3.0
2594																								3	1	3.0
2562																								3	1	3.0
1583																								3	1	3.0
785																								3	1	3.0
2446																								3	1	3.0
2278																								3	1	3.0
2110																								3	1	3.0
737																								3	1	3.0
2652																								3	1	3.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
504																													
741																													
2712																													
912																													
2533																													
1892																													
611																													
257																													
272																													
2763																													
301										1	6	1																	
543															4	2								2					
2642																					1		1	6					
1844																										3	4	1	
1201																													
2047		3			2																								
2377				2	3																								
1747					1	4																							
791						3		2																					
1889								2																					
2765													1																
391																									2	3			
719																											4	1	
1738																											3	2	
1047																													
552																													
837																													
1199				2		4													1										
1310															5														
1116																							5			1		1	
2650																										4	2	1	
1958																													2
2542																													1
201																													
786	4	1																											
452	1						4	1																					
87							4	1							1														
613							1																		4	1			
2758														4													1		1
550																			3		2	1							
2012																							3	1	2				
2282																							3					1	
1327																													
2332																													
2608	2		2																										
134		3			1																								
131								3			1																		
1730									3																				
592									3																				
1006										1											3								
443														3	1														
2027															3														
2750															1	3													
324																						2							
2183																								1	3				
825																											1	3	
431																											2		
2102																													3
2567																													1
2459																													
2017																													
2094																													
790																													
2306																													
1322																													
622																													
928																													
2382																													
724	2																												
1989	2																												
882		2																											
1039				2																									
1132				2																									
1274					2																								
410					2																								
479					2																								
1138						2																							
733							2																						
1704									2																				
2357									2																				
2778									2																				
2491									2																				
1450										2																			
1228												2																	
59														2															
339															2														
2723															2														
2426															2														
2544															2														
383															2														
1022																	2												
976																	2												
484																	2												
2490																		2											
2303																		2											

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
504					3																			3	1	3.0
741						3																		3	1	3.0
2712														3										3	1	3.0
912															3									3	1	3.0
2533															3									3	1	3.0
1892																3								3	1	3.0
611																3								3	1	3.0
257																			3					3	1	3.0
272																					3			3	1	3.0
2763																							3	3	1	3.0
301																								8	3	2.7
543																								8	3	2.7
2642																								8	3	2.7
1844																								8	3	2.7
1201																				1	6	1		8	3	2.7
2047																								5	2	2.5
2377																								5	2	2.5
1747																								5	2	2.5
791																								5	2	2.5
1889																							3	5	2	2.5
2765								4																5	2	2.5
391																								5	2	2.5
719																								5	2	2.5
1738																								5	2	2.5
1047														3			2							5	2	2.5
552																					4		1	5	2	2.5
837																					1	4		5	2	2.5
1199																								7	3	2.3
1310							1	1																7	3	2.3
1116																								7	3	2.3
2650																								7	3	2.3
1958				4	1																			7	3	2.3
2542							5	1																7	3	2.3
201																			3	1			3	7	3	2.3
786				1																				6	3	2.0
452																								6	3	2.0
87																								6	3	2.0
613																								6	3	2.0
2758																								6	3	2.0
550																								6	3	2.0
2012																								6	3	2.0
2282								2																6	3	2.0
1327														1				3	2					6	3	2.0
2332																		2	1	3				6	3	2.0
2608																								4	2	2.0
134																								4	2	2.0
131																								4	2	2.0
1730																				1				4	2	2.0
592		1																						4	2	2.0
1006																								4	2	2.0
443																								4	2	2.0
2027	1																							4	2	2.0
2750																								4	2	2.0
324															2									4	2	2.0
2183																								4	2	2.0
825																								4	2	2.0
431	2																							4	2	2.0
2102	1																							4	2	2.0
2567																				3				4	2	2.0
2459	2	2																						4	2	2.0
2017		2		2																				4	2	2.0
2094							3						1											4	2	2.0
790							3			1														4	2	2.0
2306									1		3													4	2	2.0
1322													1	3										4	2	2.0
622													3	1										4	2	2.0
928																	2				2			4	2	2.0
2382																						2	2	4	2	2.0
724																								2	1	2.0
1989																								2	1	2.0
882																								2	1	2.0
1039																								2	1	2.0
1132																								2	1	2.0
1274																								2	1	2.0
410																								2	1	2.0
479																								2	1	2.0
1138																								2	1	2.0
733																								2	1	2.0
1704																								2	1	2.0
2357																								2	1	2.0
2778																								2	1	2.0
2491																								2	1	2.0
1450																								2	1	2.0
1228																								2	1	2.0
59																								2	1	2.0
339																								2	1	2.0
2723																								2	1	2.0
2426																								2	1	2.0
2544																								2	1	2.0
383																								2	1	2.0
1022																								2	1	2.0
976																								2	1	2.0
484																								2	1	2.0
2490																								2	1	2.0
2303																								2	1	2.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
1899																			2										
925																			2										
459																				2									
1982																				2									
684																				2									
818																					2								
1465																					2								
2675																					2								
1685																						2							
2335																						2							
2343																							2						
1495																							2						
1463																							2						
242																								2					
2198																								2					
68																								2					
1548																								2					
617																										2			
668																										2			
2069																										2			
31																										2			
2352																										2			
829																											2		
1160																											2		
701																											2		
1343																											2		
2129																												2	
1755																													2
2724																													2
2516																													
2195																													
1008																													
111																													
1621																													
312																													
2054																													
681																													
1055																													
2086																													
404																													
2777																													
2226																													
97																													
2719																													
1488																													
33																													
1836																													
498																													
1235																													
885																													
1806																													
711																													
2045																													
1470																													
2133																													
2633																													
1137																													
2291																													
637																													
1258																													
2312																													
1416																													
2207																													
1034																													
1778																													
1569																													
2289																													
382																													
1977																													
1794																													
169																													
2053																													
895																													
1901																													
2640																													
593																													
105																													
1065																													
957																													
2695																													
940																													
2694																													
2477																													
547																													
1875																													
2215																													
285	1	1	3																										
485		2									2											1							
2492				3																									
1543							1	3																					
1868								2	2										1										
2625												3																	
562												3					1	1											
915																												2	
560																													

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
1899																								2	1	2.0
925																								2	1	2.0
459																								2	1	2.0
1982																								2	1	2.0
684																								2	1	2.0
818																								2	1	2.0
1465																								2	1	2.0
2675																								2	1	2.0
1685																								2	1	2.0
2335																								2	1	2.0
2343																								2	1	2.0
1495																								2	1	2.0
1463																								2	1	2.0
242																								2	1	2.0
2198																								2	1	2.0
68																								2	1	2.0
1548																								2	1	2.0
617																								2	1	2.0
668																								2	1	2.0
2069																								2	1	2.0
31																								2	1	2.0
2352																								2	1	2.0
829																								2	1	2.0
1160																								2	1	2.0
701																								2	1	2.0
1343																								2	1	2.0
2129																								2	1	2.0
1755																								2	1	2.0
2724																								2	1	2.0
2516	2																							2	1	2.0
2195	2																							2	1	2.0
1008	2																							2	1	2.0
111	2																							2	1	2.0
1621			2																					2	1	2.0
312				2																				2	1	2.0
2054				2																				2	1	2.0
681				2																				2	1	2.0
1055				2																				2	1	2.0
2086					2																			2	1	2.0
404					2																			2	1	2.0
2777					2																			2	1	2.0
2226						2																		2	1	2.0
97						2																		2	1	2.0
2719						2																		2	1	2.0
1488						2																		2	1	2.0
33							2																	2	1	2.0
1836							2																	2	1	2.0
498							2																	2	1	2.0
1235							2																	2	1	2.0
885							2																	2	1	2.0
1806								2																2	1	2.0
711								2																2	1	2.0
2045									2															2	1	2.0
1470									2															2	1	2.0
2133									2															2	1	2.0
2633											2													2	1	2.0
1137													2											2	1	2.0
2291													2											2	1	2.0
637													2											2	1	2.0
1258														2										2	1	2.0
2312														2										2	1	2.0
1416														2										2	1	2.0
2207														2										2	1	2.0
1034															2									2	1	2.0
1778															2									2	1	2.0
1569															2									2	1	2.0
2289															2									2	1	2.0
382																2								2	1	2.0
1977																2								2	1	2.0
1794																2								2	1	2.0
169																	2							2	1	2.0
2053																	2							2	1	2.0
895																		2						2	1	2.0
1901																		2						2	1	2.0
2640																			2					2	1	2.0
593																			2					2	1	2.0
105																			2					2	1	2.0
1065																			2					2	1	2.0
957																				2				2	1	2.0
2695																				2				2	1	2.0
940																				2				2	1	2.0
2694																				2				2	1	2.0
2477																				2				2	1	2.0
547																				2				2	1	2.0
1875																				2				2	1	2.0
2215																							2	2	1	2.0
285																								5	3	1.7
485																								5	3	1.7
2492									1		1													5	3	1.7
1543									1															5	3	1.7
1868																								5	3	1.7
2625		1								1														5	3	1.7
562																								5	3	1.7
915		2			1																			5	3	1.7
560	2	2			1																			5	3	1.7

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
245																													
1387	1				2																								
950	1	2																											
2663		2	1																										
796		1	2																										
538		2					1																						
1680			2																										
2125			2					1																					
1491				2			1																						
2060				1						2																			
1177					1																				2				
2204					1	2																							
563						2																							
557						1													2										
1797						1	2																						
2406							2	1																					
645								2	1																				
887										2	1																		
1788											2																		
1451												2	1																
2036															1		2												
2101																		2		1									
1950																		1											
2780																		2			1								
1703																		2		1									
275																			2				1						
2454																				1		2							
2405																								2			1		
2749																									1	2			
660																											1		
1729																												2	
1332																												2	
1318																												1	2
2728																												2	
2507																													
123																													
136																													
2032																													
2149																													
1340																													
2253																													
2294																													
1745																													
781																													
967																													
1594																													
2209																													
1664																													
292																													
1040																													
168																													
2055																													
1270																													
114																													
1865																													
1049																													
932																													
1700	1		1	2																									
803			2		1		1																						
1015						1					2						1												
1990							1	1				2																	
1276								2			1																		
1159								1							1	2													
1224								1	1													2							
71								1	1			2																	
175								1				2									1								
582								1														2							
366										2						1							1						
1956											2	1	1																
1247												1	2					1											
1101												1	2				1												
990															2				1										1
2316																					2						1	1	
2686																					1	1		2					
517																					1						1		
1207																					1	1							
995																						1							
1911																									2				
2626																										2			
653																													2
293																													2
1595																													
2621																													
1217																													
850																													
315																													
2606																													
921	1											1																1	
432	1									1																		1	
423	1	1	1																										
2452	1																												
2083		1	1	1																									
1029		1	1			1																							
2432			1		1	1																							
1222			1	1																									

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
245						3	1			1														5	3	1.7
1387																								3	2	1.5
950																								3	2	1.5
2663																								3	2	1.5
796																								3	2	1.5
538																								3	2	1.5
1680																			1					3	2	1.5
2125																								3	2	1.5
1491																								3	2	1.5
2060																								3	2	1.5
1177																								3	2	1.5
2204																								3	2	1.5
563								1																3	2	1.5
557																								3	2	1.5
1797																								3	2	1.5
2406																								3	2	1.5
645																								3	2	1.5
887																								3	2	1.5
1788										1														3	2	1.5
1451																								3	2	1.5
2036																								3	2	1.5
2101																								3	2	1.5
1950	2																							3	2	1.5
2780																								3	2	1.5
1703																								3	2	1.5
275																								3	2	1.5
2454																								3	2	1.5
2405																								3	2	1.5
2749																								3	2	1.5
660																				2				3	2	1.5
1729	1																							3	2	1.5
1332														1										3	2	1.5
1318																								3	2	1.5
2728	1																							3	2	1.5
2507			2				1																	3	2	1.5
123			1						2															3	2	1.5
136				2	1																			3	2	1.5
2032						1	2																	3	2	1.5
2149						2							1											3	2	1.5
1340						2	1																	3	2	1.5
2253								2	1															3	2	1.5
2294								1			2													3	2	1.5
1745								2						1										3	2	1.5
781								2		1														3	2	1.5
967										2	1													3	2	1.5
1594										1	2													3	2	1.5
2209											1	2												3	2	1.5
1664											2	1												3	2	1.5
292													1			2								3	2	1.5
1040													1						2					3	2	1.5
168													2								1			3	2	1.5
2055														2	1									3	2	1.5
1270																2	1							3	2	1.5
114																1	2							3	2	1.5
1865																			1	2				3	2	1.5
1049																			1	2				3	2	1.5
932																				2	1			3	2	1.5
1700																								4	3	1.3
803																								4	3	1.3
1015																								4	3	1.3
1990																								4	3	1.3
1276										1														4	3	1.3
1159																								4	3	1.3
1224																								4	3	1.3
71																								4	3	1.3
175																								4	3	1.3
582															1									4	3	1.3
366																								4	3	1.3
1956																								4	3	1.3
1247																								4	3	1.3
1101																								4	3	1.3
990																								4	3	1.3
2316																								4	3	1.3
2686																								4	3	1.3
517																		2						4	3	1.3
1207	2																							4	3	1.3
995	2																1							4	3	1.3
1911												1	1											4	3	1.3
2626	1	1																						4	3	1.3
653	1	1																						4	3	1.3
293	1																					1		4	3	1.3
1595	2						1	1																4	3	1.3
2621		1	1	2																				4	3	1.3
1217							2				1					1								4	3	1.3
850												2					1	1						4	3	1.3
315													2					1			1			4	3	1.3
2606													1	2	1									4	3	1.3
921																								3	3	1.0
432																								3	3	1.0
423																								3	3	1.0
2452	1								1															3	3	1.0
2083																								3	3	1.0
1029																								3	3	1.0
2432																								3	3	1.0
1222							1																	3	3	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
1252			1		1			1																					
1445			1											1	1														
1146			1	1																									
2145				1						1																			
1852						1								1															
497						1																					1		1
316							1	1																					
788								1								1													
1353								1	1																				
806								1																	1				
1768									1									1						1					
1706										1								1	1										
2342										1																			
581												1	1				1												
164													1	1							1								
2623														1				1											
2031															1	1							1						
2481																1			1										
1001																1		1				1							
178																	1		1				1						
361																					1		1						
421																							1				1		1
1093																									1				
49																											1		
2152																											1	1	1
2243																												1	
53																												1	
1880																												1	
1735																													1
1355																													
2099																													
2256																													
457																													
903																													
1656																													
833																													
1435	1										1																		
1060	1	1																											
659	1											1																	
1242	1			1																									
464	1			1																									
2397	1			1																									
993		1				1																							
1783		1																											
1584		1																											
2134		1										1																	
2359		1		1																									
1216			1																									1	
1630			1					1																					
1438			1									1																	
2286			1																										
226			1	1																									
52				1											1														
1302				1																						1			
1641				1		1																							
1248				1										1															
334					1		1																						
427					1								1																
1843					1							1																	
546					1							1																	
1864						1								1															
1382						1									1														
1112						1	1																						
1220						1								1															
249							1							1															
1050							1	1																					
1363								1																					
2423								1		1																			
2609								1															1						
2334								1								1													
454								1																					
2231								1														1							
198									1				1																
941									1														1						
553									1												1								
863										1	1																		
2546										1										1									
579										1	1																		
461										1														1					
2005										1	1																		
1957										1								1											
2524										1		1																	
2583											1					1													
2436											1	1																	
1813											1							1											
1398												1	1																
184													1													1			
203														1															
2789														1	1														
208														1	1														
2351														1															
512															1														
2618															1					1									
212															1	1													
2191															1	1													

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
1252																								3	3	1.0
1445																								3	3	1.0
1146																1								3	3	1.0
2145																					1			3	3	1.0
1852															1									3	3	1.0
497																								3	3	1.0
316			1																					3	3	1.0
788									1															3	3	1.0
1353																1								3	3	1.0
806																						1		3	3	1.0
1768																								3	3	1.0
1706																								3	3	1.0
2342															1						1			3	3	1.0
581																								3	3	1.0
164																								3	3	1.0
2623																		1						3	3	1.0
2031																								3	3	1.0
2481										1														3	3	1.0
1001																								3	3	1.0
178																								3	3	1.0
361						1																		3	3	1.0
421																								3	3	1.0
1093													1		1									3	3	1.0
49																1			1					3	3	1.0
2152																								3	3	1.0
2243	1		1																					3	3	1.0
53	1														1									3	3	1.0
1880			1			1																		3	3	1.0
1735						1	1																	3	3	1.0
1355	1																	1	1					3	3	1.0
2099			1	1	1																			3	3	1.0
2256							1	1		1														3	3	1.0
457										1				1				1						3	3	1.0
903										1	1							1						3	3	1.0
1656												1		1	1									3	3	1.0
833																		1	1		1			3	3	1.0
1435																								2	2	1.0
1060																								2	2	1.0
659																								2	2	1.0
1242																								2	2	1.0
464																								2	2	1.0
2397																								2	2	1.0
993																								2	2	1.0
1783				1																				2	2	1.0
1584																1								2	2	1.0
2134																								2	2	1.0
2359																								2	2	1.0
1216																								2	2	1.0
1630																								2	2	1.0
1438																								2	2	1.0
2286																				1				2	2	1.0
226																								2	2	1.0
52																								2	2	1.0
1302																								2	2	1.0
1641																								2	2	1.0
1248																								2	2	1.0
334																								2	2	1.0
427																								2	2	1.0
1843																								2	2	1.0
546																								2	2	1.0
1864																								2	2	1.0
1382																								2	2	1.0
1112																								2	2	1.0
1220																								2	2	1.0
249																								2	2	1.0
1050																								2	2	1.0
1363																1								2	2	1.0
2423																								2	2	1.0
2609																								2	2	1.0
2334																								2	2	1.0
454										1														2	2	1.0
2231																								2	2	1.0
198																								2	2	1.0
941																								2	2	1.0
553																								2	2	1.0
863																								2	2	1.0
2546																								2	2	1.0
579																								2	2	1.0
461																								2	2	1.0
2005																								2	2	1.0
1957																								2	2	1.0
2524																								2	2	1.0
2583																								2	2	1.0
2436																								2	2	1.0
1813																								2	2	1.0
1398																								2	2	1.0
184																								2	2	1.0
203													1											2	2	1.0
2789																								2	2	1.0
208																								2	2	1.0
2351																						1		2	2	1.0
512				1																				2	2	1.0
2618																								2	2	1.0
212																								2	2	1.0
2191																								2	2	1.0

Node	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	wk13	wk14	wk15	wk16	wk17	wk18	wk19	wk20	wk21	wk22	wk23	wk24	wk25	wk26	wk27	wk28	wk29
2188																1			1										
473																1													
2639																1													
914																1	1												
1429																1												1	
1267																	1												
1907																	1												
2547																			1										
2128																			1			1							
2661																			1	1									
2717																			1								1		
280																			1	1									
958																				1									
1400																				1	1								
1468																					1			1					
597																					1				1				
1163																					1	1							
414																					1	1							
85																					1	1							
236																						1			1				
372																						1	1						
513																						1	1						
1149																						1							
2776																							1						
1119																							1						
1941																							1						
1650																							1						
17																							1				1		
2797																								1					
2287																								1	1				
1471																								1					
279																									1	1			
1857																									1				
268																									1				
1828																									1				
1497																									1				
18																									1	1			
2709																									1				
2422																									1	1			
1837																									1	1			
336																										1			
821																										1			
2714																										1	1		
2013																										1			
1342																										1			
1489																										1			
100																										1	1		
851																										1	1		
2418																											1		
2668																											1		
1774																											1	1	
1359																												1	
1075																												1	1
2473																												1	1
22																												1	
961																												1	1
2392																												1	1
2654																												1	1
60																													1
1351																													1
2255																													1
1195																													
2678																													
1401																													
979																													
1147																													
602																													
1968																													
351																													
904																													
2503																													
1979																													
1888																													
190																													
157																													
2528																													
496																													
1967																													
399																													
1835																													
1113																													
1374																													
2072																													
2410																													
2796																													
973																													
1087																													
124																													
1558																													
1763																													
1848																													
2006																													
1331																													
2223																													
20																													

Node	wk30	wk31	wk32	wk33	wk34	wk35	wk36	wk37	wk38	wk39	wk40	wk41	wk42	wk43	wk44	wk45	wk46	wk47	wk48	wk49	wk50	wk51	wk52	Total of msgs	Num active weeks	Rate msg/wk
2188																								2	2	1.0
473												1												2	2	1.0
2639				1																				2	2	1.0
914																								2	2	1.0
1429																								2	2	1.0
1267			1																					2	2	1.0
1907	1																							2	2	1.0
2547										1														2	2	1.0
2128																								2	2	1.0
2661																								2	2	1.0
2717																								2	2	1.0
280																								2	2	1.0
958																				1				2	2	1.0
1400																								2	2	1.0
1468																								2	2	1.0
597																								2	2	1.0
1163																								2	2	1.0
414																								2	2	1.0
85																								2	2	1.0
236																								2	2	1.0
372																								2	2	1.0
513																								2	2	1.0
1149										1														2	2	1.0
2776	1																							2	2	1.0
1119																				1				2	2	1.0
1941																	1							2	2	1.0
1650			1																					2	2	1.0
17																								2	2	1.0
2797														1										2	2	1.0
2287																								2	2	1.0
1471						1																		2	2	1.0
279																								2	2	1.0
1857										1														2	2	1.0
268						1																		2	2	1.0
1828	1																							2	2	1.0
1497										1														2	2	1.0
18																								2	2	1.0
2709																							1	2	2	1.0
2422																								2	2	1.0
1837																								2	2	1.0
336								1																2	2	1.0
821																						1		2	2	1.0
2714																								2	2	1.0
2013																	1							2	2	1.0
1342							1																	2	2	1.0
1489											1													2	2	1.0
100																								2	2	1.0
851																								2	2	1.0
2418		1																						2	2	1.0
2668							1																	2	2	1.0
1774																								2	2	1.0
1359													1											2	2	1.0
1075																								2	2	1.0
2473																								2	2	1.0
22			1																					2	2	1.0
961																								2	2	1.0
2392																								2	2	1.0
2654																								2	2	1.0
60			1																					2	2	1.0
1351								1																2	2	1.0
2255			1																					2	2	1.0
1195	1																				1			2	2	1.0
2678	1	1																						2	2	1.0
1401	1													1										2	2	1.0
979	1	1																						2	2	1.0
1147		1					1																	2	2	1.0
602		1																			1			2	2	1.0
1968		1			1																			2	2	1.0
351		1		1																				2	2	1.0
904		1	1																					2	2	1.0
2503			1	1																				2	2	1.0
1979			1	1																				2	2	1.0
1888				1		1																		2	2	1.0
190				1																			1	2	2	1.0
157				1	1																			2	2	1.0
2528					1	1																		2	2	1.0
496					1			1																2	2	1.0
1967						1															1			2	2	1.0
399						1				1														2	2	1.0
1835						1	1																	2	2	1.0
1113							1					1												2	2	1.0
1374								1	1															2	2	1.0
2072								1									1							2	2	1.0
2410									1						1									2	2	1.0
2796									1							1								2	2	1.0
973										1	1													2	2	1.0
1087										1		1												2	2	1.0
124										1								1						2	2	1.0
1558										1	1													2	2	1.0
1763											1	1												2	2	1.0
1848											1	1												2	2	1.0
2006											1	1												2	2	1.0
1331												1			1									2	2	1.0
2223												1						1						2	2	1.0
20													1		1									2	2	1.0

C. Time of messages exchange in CoPs

C.1. Spreadsheet with time communications in CoP *xtrprg* (excerpt)

code_from	code_to	msg_week_num
3	3	5
4	193	48
4	260	50
4	52	50
4	589	51
4	292	51
4	290	51
4	260	52
4	47	52
4	4	52
4	537	52
5	53	39
5	555	39
5	478	39
5	571	50
6	479	2
7	139	50
7	328	50
8	571	28
10	664	12
11	260	6
11	139	6
11	142	13
14	130	43
15	544	5
15	543	5
17	606	35
18	604	4
18	588	23
18	571	45
18	571	45
18	571	52
18	571	52
20	478	3
20	68	3
20	437	3
22	553	7
24	260	9
25	167	5
27	345	1
27	139	1
27	139	1
27	130	1
27	130	2
27	139	2
27	525	3
27	130	40
27	604	41
27	130	48
29	167	4
29	310	5
29	167	5
31	452	3
32	334	15
32	378	15
32	334	15
32	32	15
32	334	15
32	266	15
33	381	15
33	130	15
33	571	15
33	426	15
34	4	52
35	130	46
35	130	46
35	571	47
37	44	4
38	442	41
41	41	1
42	604	30
44	130	3
44	658	3
44	68	3
44	68	3
44	525	3
44	426	3
44	426	4
45	251	37
45	571	37
45	130	37
45	571	37
45	555	40
45	555	40
45	478	40
45	53	40
45	555	40
45	555	41
45	555	41
45	662	41
45	27	41
45	662	41
45	662	41
45	555	42
45	662	42
45	260	42
47	260	43
47	491	43
47	442	48
47	312	50
47	312	50
47	555	52
47	525	52
47	525	52
47	4	52
52	260	50
52	260	50
52	260	50
53	606	35
53	555	39
53	555	39
53	5	39
53	555	39
53	555	39
53	555	40
53	555	40
53	555	40
53	571	40
53	45	40
53	45	40
55	317	52
57	41	1
57	130	2
57	571	2
57	130	2
57	130	2

code_from	code_to	msg_week_num	code_from	code_to	msg_week_num
57	260	2	62	522	9
57	130	2	62	619	9
57	604	3	62	633	9
57	405	26	62	551	9
57	567	26	62	633	9
57	353	26	62	633	9
58	604	35	62	633	9
58	619	35	62	662	9
58	619	35	62	646	9
58	619	35	62	633	9
58	427	38	62	604	9
59	13	4	62	522	9
59	59	4	62	260	9
61	604	35	62	604	10
61	478	35	62	604	10
61	76	35	62	571	10
61	571	35	62	260	11
61	653	35	62	571	11
61	604	35	62	426	11
62	447	11	62	598	11
62	222	12	62	500	11
62	222	12	62	500	11
62	222	12	62	662	11
62	551	12	62	426	11
62	222	12	62	500	11
62	571	15	62	604	11
62	571	15	62	551	11
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62	571	5	62	662	11
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62	604	6	62	604	13
62	301	6	62	562	13
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65	646	48
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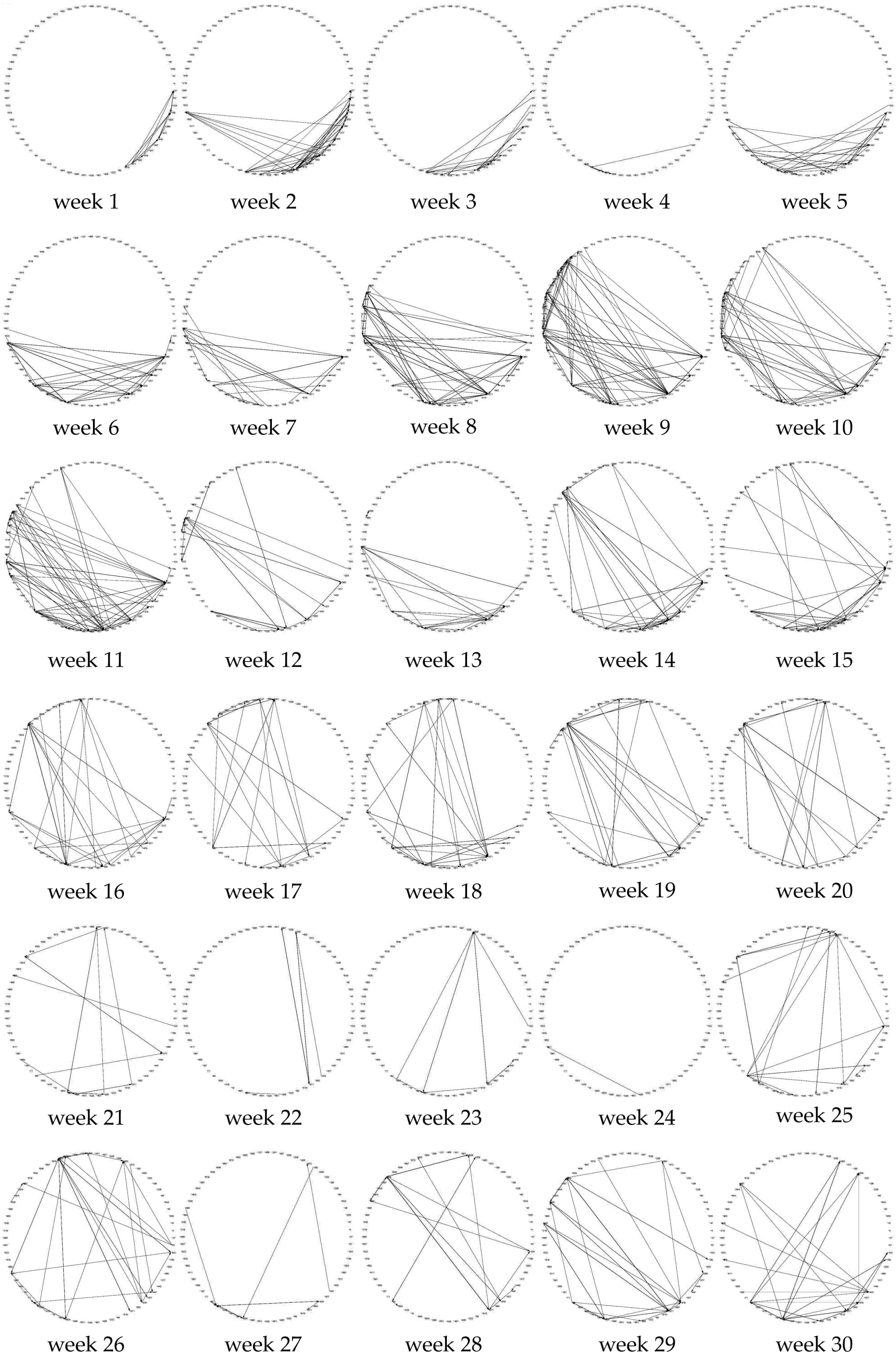
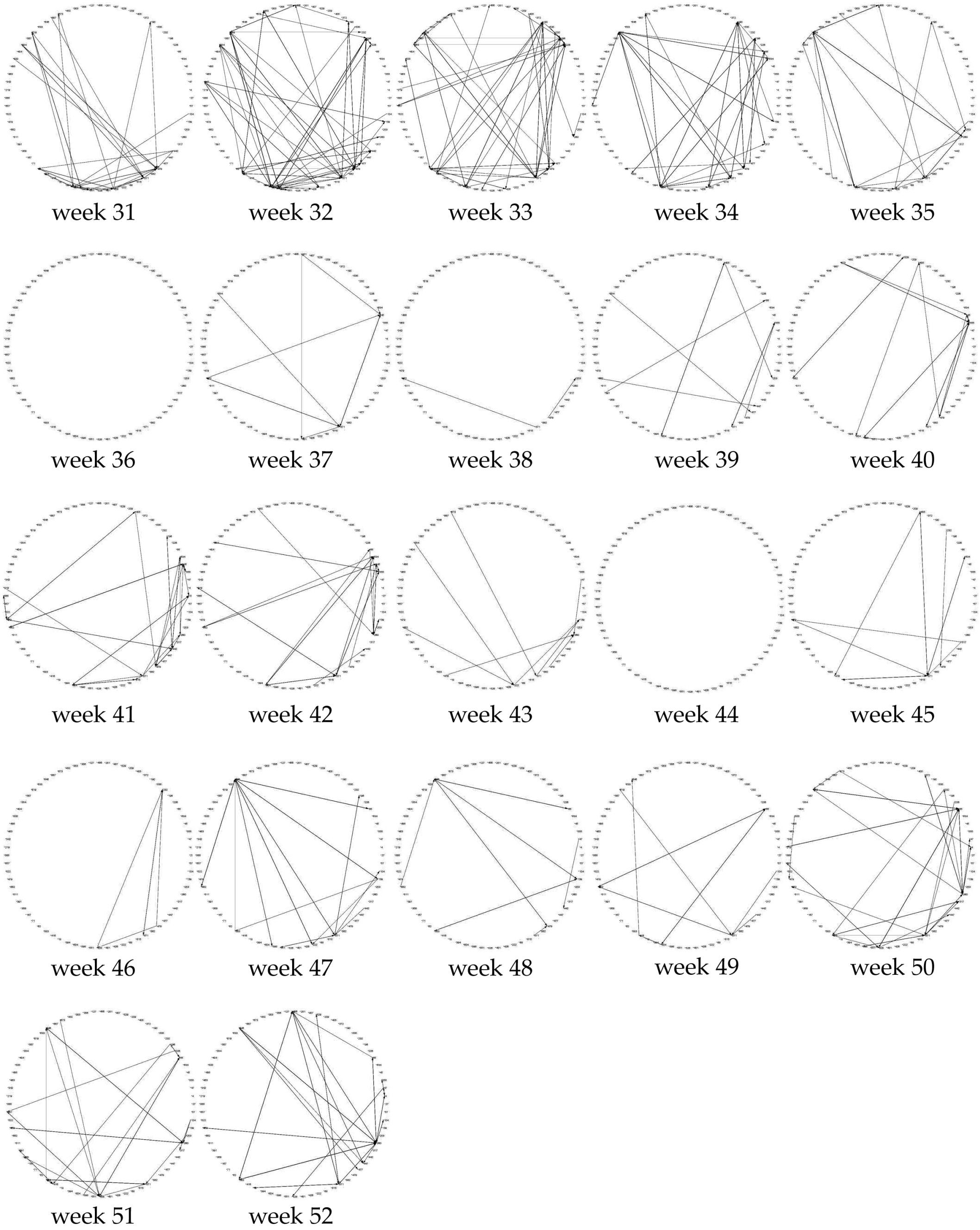
65	604	49

D. Messages exchange in time - Circular graph

D.1. Communications in CoP *xtrprg*




week 31
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week 33
week 34
week 35
week 36
week 37
week 38
week 39
week 40
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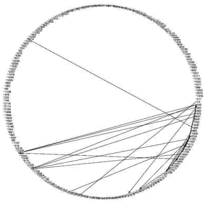
week 47
week 48
week 49
week 50
week 51
week 52

D.2. Communications in CoP *taxes*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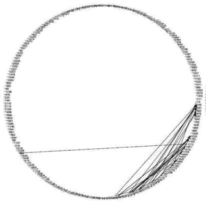
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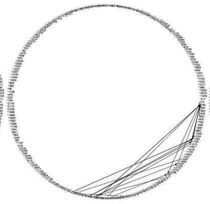
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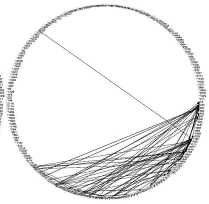
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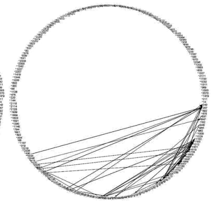
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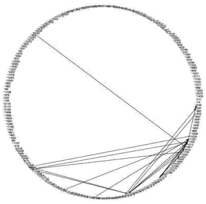
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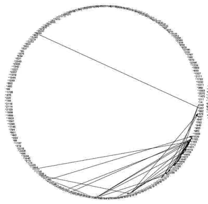
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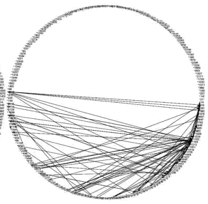
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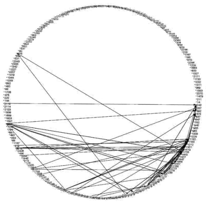
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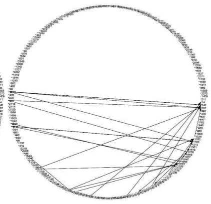
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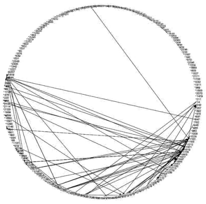
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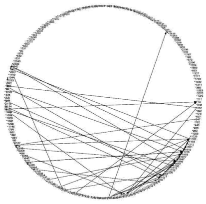
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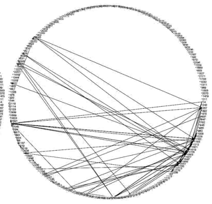
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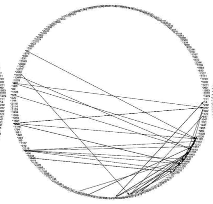
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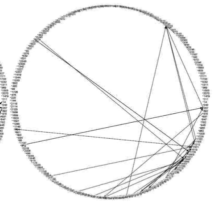
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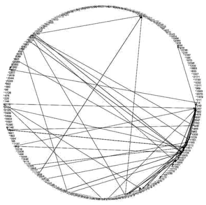
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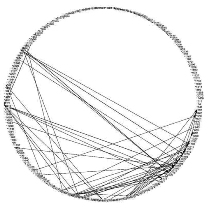
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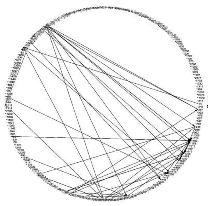
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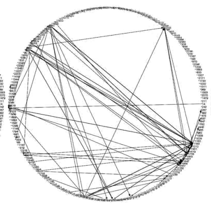
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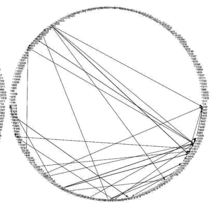
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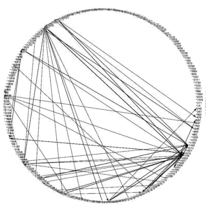
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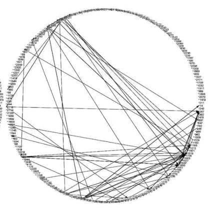
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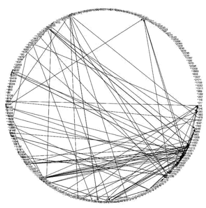
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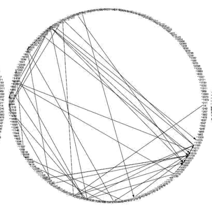
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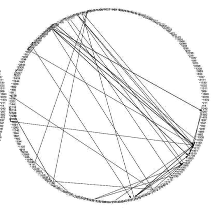
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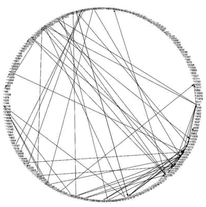
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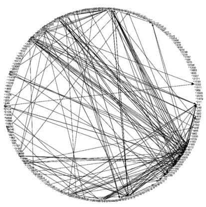
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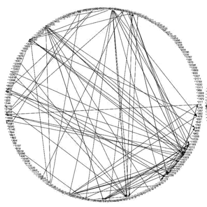
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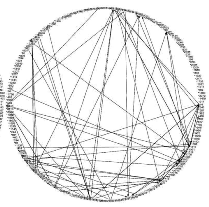
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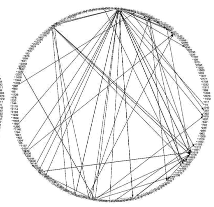
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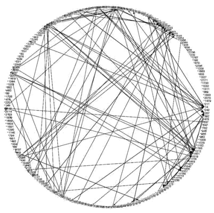
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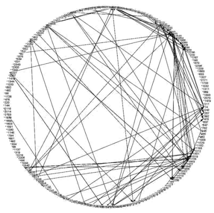
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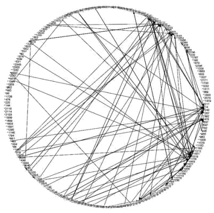
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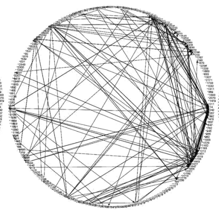
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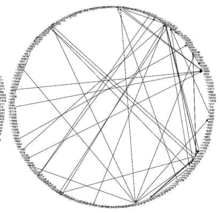
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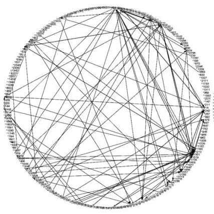
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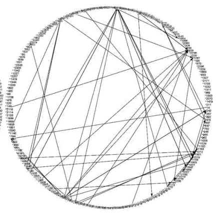
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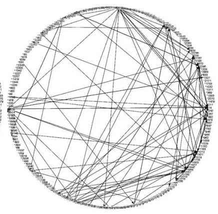
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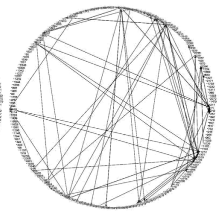
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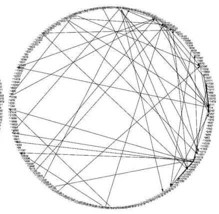
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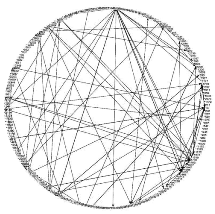
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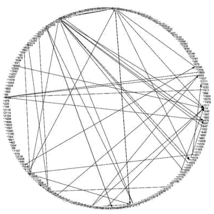
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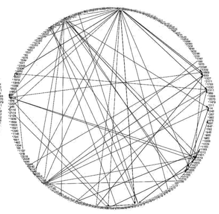
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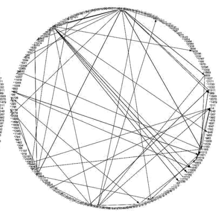
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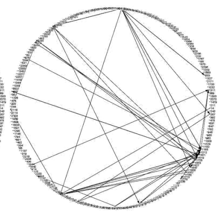
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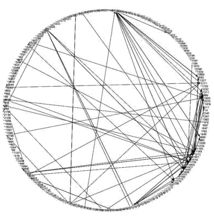
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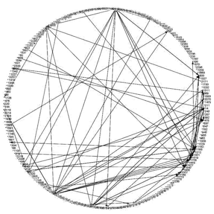
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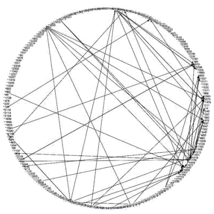
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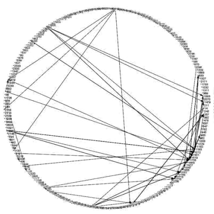
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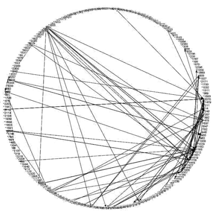
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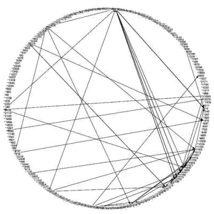
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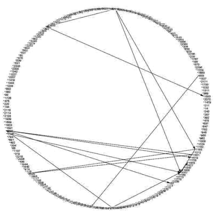
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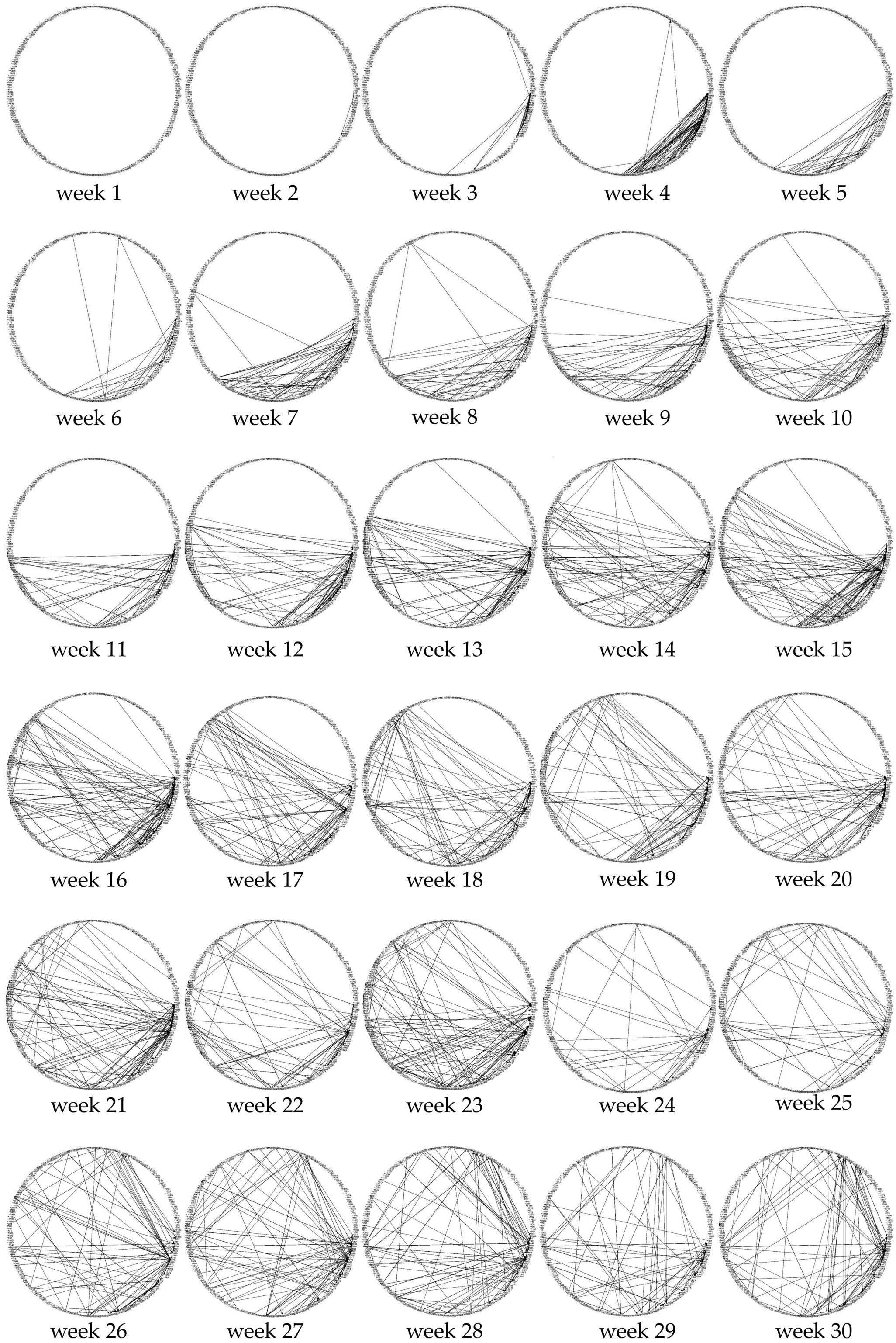
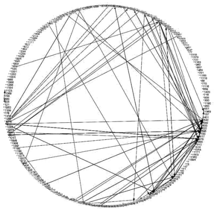
D.3. Communications in CoP *physres*

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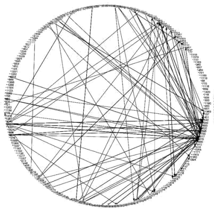
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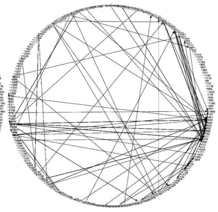
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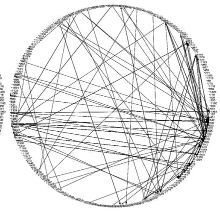
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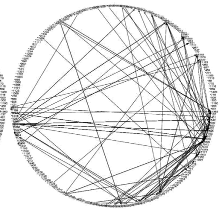
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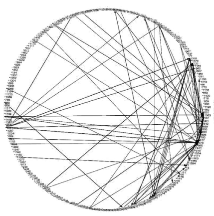
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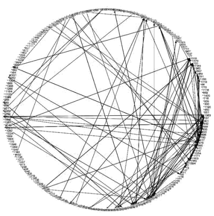
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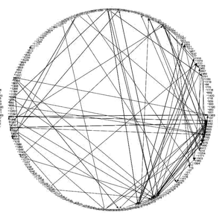
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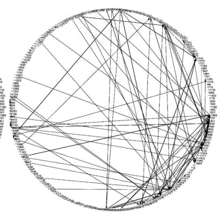
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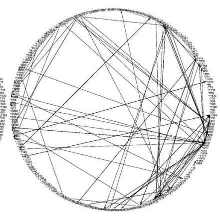
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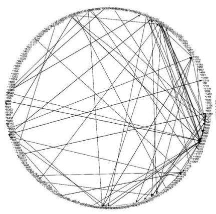
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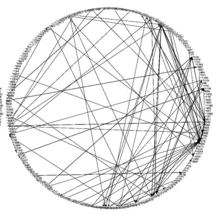
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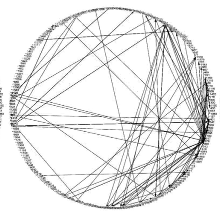
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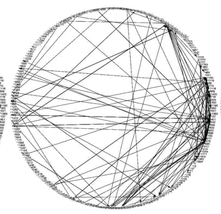
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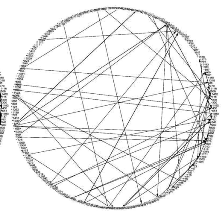
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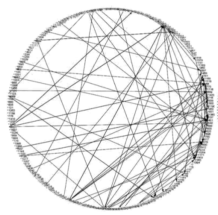
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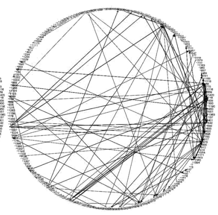
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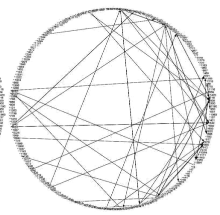
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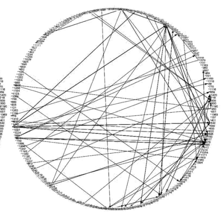
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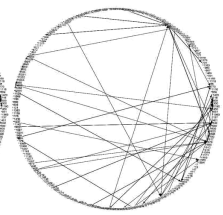
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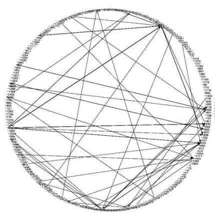
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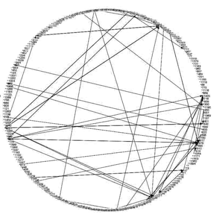
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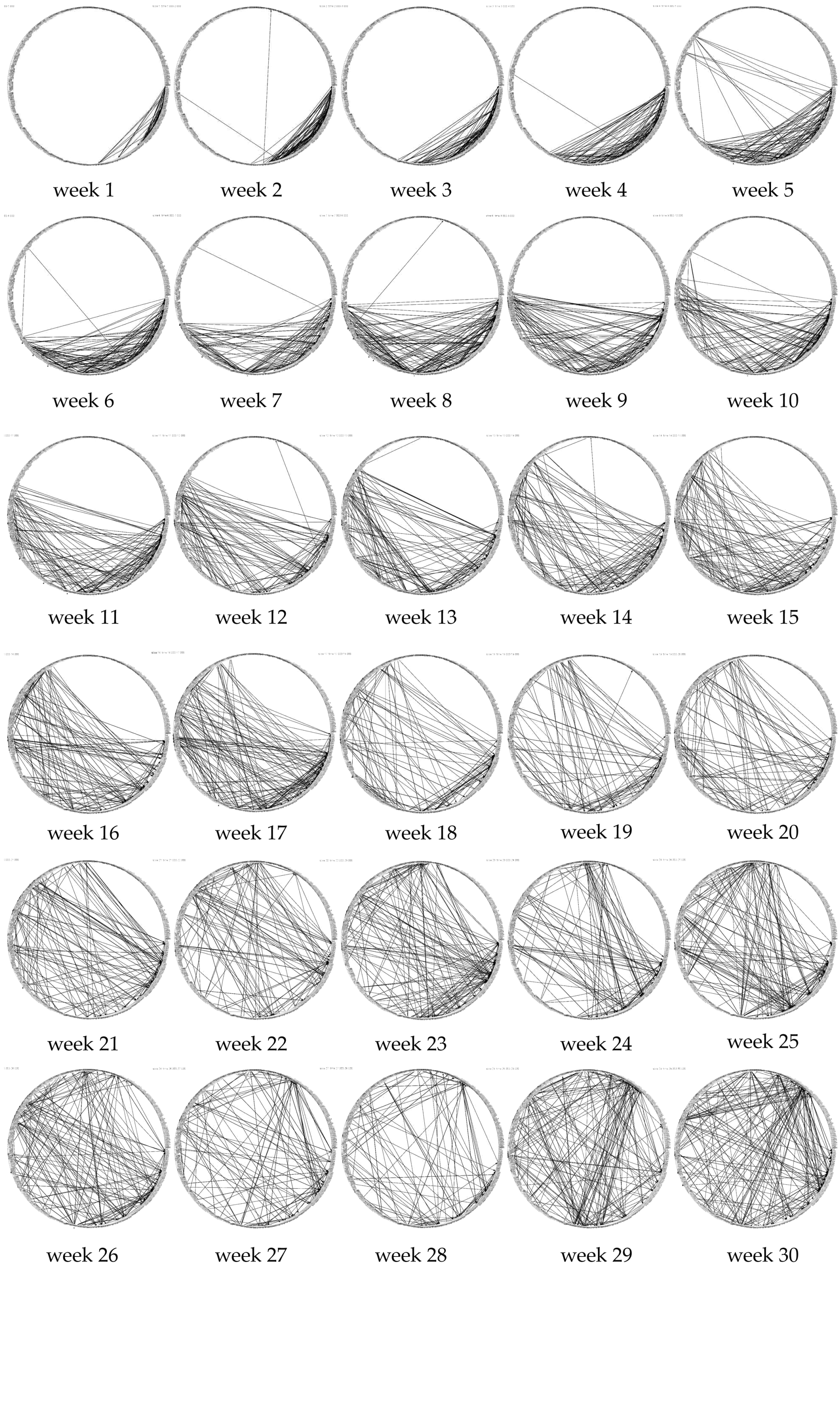
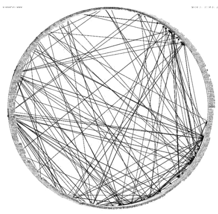
D.4. Communications in CoP *cplus*

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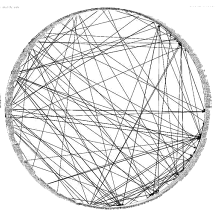
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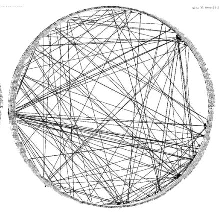
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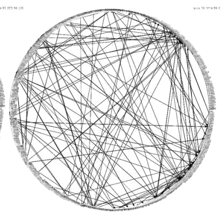
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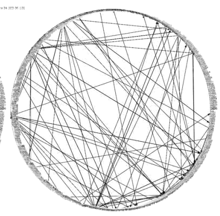
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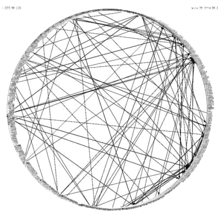
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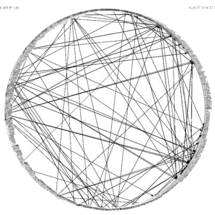
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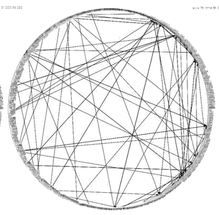
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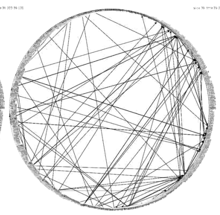
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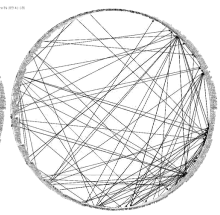
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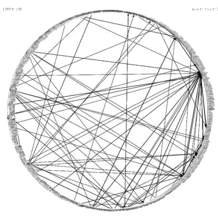
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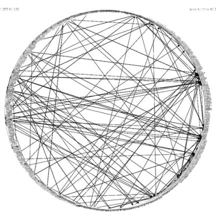
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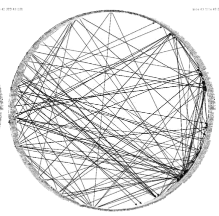
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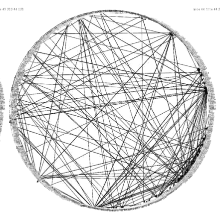
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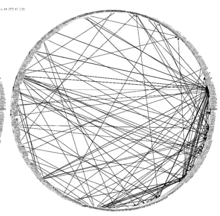
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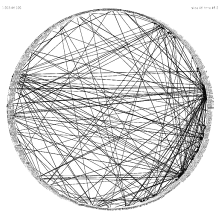
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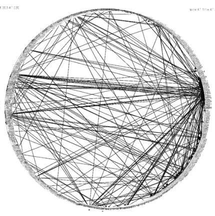
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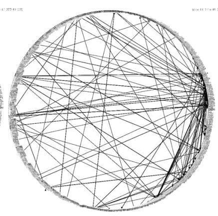
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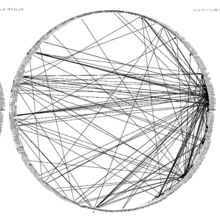
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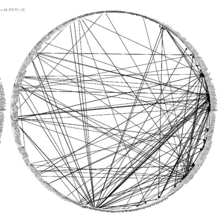
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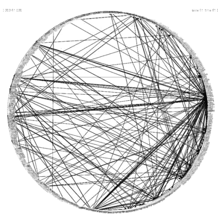
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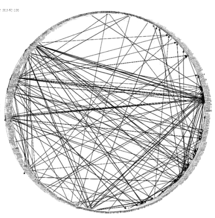
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