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The Process of Innovation and Structure of the Open Source Software

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The Process of Innovation and Structure of the Open Source Software Community

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Abstract

This paper explores the process of innovation within a virtual community of open source developers. We analyse a subgroup of the hacker community called the free and open source community as they possess unique structural and processual characteristics conducive to innovative product development. We propose a conceptual model of the innovation process and further examine the core and peripheral structure of the community and assess its impact on the innovation process.

This paper builds an initial understanding of how the hacker community is organized and how innovation occurs in the open source virtual environment. We show that the process of innovation is systematically different from other traditional patterns of innovation development. This enables us to hypothesize the behaviour of the open source community that leads to an understanding of the process of knowledge creation, through the characteristics and processes of the community.

We identify the core and periphery of the community as central to innovation in the virtual environment and thus provide a direction for further research.

Keywords: Hackers, Open Source Software Community, Open Source Innovation, Core-Periphery structure, structural holes, ties

Introduction

The growth of the internet has led to the formation of new forms of social exchange, creating what are generically known as 'virtual communities' (Klang & Olsson, 1999). Virtual communities have received increasing attention in recent years. Numerous articles have emerged on virtual firms, organizations, and work teams. However there is little theoretical insight into the different ways that virtual communities can work. The hacker community provides one of the most intriguing examples of how virtual communities can be innovative on-line.

In contrast to the traditional form of innovation advances in technologies have shifted the locus of innovation to particular user communities such as the open source software (OSS) community that are able to create software applications of superior quality as compared to commercial organizations (Fuller et al , 2004).

Open Source Software represents a new form of software development and is an example of innovation that takes place outside the traditional boundaries of a formal organization. The altruism and oneness of the open source community has been puzzling for researchers. Scholars have often asked why software developers would freely contribute their time and effort in the development of software and then give away the fruits if their labour (Bonaccrosi and Rossi, 2004; Markus, Manville and Agres, 2000). Further the ability of the OSS community to integrate members with varied skills from diverse geographical locations, facilitated by modularization and fluid boundaries (Osterloh and Rota, 2007) is also puzzling. Initially OSS was judged as a weak alternative to proprietary software as it did not adhere to traditional practices , however over a period of time it was evident that there were certain characteristics of the OSS community made it possible to develop high quality , bug free software products as the software was being developed , reviewed and tested by thousands of users while generating continuous feedback to the project (Onetti & Capobianco ,2005).

The purpose of this paper is to be to investigate the existing literature in order to understand what is different about the emergent form of innovation

exemplified by the OSS community having examined existing theories of innovation that account for how innovation takes place.

The paper provides a window into several aspects of the hacker community, analysing the theoretical implications for knowledge creation and innovation that characterizes one type of hacker community: the open source software (OSS) community

We argue that the OSS community has certain distinct characteristics regarding membership, purpose and its core-periphery structure, that makes it useful to explore the process of innovation, peripheral participation and distributed problem-solving through which we can understand critical conduits for knowledge transfer and sharing within the community.

This paper begins by characterising the open source community within the hacker community and goes on to explore the innovation process in the OSS community. The characteristics of the innovative virtual community are highlighted and the role of the core and peripheral members in the development of innovative artefacts is identified. The paper concludes by evaluating the utility and relevance of conceptualizing OSS communities as virtual communities of practice (VCoP).

The Hacker Community

In the study of virtual communities there is little reference to innovation. Few authors, such as Lazar *et al.* (1999), have considered the semi-virtual nature of certain communities, which we refer to as 'hybrid virtual communities'. That is, although they largely operate in the virtual environment, these communities also create occasions for face-face interaction. For the purpose of this paper, we focus on the sub group of the hacker community and argue that they have the organizational potential to be knowledge based and innovative.

Levy (1984) provides one of the earliest definitions of hackers, describing 'to hack' as an activity or project that is undertaken not just as an objective task but for pleasure and involvement. The core elements of the early 'hacker ethic'

emerge from this point and include the creative use of technology, the inclination towards reverse engineering and a curiosity to explore systems (Taylor, 2005). As the generations of hackers have evolved, they have diverged and have taken on different interpretations of what it is to be a hacker, i.e. hacker identity. Figure 1 illustrates the different kinds of hacker group.

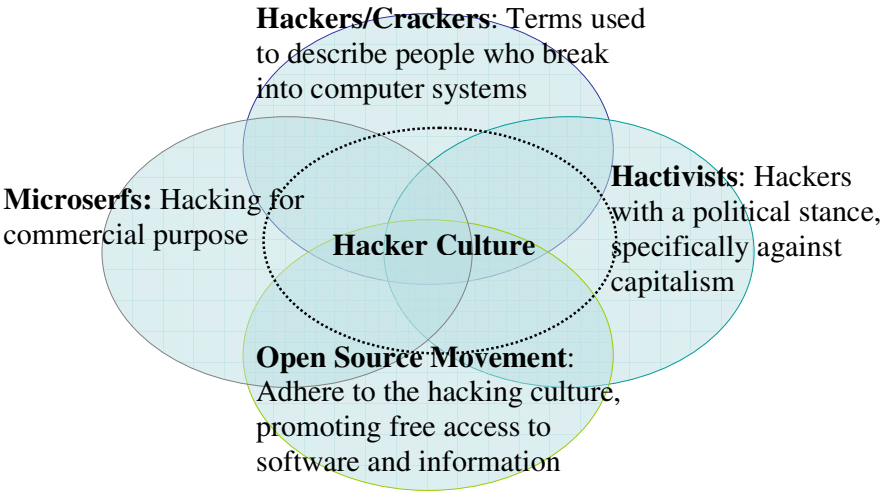


Figure 1: A taxonomy of Hackers (Adapted from Taylor, 1999)

The Figure distinguishes four subtypes of hacker culture. Hackers/Crackers and Microserfs are groups that hack for deviant purposes and for commercial gain, while Hactivists take a moral stance again certain issues but do not necessarily penetrate systems. Our focus is on the group of hackers involved in the open source software movement

The open source movement is shaped by the original hacker values. (Raymond, 2001) dates the origin of the hacker culture to 1961, in the MIT computer laboratories, where the name 'hackers' was first used. He emphasizes that the 'programmer culture', known later as the' hacker culture', gave rise to interactive computing and networked and more importantly

established a new tradition of software programmers who push the limits of the doable.

Much of the research on hackers thus far has viewed hackers as criminal deviants focusing on technical solutions to protecting systems (Hollinger, 1991; Sukhai, 2004, Smith, 2002). A large number of studies have also been devoted to understanding the motivation behind hacking. For example, researchers such as Goldschmidt (2005), Taylor (1999), Lakhani and Wolf (2005) have attempted to profile hackers and have explored their motivations for participating in hacking practices. Some of the most common characteristics identified as drivers for participation are extrinsic factors such as career advancement, monetary benefits, job prospects and intrinsic factors such as curiosity, excitement, thrill, creativity and intellectual stimulation.

Although these diverse accounts are insightful and provide valuable information about the hacker culture, it leaves many questions unanswered. For example, it does not take into consideration the underlying social and cultural mechanisms associated with the 'gift culture'. 'Gift Cultures' are based on gift economies, where social relations are not regulated by monetary transactions. The hacker culture is a gift culture as the community relies on giving away codes of the software programs, ideas and prototypes for circulation (Bergquist, Ljungberg 2001).It has been suggested, that this gift economy is maintained by a set of rules that govern the use and distribution of software, competitiveness and status within the community (Lin, 2003). However, we need to develop a more complex set of theoretical ideas in order to explain the practices within hacker communities that lead to knowledge generation and innovative software development.

Methodology

There is a need for open source theory that explains the development of public software and the process by which community members join and contribute to free software. This paper contributes to the theory of OSS innovation by examining the OSS community characteristics and behaviour of developers. The sparse research on virtual innovation processes suggests a qualitative

approach , using grounded theory, that allows for simultaneous development of theory and empirical observation while being grounded in empirical data, (Meyers, 1997). The inductive nature of grounded theory and its fit with the development of context based process oriented dynamic descriptions of phenomenon (Orlikowski, 1993) is ideal for understanding the social context of the use and change of technology within community over a period of time.

Our theoretical development was based on sample of the open source community, followed by data collection and analysis. Firstly 15 interviews were conducted with developers of the Gnome project, in the UK followed by 9 interviews in India. Each interview was based on a semi structured questionnaire and lasted between 0.45-1.5 hours. Stratified sampling technique was used. Members interviewed played different roles within the community such as users, bug fixers, core developers, moderators as well as members involved in non technical activities such as finance and marketing. Information was obtained about background, project structure, motivation for joining, and technical characteristics of the project. Based on the understanding of the project structure, from the first few interviews the questionnaire was modified to gain an understanding of open source processes and characteristics based on various roles played by community members. Information was also gleaned about the nature and type of work, their identity with the hacker community, communication patterns and the process of contribution and governance mechanisms.

In India interviews were conducted across organizations involved in open source development for non profit, members from proprietary software companies were also interviewed, who were contributing their personal time towards open source development.

The analysis suggests that the community has a particular form of hierarchy based on ‘meritocracy’ with fluid membership and boundaries. The analysis also suggests the critical role of trust within the community, with members taking on different roles over a period of time. In terms of processes the feedback loops and quality control at various levels is significant aspect of the development process. The structure of the community although not formal has a core and a periphery. These aspects are taken into consideration in

understanding the innovation process and are discussed in the following sections.

Open Source Software Innovation

In virtual communities such as OSS, innovation has been regarded as 'open innovation',

'User innovation' or 'community based innovation', however there has been no formal definition proposed for innovation in the virtual environment.

User innovation occurs through collaborative sharing of ideas and opinions amongst friends or peer groups through which solutions are offered and new product ideas are realized. This generates a feedback loop that creates an understanding about the innovation through which common knowledge emerges. This knowledge then disseminates through the community and becomes the foreground for further development of ideas. Through the process of interactions community members innovate and new products are continuously developed, as a result of emergent relationships. (The concept of 'user innovation' is used more in the context of online consumer groups but recent studies have also applied the concept to open source communities (Füller et al., 2001; Shah, 2000)

Open innovation and community based innovation are similar terms coined as a new approach to harnessing collective creativity , an essential feature of which is the free revealing of technical information (Chesbrough,2003). Such behaviour is desired as it allows for advances as it provides innovators with access to resources such as information, assistance and links to other individuals and works on a mechanism of generalized exchange, the benefits of which are psychological as well as benefits for the innovators themselves (Franke and Shah; 2003), such as mechanism is also known as 'collective invention' (Allen, 1983). Free revealing is one of the key drivers of innovation in the Open Source community (Raymond, 1999).

In the community based innovation system free revealing works because it induces improvements by others through assistance , works even in low or high competitive environments and the continues to exist as it affects individual reputation and sets expectations of reciprocity (Franke and Shah ;2003).

Thus, user innovation or community based innovation exists (Von Hipple, 1988) and the above discussion provides useful insights on various aspects of virtual

innovation; but there are also puzzles that are yet to be investigated. The innovation process itself is unclear and the question of how such community based innovations are initiated is yet to be addressed. Also the social structure of such voluntary communities and their impact on the innovation process remains unanswered. To explore these questions further the characteristics of the OSS community are examined and theories of OSS innovation are discussed.

Characteristics of the Open Source Community in the context of Innovation

Open source software development is described as one of the most successful cases of collective invention (Meyer and Lopez, 1995). The OSS community possesses certain characteristics that make it distinct from other virtual and physical forms of communities. It represents a process of 'gift exchange'. The community is characterized by voluntary participation, loosely affiliated users with common goals, free flow of information, less hierarchical control and high degree of coordination (Shah, 2005). These characteristics are known to allow the community to solve a wide range of problems but also effectively exploit the potential of the community members and generate continuous feedback that increases the problem solving abilities of members (Shah, 2005)

Innovation under such conditions exhibits characteristics, successfully enabling knowledge creation beyond the boundaries of the community. Innovation in the OSS communities is representative of private and collective aspects of innovation where in the source code is available freely for public knowledge while the learning and expertise developed by the innovators remains private to the developers and is intangible (Grand etal.,2004).While we agree that there is an element of tacit knowledge , we argue that through communities of practice and the collaborative learning that occurs through the process of 'socialization and 'externalization' (Nonaka and Takeuchi , 1995) the tacit knowledge does not remain with the individuals or is not privately held but gets transferred to other members of the community. This aspect of knowledge transfer mechanisms is dealt with in detail on the forthcoming section.

Grand etal. (2004) have also proposed that the only means to be able to innovate in the OSS community is skill and adherence to the open source philosophy and

that the innovation is highly dynamic and cumulative process of 'gift exchange' at the individual and collective level.

Thus, in the OSS community, software applications are developed through a process characteristic of collective action for the development of public goods. Existing theories of innovation are built on the premise that innovations are supported by private investments from which private returns are appropriated (Von Krogh, Spaeth, and Lakhani, 2003). Open source community on the other hand freely reveals and shares software codes. This calls for the study of the process of innovation taking into consideration the nature of open source development and the production of public goods through virtual interactions.

A few models of OSS innovation have been put forth and these are examined in detail to shed light on how the innovation processes unfolds in virtual space.

The Private -Collective model of innovation

Von Hipple and Von Krogh (2003) have suggested the 'private-collective' model of innovation. This is an extension of the collective invention model and has been proposed from an economics viewpoint. The private investment model assumes that returns to the innovator result from private goods and efficient regimes of intellectual property protection. Under this model innovators would avoid spillovers of proprietary knowledge as it would reduce profits

The collective action model assumes that under conditions of market failure, innovators collaborate in order to produce a public good. This model applies to public goods where a public good is defined by non excludability and non rivalry, this requires that contributors relinquish control of the knowledge developed and supply it to a 'common pool'. This model overcomes the problem of restricted access to knowledge that occurs in the private investment model. (Von Hipple and Von Krogh, 2003; Osterloh and Rota, 2007)

Open source software development is an exemplar of a compound "private-collective" model of innovation that contains elements of both the private investment and the collective action models and can offer society the "best of both worlds" under many conditions. This is because, while the community members could claim property rights over the codes produced, they do not do so and instead freely share the source codes as a public good (Von Hipple and Von Krogh, 2003). OSS innovation model is different from the other innovation models as actors of the OS community invest private resources for the production

of public goods. While they propound that this form of joint innovation works in the OSS community because the software is representative of a product and innovation, further users themselves are innovators and the modular nature of software development facilitates the private-collective form of innovation.

This model eliminates the assumption of loss of profit in the private investment model and instead proposes that free revealing results in a net gain for the innovator that occurs through diffusion of innovation and the creation of social networks (Von Hipple and Von Krogh, 2003).

This model offers very valuable information on why the private-collective innovation model works and the reason why OSS flourishes, however it only provides a narrow perspective on the occurrence of innovation in the OSS communities. It does not take into consideration behavioural and social aspects of the community, the influencing factors and does not explain the process by which innovation occurs, the critical aspects of interest in this thesis.

Next I examine a model proposed by F¨uller etal. (2006) to see if it can shed some light on the process of innovation in the OSS community

Three stage innovation process model

Fuller etal. (2006) have proposed that the innovation process occurs in three stages namely 'idea generation and concepts', 'design and engineering' and 'test and launch'.

In the first stage of *'idea generation and concepts'*, novel concepts and ideas emerge from internal and external resources. These ideas and concepts are later evaluated and refined. In this early stage of innovation the members of the community not only generate ideas but also evaluate them. In the next stage *'design and engineering stage',* member*s* of the community design their own products and modify the products to meet the needs through 'interactive toolkits' that provide the community members the ability to learn by doing and through trial and error. In the final stage '*test and launch'* the community members take on the roles of end users or buyers , thereby integrating all members in the innovation process and utilising the potential of the entire community as a form of 'collective innovation' .

This three stage model is very useful in that it is a contrast to the tradition innovation process as discussed earlier. In the traditional innovation process the idea generation stage and the adoption stages are well defined with members

playing particular roles. On the other hand in the case of virtual innovation as seen from the proposed model the roles are more fluid, members can take on different roles and be involved in various stages of the innovation process. Here the innovation occurs 'collectively'. This model highlights the importance learning by doing and demonstrates the impact of 'communities of practice' in the virtual environment.

However, the main flaw in this model of innovation is that it assumes that innovation occurs in a linear form. It fails to acknowledge the complex and iterative process of innovation. It does not identify factors that would trigger the innovation process and the social mechanisms that allow for coordination and the subsequent transfer of knowledge from the idea generation stage to the test and launch stage. This model also does not address the key question of why individuals of the virtual community would engage in the innovation process. There are 'black boxes' between the three stages that have not been explained.

An innovation process theory is required to understand the innovation processes specifically in the virtual environment. Such a theory should explain how the temporal sequences of events unfold and examine the transformation of innovative ideas into a realistic form (Van de Ven and Poole, 1990). Such a theory needs to take into consideration not only the phases of the innovation process but also the origin of ideas, people involved in the innovation process , nature of transactions, the context and environment in which these transactions occur and the final outcome (Van de Ven and Angle, 1989)

A Conceptual Model of Innovation in the Community of OSS Developers

The primary purpose of most studies has been to demonstrate the existence of empirically distinguishable dimensions of innovation and identify their associated determinants. No study, however, has tested the proposed sub theories of innovation in different contexts or compared or evaluated the effectiveness of various factors of innovation. Such an evaluation would help determine the moderating power of each factor. The proposed model intends to focus on critical aspects of innovation while taking into consideration the nature of the OSS community.

We build on the model proposed by Fuller etal. (2006) but consider innovation as occurring through and multiple sequences and in a non linear form. As seen from the diagram, while there are distinct stages of idea generation and adoption of

innovation they do not have to occur in a linear fashion. We propose that there are generative cycles between the various stages and that innovation occurs through an iterative process.

In the first stage idea generation and conceptual development takes place where the internal innovation process is opened up by integrating ideas from the external environment and extending the innovation activities across the organizational boundaries. Here the locus of exploration is at the interface between the community and the external environment.

In the next stage the ideas are realized in a more tangible form by the development of testable software. In this stage the knowledge of the prototype developed within the community is externalized, thus shifting the locus of exploitation to outside the boundaries of the community. This change the locus of exploitation outside the organizational boundaries. Here ideas are transferred to the external environment.

The innovation process is iterative and could go through many feedback cycles at various stages. Once the prototype is ready adoption takes place by the users. The users could be a part of the community or could belong to the external environment. This again generates a feedback that leads to further development of the prototype. Following this, the product is officially launched.

This model was developed taking into consideration the FOSS development lifecycle (Fitzgerald B.; 2006; Feller and Fitzgerald 2002 ;), which comprises of four broad phases namely planning, analysis, design, and implementation. In the planning, analysis and design stage individuals 'scratched an itch', by working individually or in smaller groups, leading to the development of a prototype. The

High modular nature of OSS projects allows for the distribution of work and reduces the skill level required for new developers to participate. The implementation stage comprises of several sub phase namely:

- Code – The code is written and submitted for review
- Review – The code is then reviewed by peer groups
- Pre-commit test – the codes are tested carefully before being committed

- Development release – When the codes are accepted they can be rapidly released in a within a short time of having been submitted

- Parallel debugging – the so-called Linus's Law ('given enough eyeballs every bug is shallow') as the large number of potential debuggers on different platforms and system configuration ensures bugs are found and fixed quickly

- Production release – a relatively-stable debugged production version of the system is released

  As seen from the diagram each of these stages of the open source life cycle can be linked to the phases of the innovation process.

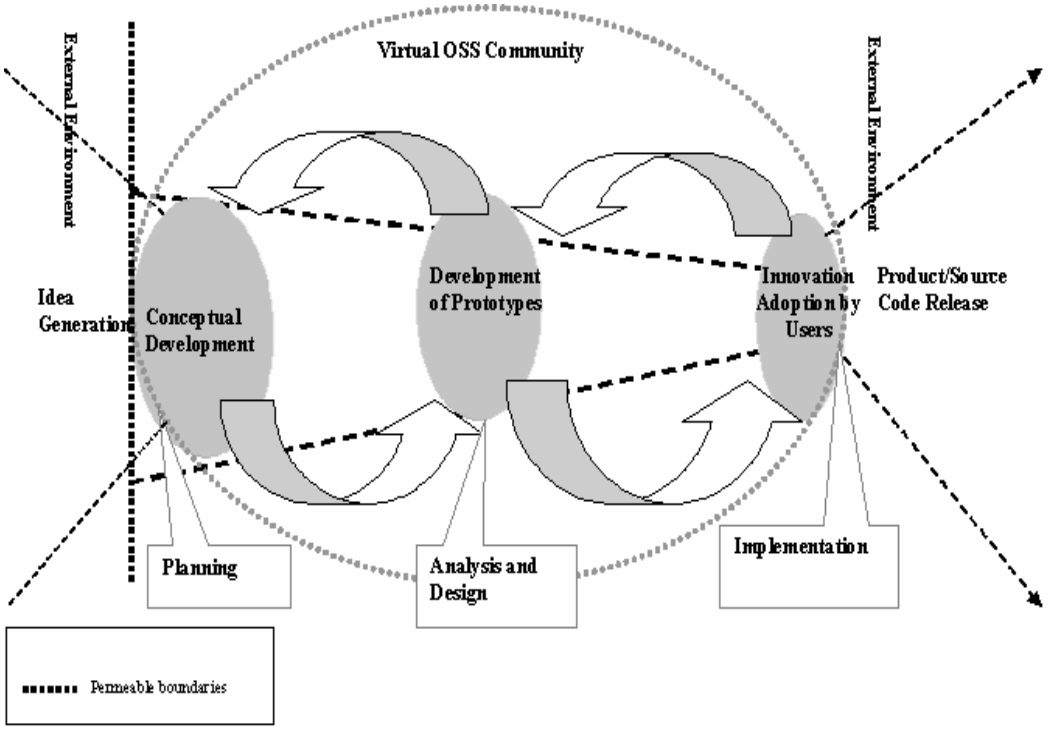


Figure 2: A model of the process of innovation in the OSS community

The innovation generation phase of the OS community also highlights the significance of 'boundary spanners' and the role of 'periphery' of the community as the interface between the external environment and the community enables the community to obtain knowledge which is unfamiliar but closely related to its

activities, Such knowledge is known to be advantageous for increasing innovativeness (Vanhaverbeke., Vrande,. van de, 2007). Further, as public knowledge is complementary to tacit forms of knowledge in the innovating units , variations of innovation occur due to the interaction of various knowledge bases (Dosi,1988), a factor that could be attributed to the high level of innovations in the OS community.

In the OSS innovation process there is no separate phase of confirmation at the end of the process where the innovation decision is reinforced, because the innovators are users themselves and the innovation is iterative and based on continuous feedback and high levels of coordination.

A key difference between the traditional innovation process and the open source innovation process proposed is that the boundaries between the community and the environment are more porous. Further, individuals move easily between different roles thereby integrating the innovation generation and innovation adoption phases. This also suggests that innovation in the open source community is rooted in the free flow of knowledge. The free pursuit of knowledge also ensures that ideas are not immediately discarded in the generation phase and is therefore able to exploit the potential of most ideas. In addition, as the structure and roles of members are fluid it is logical that the innovation process itself is not rigid, it could occur in a more unsystematic manner as compared to the traditional innovation process. The main differences between the traditional and virtual innovation process can be summarized as a 1) change in structure -with fewer levels of hierarchy and restriction in the different phases of innovation 2) change in the innovation process – the free flow of knowledge in such a decentralized environment would require intensive interaction and coordination that promotes a synergy between exploratory and exploitative forms of innovation. This highlights the importance of people in such a form of organizing (Whittington, 2002). 3) Change in knowledge flows and boundaries – knowledge creation in the OSS community is not restricted within the boundaries of the organization (Grand, Von Krogh, Leonard and Swap, 2004) and the

community therefore has a more fluid boundary as compared to organizations in which the conventional innovation process occurs.

By comparing the traditional innovation process to the virtual innovation process, it is clear that the virtual innovation process has a positive influence on creativity, creates a synergy between exploratory and exploitative forms by bringing together tacit and explicit knowledge.

Through this conceptual overview we have explored the transition in the innovation process from a conventional organization to a virtual community. A drawback of the proposed innovation model is that it still does not explain the mechanism that drives the innovation from one phase to the other. To shed light on what drives these phases of innovation we explore factors such as structure of the community and its impact on innovation.

The following section focuses on the structural characteristics that affect the innovation process in the OSS community.

Innovation and OSS Community Structure

The structure of the open source community has often been described using metaphors such as 'cathedral and bazaar'. Raymond (2000) suggests that the structure of communities that build proprietary software resembles a 'cathedral' where software is carefully crafted by individuals or small group working in isolation. In stark contrast the Linux (OSS) community is said to resemble a great babbling 'Bazaar' where developments are released early and often and every task is delegated if possible. The Bazaar system comprises different approaches and agendas. The 'bazaar' form of organizing is more effective than the 'cathedral' form primarily because in the bazaar view 'bugs' in the software program are not seen as being tricky or problematic unlike the 'Cathedral ' view , as they are exposed to thousands of developers and the early releases of the software ensures continuous corrections and feedback. Simply put 'Given enough eyeballs, all bugs are shallow." This is often known as "Linus's Law".

While the 'Cathedral and Bazaar' model broadly explains the organizational form of OSS community, further investigation is required to reveal the structure of the community and role of members that would enable us to understand the influence of the community structure on the process of innovation.

We apply the structural ideas of core-periphery relations in a CoP (discussed in the following section in the context of virtual communities) to examine the knowledge creation and innovation of OSS communities. Based on numerous case studies, it is proposed that the open source community has an onion-like structure with key contributors at the 'core' of the project and members at different levels, based on expertise and involvement in the innovation project (Crowston and Howison, 2003). Empirical studies have also found that, in a large majority of Open Source projects, a core group is responsible for a great proportion of the work accomplished and a very large group of peripheral participants is responsible for the remainder (Ghosh & Prakash, 2000; Healy & Schussman, 2002; Mockus et al., 2000).

Nakakoji et al. (2002) have suggested that within the core and periphery of the community members have different roles such as:

Passive Users: who just use the OSS due to its high quality and potential for adaptability and change?

Reader: Readers are active users of the system who are involved in reviewing the code.

Bug Reporter. Bug Reporters discover and report bugs; they do not fix the bugs themselves, and they may not read source code either.

Bug Fixer. Bug Fixers fix the bug that is either discovered by them or reported by Bug Reporters.

Peripheral Developer. Peripheral Developers contribute occasionally new functionality or features to the existing system. Their contribution is irregular, and the period of involvement is short and sporadic.

Active Developer. Active Developers regularly contribute new features and fix bugs; they are one of the major development forces of OSS systems.

Core Member. Core Members are responsible for guiding and coordinating the development of an OSS project. They are very involved in the project and make significant contributions. They are often known as 'Maintainers'.

Project Leader. Project Leader is often the person who has initiated the project and is responsible for the vision and overall direction of the project

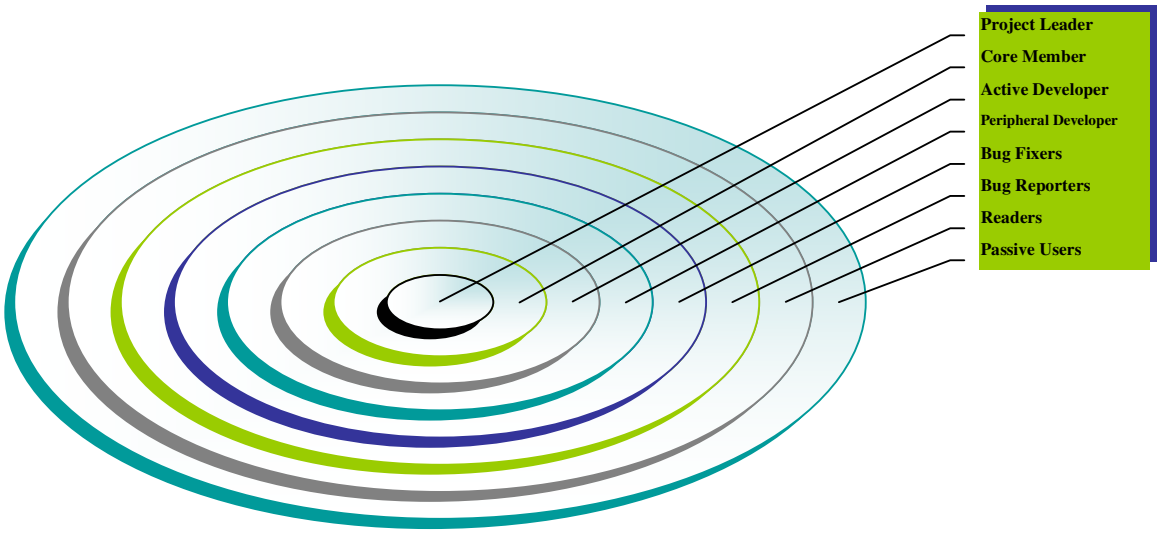


Figure III: Core-periphery relations in the virtual CoP (Ye Y, Kishida K, Nakakoji K, and Yamamoto Y. 2002)

From the above diagram it is evident that the OSS community has a dedicated core team and also peripheral members who contribute marginally. The parallel to the dual core structure is to the extent that both formal and informal structures exist, that facilitate innovation. I propose that the informal structure that allows ad-hoc participation and fluid membership supports the innovation generation process while the semi formal structure of the core and periphery facilitates the adoption process.

The distinctive structure of the OSS community provides support for it to be regarded as a 'hybrid' because it allows for asynchronous, ad-hoc participation dependent on virtual technologies, on the other hand the community has a formal/informal structure and governance mechanisms that can be related to traditional organizations.

Next I examine the roles of the OSS community members in relation to its structure, to explore in detail, the social mechanism that allows for the generation and transfer of tacit knowledge, crucial for the process of innovation.

There are variations in the roles depending on the type of OSS project and none of the roles is fixed. This indicates that the structure of the OSS community is

unique and is self evolving. However, it raises questions about the value of peripheral members in the community about why they are involved in the community despite their meager contributions, while the core developers could easily create a private group and disregard non-contributors. The concepts of CoP, knowledge stickiness, strong/weak ties and legitimate peripheral participation would help shed light on this puzzle.

The evolution of OSS has been linked to the social mechanism that enables the change of roles and which encourages the existence of such an organic form of organizing. This social mechanism is Legitimate Peripheral Participation (LPP) (Lave and Wenger, 1991; Ye Y et al., 2002)

The social relationships and interactions in an organization can influence the process by which ideas develop and the can also impact the process by which the organization evolves. Therefore in order to understand how community members move from the periphery to the core and how this affects the generation and adoption of innovation, it is necessary to apply the concept of LPP and view learning as participation in social practice, as learning is understood as a socialization process with the formation of communities and change of identities. CoP not only highlight the relationship between the new member and the mentor but also the relationships between the other new members, this is a vital point as innovation need not occur at the core of the community but is a result of the collective practices of the community.

The concepts and theory of CoP offer critical insights into knowledge sharing and innovation in virtual communities, which share certain features with the CoP. In particular the following aspects play an important role in the creation and transfer of knowledge among members of the community thus leading to innovation.

1. The role of boundary objects such as software artifacts
2. The nature of peripheral participation, i.e. how do members participate at the periphery, are they 'free riders' or do they participate by observation and what technological tools they use

3. The nature of their contribution – do they offer suggestions or are members involved in bug fixing, patches , writing codes and the relationship to the central focus of the project
4. Member's ties: do they have strong or weak ties with other members at the periphery or are they actively encouraged and guided by other participants; and how does this relates to the coordination of activities and the diffusion of innovation

Since the open source community has a 'core-periphery' structure where most of the new members are at the periphery and are slowly integrated into the community,
We argue that OSS communities share some characteristics of CoPs and can therefore be usually examined within this framework.

Borgatti and Everett (1999) distinguish between the core and periphery based on the density of ties among the participants. They conceptualize the periphery as comprising members associated with the core and wanting to move into the core. Core members are also characterized as being closely knit while peripheral members are more loosely knit with more ties to the core than with each other (Borgatti and Everett, 1999).

Lave and Wenger (1991) distinguish between the core and periphery by specifying that members at the periphery would have limited knowledge and would cultivate the skills through the process of apprenticeship, i.e. by undertaking a journey from periphery to centre, through the process of 'Legitimate Peripheral Participation' (LPP). LPP suggests that peripheral members understand the practices of the community and develop skills by legitimate participation in community practices, over a period of time (Lave and Wenger, 1991).
Virtual communities such as OSS share many of the characteristics of CoP. Open source communities, as seen earlier, are a hybrid between physical and virtual communities. They are characterized by three dimensions: (1) membership—people experience feelings of belonging to their virtual community, (2) influence––people influence other members of their community, and (3) immersion—people

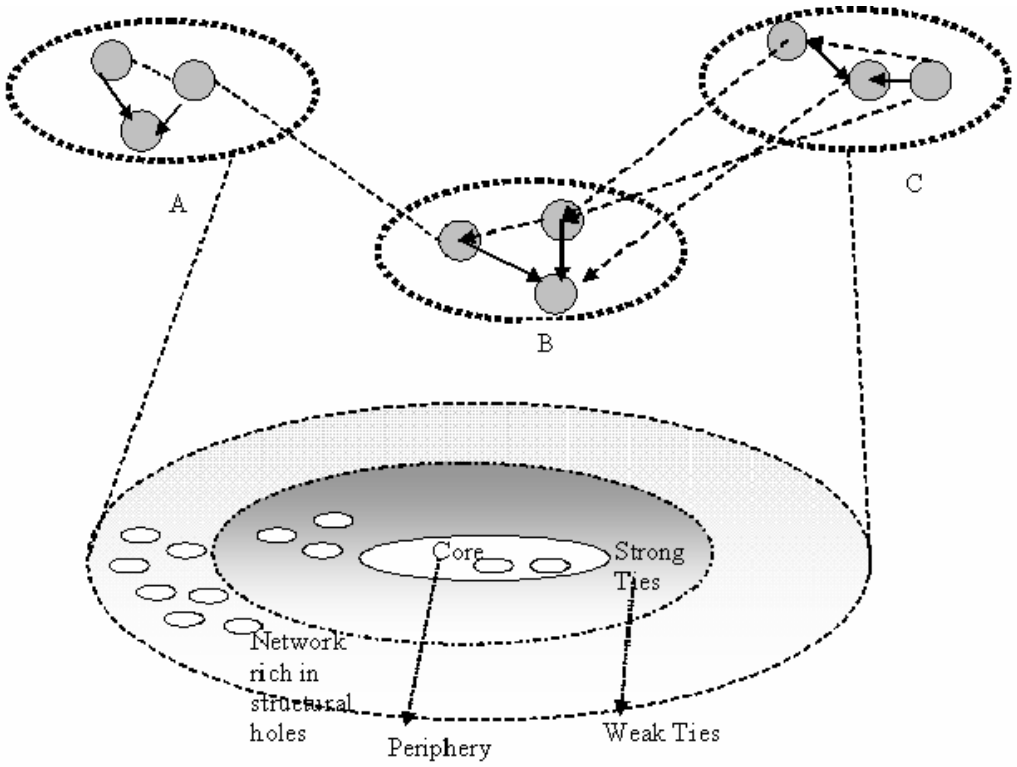
feel the state of flow during virtual community navigation. The dimensions of membership, influence, and immersion reflect, respectively, the affective, cognitive, and behavioral aspects of virtual community members (Koh and Kim, 2004).

However Lave and Wenger do not acknowledge the presence of a central core and further do not consider LPP as a knowledge generating process but examine it from a social learning lens. Unlike CoP that considers the periphery as comprising of members who develop skills to attain full membership to the community, we propose that the core and peripheral members are involved in creating innovative artefacts and practices and thus need to be viewed from a different perspective.

Granovetter (1983) suggests that weak ties are greater facilitators of information than strong ties and will traverse greater social distances and would operate as bridges between different sub networks. Therefore peripheral members do not necessarily have limited knowledge but possess diverse knowledge and serve as a resource for knowledge diffusion. Further seminal work on the nature of knowledge has identified knowledge as being sticky (Von Hippel, 2002), suggesting that the locus of innovation would shift where the information is sticky leading to task subdivision to draw upon multiple sources of sticky information. This suggests that, in OSS projects, innovation primarily occurs at the periphery and contribute unique knowledge to the core. These theoretical insights indicate that in the OSS community peripheral members bring in newer knowledge, acting as knowledge brokers. Further as members have weaker ties at the periphery novel information is transferred to the core.

The argument of 'structural holes' further illustrates this point. Structural holes refer to the separation between non redundant contacts, this is indicative of weak relationships. Strong relationships on the other hand do not have structural holes (Burt, 1993). There exist very little investigation on structural holes and the strength of ties in virtual communities. The core peripheral structure of open source community and the presence of unilateral relationships suggest that ties under such virtual conditions are embedded in the community. The synchronous and asynchronous patterns of collaboration also influence the nature and density of ties among members of an OSS community.

We can conceptualize that the presence of strong ties at the centre and structural holes enable the synthesis of tacit to explicit knowledge and the transfer of tacit knowledge.



As seen from the diagram, A, B and C are different sub groups within the virtual community. Each of these groups is characterized by strong and weak ties, within the subgroups. The absence of a link between A and C suggests a structural hole. This is more likely to occur at the periphery, where members are loosely affiliated to the community. Further, the density of structural holes is greater towards the periphery. This, taken into consideration with the presence of ties provides valuable information about the transfer of technical and social knowledge. Constant et.al, 1996 have proposed that weak ties are better suited to transfer technical information where as strong ties are used to exchange social information.

From this it can be inferred that the periphery plays a critical role in innovation process, as it allows for 'exploration' to occur and bring in tacit knowledge. But tacit knowledge can only be shared effectively between two or more people when they share a common social context: shared values, language and culture. The concept of strong/weak ties and structural holes does not provide an explanation for

this. Thus these concepts have been useful in identifying how the core-periphery structure facilitates knowledge transfer and innovation and brings to light the important role of the periphery.

Summary

This paper addresses the development of innovation in the open source community. We have focused on the open source innovation process and have shown that the innovation process is not linear but occurs through generative cycles of iteration. Through the identification of the innovation process an understanding of the influence of the community structure on the innovation process is developed. The significance of 'boundary spanners' and 'core-periphery' as interfaces between the internal and external environment is underscored through this discussion. The concepts of LPP, strong /weak ties and structural holes have been used to build on our comprehension of innovation as a social process. This paper provides a direction for further theoretical research on various social aspects relating to the innovation process such as the links between the community structure and forms of knowledge, motivation and knowledge sharing and its impact on the innovation process. In depth empirical research on the innovation process also needs to be conducted to further analyze the various facets of the innovation process. The paper proposes the basis from which theoretical and empirical can be developed to explore the new emergent forms of virtual innovation.

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