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PERSONAL AND SOCIAL PROXIMITY: SHAPING LEADERSHIP IN A FREE SOFTWARE PROJECT

Open software projects are usually portrayed by focusing on charismatic leaders, friendly communities, and meritocratic language. We dig under the surface of this stereotypical picture and analyse the social relationships of the people involved; specifically, whether they are related through personal proximity or they are distant social partners. We contribute to the literature on free/open source innovation in three ways. First, we highlight the continuum of roles played by individual leaders in the open source project, as brokers and/or initiators. Second, we delve deeper in the social networks of the Videolan software community to layout where and how leaders are organised in groups and play the role of brokers and initiators. We study leadership emergence over time by taking into account the context of activities. Finally, we produce a typology of three Videolan communities with specific social networks that evolved over time in terms of leaders and social structure.

Keywords: Open source, community, leadership, social network, proximity, computer software

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1) Introduction: open source communities and their leaders

The organisational structures in the open source field are heterogeneous (Currie, Kelty, and Murillo 2013, Dahlander, Frederiksen, and Rullani 2008) ranging from projects carried out by only one developer to others supported by thousands of contributors (Madey, Freeh, and Tynan 2002). In these collective projects we find volunteers and salaried contributors, non-profit organisations and international companies (Fitzgerald 2006, West and O'mahony 2008). Another distinction concerns intellectual property management. Different strategies are chosen ranging from strictly open content production to various mixes of proprietary and open content (Aksoy-Yurdagul 2015).

Generally, contributors can be distinguished between followers and leaders. Open source communities are mostly consisting of followers with professional activity. These contributors are independent and have intrinsic motivations to participate such as the need for a specific software, the fun to solve technical problems, the wish to offer a program to the hacker community (Bitzer, Schrettl, and Schröder 2007). In other words the contributors do not need a leader to motivate them or control their enrolment (Pink 2011). However, even though contributors cannot be forced to produce (Michlmayr and Hill 2003), there is at least one person who manages the project and takes the final decision for action and sharing content beyond the core of producers (Sack et al. 2006). People assuming leadership roles come with different profiles such as that of an entrepreneur (Giuri, Rullani, and Torrisi 2008), a public servant, a student, and so on. They may lead different kinds of hierarchy(Gadman and Cooper 2009, Zhu, Kraut, and Kittur 2012). Such types of leadership in the information technology sectors complement other innovative forms of open management in different areas such as the Lego corporation (Bughin, Chui, and Johnson 2008, Aslesen and Freel 2012).

The spread of open source management relates to its apparent usefulness for distant learning and innovation activities. In most projects contributors are not geographically close, and they produce complex tasks. The contributors' relationships can be based on online contacts, professional relationships, school relationships (schoolmates), friendship, or family linkages. In the context of a virtual team, leadership is of strategic importance due to the difficulty of communication between leader(s) and followers (Gilson et al. 2015, Hertel, Geister, and Konradt 2005). Recent work shows the importance of tacit knowledge such as such as competence and experience in the communities' performance (Faraj et al. 2016).

People in charge of open source projects come with various qualifications and names: leader, administrator, first developer, manager, senior hacker, or moderator. Nonetheless, there is no official career plan, no well-defined professional development, no central control institution, and no skill definition. S/he is a leader because s/he succeeds in doing so. Following Max Weber (Weber, Kalinowski, and Sintomer 2013), this type of leadership can be considered as anti-bureaucratic, reflecting a non-rational economic domination. In this sense the social and personal proximity between core developers is more than a geographical, institutional, organisational or cognitive proximity (Boschma 2005). The personal proximity between these people is built on a mutual feeling of creativity (Caniëls, Kronenberg, and Werker 2014). We explain that type of closeness herein through concepts of confinement, innovation, or discipline and study how such proximity transforms into a form of hierarchy. Such an approach has proven useful when looking at the impact of offline interactions on online activities (Cummings, Butler, and Kraut 2002). In the software field analysts have underlined the influence of proximity between developers in the code source production process (Kraut et al. 2002).

The leaders have specific links with the collective project. In the early period, leaders enjoy some sort of special charisma or capability (a specific skill or idea). Later on their power is routed primarily in their function as a community administrator (Raymond 1999). In other words, leaders can evaluate and validate individual performance and apply collective discipline. In this sense, there is a common understanding of an informal hierarchy. The personal proximity between project leaders is marked by relationships with their superiors, subordinates, and peers in the social network community (Yan 2014). Still, however, the reason for that proximity between leaders and the rest of the community remains obscure (Yoo and Alavi 2004, Fleming and Waguespack 2007) due to the strong ideology of equality and meritocracy in open source projects (Coleman 2013).

Our work purports to understand the nature of the sociability in the personal network of leaders in open source networks. We start from the observation of Alexis de Tocqueville: '*It is in vain that wealth and poverty, authority and obedience, accidentally interpose great distances between two men; public opinion, founded upon the usual order of things, draws them to a common level and creates a species of imaginary equality between them, in spite of the real inequality of their conditions. This all-powerful opinion penetrates at length even into the hearts of those whose interest might arm them to resist it; it affects their judgement while it subdues their will*' (Tocqueville 1961). In this vein, two questions seem important in situations of imaginary equality where people have a subjective feeling of being part of a

community. First, what is the degree of liberty in choosing their partners? Second, what kinds of relationships structure leadership and authority (Freeman 1979)?

We address these questions concerning the nature of sociability in the personal network of leaders, and the relation to '*imaginary equality*' in two ways. First, we look at the literature concerning leadership behaviour in open source project and cognitive approaches. Second, we analyse the case of the Videolan open source organisation which allows to observe the constraints these freedoms create in the contexts in which people meet. We analyse the emergence of three types of communities that evolved through time and shaped Videolan: superimposed, captured, and chosen. In each of them, the proximity and inter-personal relationships are different. We observe these evolutions in people discourses and their social networks.

The rest of the paper is divided into 4 parts. Section 2 summarises important theoretical concepts from the behavioural leadership literature and cognitive research that underlie our work. Section 3 develops and analyses the Videolan (VLC) case. Section 4 interprets the results. Finally, Section 5 concludes by summarising the main results and suggesting extensions.

2) Leaders open source communities': behavioural and cognitive perspectives.

Free open source communities challenge traditional computer engineering and incentive models. On the Internet, the distant and the informal relationship create *'a species of imaginary equality'* as a critic of industrial bureaucracy (Kreiss, Finn, and Turner 2011). In open source projects equality is reinforced by the collective property right written in free licences. That formal point of view, though, does not allow to explain either charisma or leadership observed in communities.

Establishing leadership signifies increasing the chance to be obeyed. From this point of view, formalised by Max Weber (Weber 1978), the individual leadership based on charisma is limited over time. To be stable the leadership and domination have to be integrated and shared in a collective action. The use of this capability is analysed in the literature to established styles of leadership.

In some ways the open source leadership literature is consistent with the broad leadership literature shape by two important dimensions: individual behaviour and cognitive

skills (Day et al. 2014). The open source literature proceeds insights on both of them through individual incentives (Lakhani and von Hippel 2003, Tirole 2016) and the collective institutional approach of the communities (Hess and Ostrom 2005).

On the one hand, a strategic and behavioural point of view is implied to perform a system of constrains and rewards to be obeyed in a vertical organisation. These studies of balance of power in open source communities (Weber 2004, Bitzer and Schröder 2006, Li, Tan, and Teo 2012) looks at how leaders perform their personal skills and why they fall and they are replaced by new leaders while using the source to create a concurrent project.

On the other hand, a cognitive point of view is more shaped by altruism and individual initiatives than inspiring others through performance or their ideology in a horizontal organisation. These researches are focused on the institutional context of communities (O'mahony and Ferraro 2007) indicate leadership transformation over time and community involvement in the decision process (Fielding 1999).

Behavioural perceptive: leader as manager of **individuals' incentive.**

Mancur Olson (Olson 1965) highlighted the main ordeal in collective actions: free-rider behaviour. Typically, the open source communities are facing this question where products are shared outside of the developers' community. As Jean Tirole and Josh Lerner in their seminal paper (Lerner and Tirole 2002) asked, "*why should thousands of top-notch programmers contribute freely to the provision of a public good?*" One of the solutions proposed by Mancur Olson is the leader who has skill and power to initiate collective action and constrain involvement. In the case of free software project constrains on neglected involvement is not that easy to perform (Michlmayr 2004).

The answer proposed by Jean Tirole and Josh Lerner concerning the top-notch programmers involvement is based on intrinsic and extrinsic motivations such as solving technical problems encountered in professional activity or highlight personal skill on the job market with a public contribution. From that point of view, the leader of free software appears to some extent as the neutral manager of a project since it has the right to monitor the collective resources. He indicates the tasks to be carried out and selects the contributions. The cooperative relations between (s)he and the other developers are maintained insofar as respect of collective property rights guarantees the project sustainability. Some authors highlight the role of leader as tasks' distributor by taking account the individual skills to improve the community performance rather than leave community as an organism with a self-determination (Ke and Zhang 2011).

However, taking in isolated manner that perspective has limitations in terms of addressing real world situations (Aggeri 2015, Healy and Schussman 2003). The role of the open source leader as a broker in that theory must be emphasised. The issue is to understand what kind of link there is between leader and contributors.

Cognitive approach: altruist leaders and imitation game.

The paper of Jean Tirole and Josh Lerner presents a surprising contradiction between the contributors' behaviour and the leaders'. Concerning the contributors "*any explanation based on altruism only goes so far*." However, few page letters "*it may be important that the leader does not perform too much of the job on his own and leaves challenging programming problems to others*." In other words, the leaders have to take care of contributors and abandon his interests.

In the altruist research field the leader is more a problem rather than a necessary asset (Nowak and Highfield 2011). However the social network altruism perspective shows that the altruism is broadcasted through the interpersonal relationships (Fowler and Christakis 2010, Keser and Van Winden 2000). In other words, an altruist leader can influence a wide range of contributors through intermediaries. This point of view is followed by managers to improve performance in organisation (Mackey and Sisodia 2013). In the open source field this approach is fed by *a priori* democratic equality-in-law and the theories of the public domain (Boyle 2003).

This organisation theory has implications in the open source field because of the high moral intrinsic motivation to contribute. Sharing ideology is not only a win/win calculation but also spontaneous comportment facilitating by the intangibility of digital goods. Cultural explanations such as Hacker ethic or Commons are contributing to broadcasting altruist online behaviour with individual motivations. In this perspective leaders are presented as a defender of collective ideology of sharing such as Richard Stallman initiator of the Free Software Foundation in the 80th (DiBona and Ockman 1999).

The leader's popularity is an important point in the free software project (Blincoe et al. 2016). It attracts new contributors and inspires new initiatives. The work from Raymond contributes to explaining this imitation approach. The cathedral and the Bazaar' (Raymond 1999) describes the personal experience of the author as an open source leader. He conducted the development of Fetchmail drawing on the Linux project. Such formalisation has been disputed by some software developers (Bezroukov 1999). They argue that the social relationship in an open source project cannot be simplified and replicated by following a

meritocratic hierarchy because of some contributors' ego or the leaders' burnout. In other words the self-motivations can be unproductive and ruin the collective action.

Our perspective is to complement these approaches by showing that leaders often work in teams. This point of view is in the feet of Alberto Melucci (Melucci 1996) who analysed leadership as an unconcentrated and diffused attribution in a group. This approach is consistent with the research insisting on the cognitive dimension of contributions such as online discussion (Johnson, Safadi, and Faraj 2015). We will look at open source community sociability through the intensity of different relationships. Some works had already shown that these teams can have different kinds of leaderships (Shaikh and Henfridsson 2017) such as autocracy, oligarchy, federation, meritocracy. Others research are focusing on the emergence of leadership over time in self-governing organisation (Eseryel and Eseryel 2013). These changes are due to the evolution in terms of needs in the community passing from technical skills to coordination activities (Dahlander and O'Mahony 2011, Bert-Erboul 2017). Research on leadership style in open source communities emphasises that technical skills are not the only determinant to be a leader (Faraj, Jarvenpaa, and Majchrzak 2011). Some monographic research show how some communities grow or stay limited to a core of developers (Conlon 2007).

Unfortunately, this literature fails to provide much information on the origin of leadership except for references to some special 'energy' of core developers. They don't explain how people met and especially how leaders met and how they associated with each other and with the contributors all along the project's life. In the works, people contribute to project because they share the same feeling concerning the project's spirit and objectives, and they are motivated by career incentives and/or ego issues. We do not, however, understand how they become the foundations of innovation, or why they decided to lead a collective action. The history of Videolan illustrates the importance of institutions in personal relationships. The context of the leaders' training, the legal framework in their countries, and the institutional form of the project help explain why leaders engage in open source.

3) Videolan communities: from boarding school to world-wide

The Videolan software[1] development is based on a core of contributors analysed as a college of experts (Waters 1989, Basset 2005, Bert-Erboul 2013). They are mostly in the same

[1]Today the Videolan software developers claim 2 000 000 000 downloads.
http://www.videolan.org/vlc/stats/downloads.html

organisations, and from the same European countries, and under the same law on informatics (the European law does not recognise patents on software). We can frame the community's story in terms of three periods with three types of communities marked by different forms of partner meetings.

Videolan was initiated in 1996 as a student project. The Videolan software known as VLC (Video Lan Client) reads and broadcasts multimedia contents (movie, music, TV, DVD). The development was related to the training program for second-year students at the Ecole Centrale de Paris[2] (ECP). In addition to the school work, students have further developed the software by their own means. During their spare time they coded the software in the boarding school where a floor was reserved for the project's members.

A decade later, in 2006, the Videolan project team was gradually being organised outside the Ecole Centrale de Paris for several reasons. The growing number of VLC users had increased costs development (bandwidth, electricity) at the ECP. Furthermore, the students tended to host occasionally illegal content (hacked software) that the ECP management wouldn't accept. An Internet provider, accepted to host the software download platform with high bandwidth at no cost. This company was using the Videolan software in its online TV service and had supported its development. This partnership was set via a contributor and ex-ECP student who worked in this Internet provider company.

Videolan mainly works with a small team of volunteers, mostly alumni from the ECP. They manage economic, legal and technical issues through a non-profits organisation created in 1999. The socio-economic issues are most important because parts of Videolan software are used by the ICT industry. Despite the historical community centralisation around a small core, the organisation is still brittle as highlighted by a contributor:

'*The first circle is five or six people, the second circle is very close to a dozen to fifteen people and then it's scattered. You can have 100 or 150 people who bring something and leave each year. What happens if the five of the first circle decide to have a real life*?'

This arrangement in concentric circles (Crowston and Howison 2006) has experienced several periods. During the period in which the project was located at the ECP contributors depended on the rotation of student promotions. Subsequently, although the project was internationalised, the organisation has remained centralised around alumni ECP students. A core of them extends their participation for several years.

[2] The Ecole Centrale de Paris is one of the most selective French « Grande Ecole ». The tradition of this school is mainly industrial rather than political or military.

Late 2012 a group of contributors mostly from the ECP and from other French engineering schools created a company named VideoLabs. This company produces VLC services for different clients: microprocessor manufacturers, operating systems, and production or film distribution companies.

In the following parts we are detailing the social network database and our ethnographic work. Then we analyse three chronological sequences spanning fifteen years of observation. Each of these periods is characterised by a different type of community leadership mixing behavioural and cognitive approaches. First, in the superimposed community leaders were selected by the school which initiated and hosted the community. Second, the captured community is organised by leaders who face up to legal and technical challenges, now outside the original host organisation (ECP). Third, the chosen community is closer to the free software initiators and their institutional framework, but the leaders inherit all previous rules, friendships and hierarchies set up during the prior history of the community. These three communities complement the classic framework of open source organisations that we presented in the previous section.

a) Data: Mailing list network and ethnographic work

Our community network analysis is based on the mailing archives organised in periods of 12 months (January to December). These messages are exchanged by participants to the list 'VlcDevel' dedicated to the development of the VLC media player software, the most popular software in the Videolan project. The messages on the list are related to the use of software features, code changes, or more rarely the distribution of rights between contributors to modify the software code. The mailing archive is public and represents 108,512 messages exchanged between 3276 different email addresses from 2001 and 2015[3].

To study the interactions revealed by the discussions we have established the relationship between contributors on the basis of different topics of discussion (thread). This results in a set of bimodal relationships (contributor A/ thread / contributor B). We then link all persons within the same thread to obtain an undirected unimodal network (contributor A / contributor B).

This approach gives messages equal values: a question has the same weight to an answer. All messages and all contributors have the same weight also. A core member is as important as a peripheral contributor. This methodological homogeneity reflects the egalitarian rules on the list, which is public and without a moderator.

[3] https://mailman.videolan.org/pipermail/vlc-devel/

The sum of contacts for each participant allows to record the interactions and the centrality into the list (Ducheneaut 2005, Freeman 1979). The subscribers' interventions on the mailing list make it possible to study the evolution of the personal communications of network developers. Considering degree centrality, we highlight that a contributor is even more central to the network that is in terms of interaction with different individuals. The multiplication of different contacts indicates the contributor's expertise extension, his/her ability to react on topics from varied origins and the time spent on the project.

The networks are centralised around two or three contributors who take in charge the answers. Betweenness centrality highlights[4] the role of other contributors to the networks (especially in the last stage). This indicator reveals the importance of people in contact with others who are not linked with the two or three central actors. People making the bridge are also important for transferring information and reducing the question weight usually managed by the core developers. This measure gives the opportunity to analyse the rise of confidence in the virtual team (Breuer, Hüffmeier, and Hertel 2016). If the betweenness remains at the core of developers, it would indicate that proximity is dependent on the previous relationship. If betweenness rises, proximity can be built thought contribution activity and not only by previous institutional relationships.

We also calculate clustering coefficient (transitivity) over time to analyse if some discussions happen without core developer interventions. The transitivity in a network evaluates the number of triads in a network. If A and B and, A and C are connected, the transitivity check if the edge between C and B exists (Newman 2001). This indicator shows the spread of trust in the community and how much the core developers' interventions are needed in the community activities.

In addition to the structural analysis, one of the authors also carried out 10 extensive interviews between 2010 and 2012 with contributors who have participated in different periods of the project. They tend to indicate that developers of Videolan do not operate in a vacuum but interact with the broader professional and amateur computer field. They are also in touch with the local institutions in charge of Internet and copyright (droit d'auteur) regulation. The interviews focused on the participation of contributors and the use of free licences and resources (material, economic, symbolic) available to the group at different periods. In addition, we observed three development meetings between 2010 and 2012

[4]The betweenness centrality is calculated by the geodesic distance (the shortest way) between two points (see (Bird et al. 2006)).

involving hundreds of people. During these workshops and conferences developers and members of private IT companies meet to discuss future software direction.

The combined material gives us information about individuals' comportment for fifteen years. The relational data tend to reflect and objectify relationships even if the community posed other channels to interact. The links smooth a part of the diversity of opinions, and intensities of emotional and moral relationships. The type of data collection and compilation also erase oppositions and conflicts in the exchanges because matrices are encoding only the presence or absence of relations. However, this data show the emergence of coordination in different contexts. The compilation of this data creates an artefact to understand the rise of collective action from individual activity.

b) The superimposed community: external selection and innovation

Between 2001 and 2006[5] the VLC software was created and developed by students at the Ecole Centrale de Paris. During this period, the contributors were part of a community superimposed from above. This community is marked by an external selection of contributors regardless the developers' will (the leaders and the other contributors). The schoolmates at ECP pass a selective test after two years of training next to the baccalaureate. For five years, most of the community was built within the ECP and its collective life. In this first community, the hierarchy is framed by school grades and student turnover (students stay three years at ECP). Common living at the boarding school creates a strong bond between students who share a lot of their personal life in face-to-face relationships and parties.

The network of the superimposed community stage has clusters centralised by successive students' promotions at the ECP (Figure 1). Each of these clusters has external contributors who ask technical and legal questions to students. Only few of these external contributors are specialists of very specific topics and have a certain importance in the network on the basis of their degree centrality. We also observe on the graph that most of the clusters are built by contributors active between 2004 and 2006. This graph gives the opportunity to observe the emergence of a collective project through successive involvement of contributors from the ECP School. Between leader and broker status, the activity of these students was motivated by compulsory school work and ideological proximity to the free software movement as the followed interview shows. The ECP students wanted to create free

[5] Between 1996 and 2001 the Videolan is in project. The Ecole Centrale de Paris realizes works site to renew its network installation. The Videolan project is directly related to this change. The source code development and the rise of the community started in 2001 after the work plan realised.

software because they share the ideology of this movement, and they asked advice from that community.

'Our model was Berkeley. We have been helped by the Free Software Foundation and these kinds of people. It has been done very naturally. Since the beginning our idea was to do something free. You can see one of us has been the European leader of one famous free software project (Debian). So when he was in Videolan he started to meet people in the free software field.'

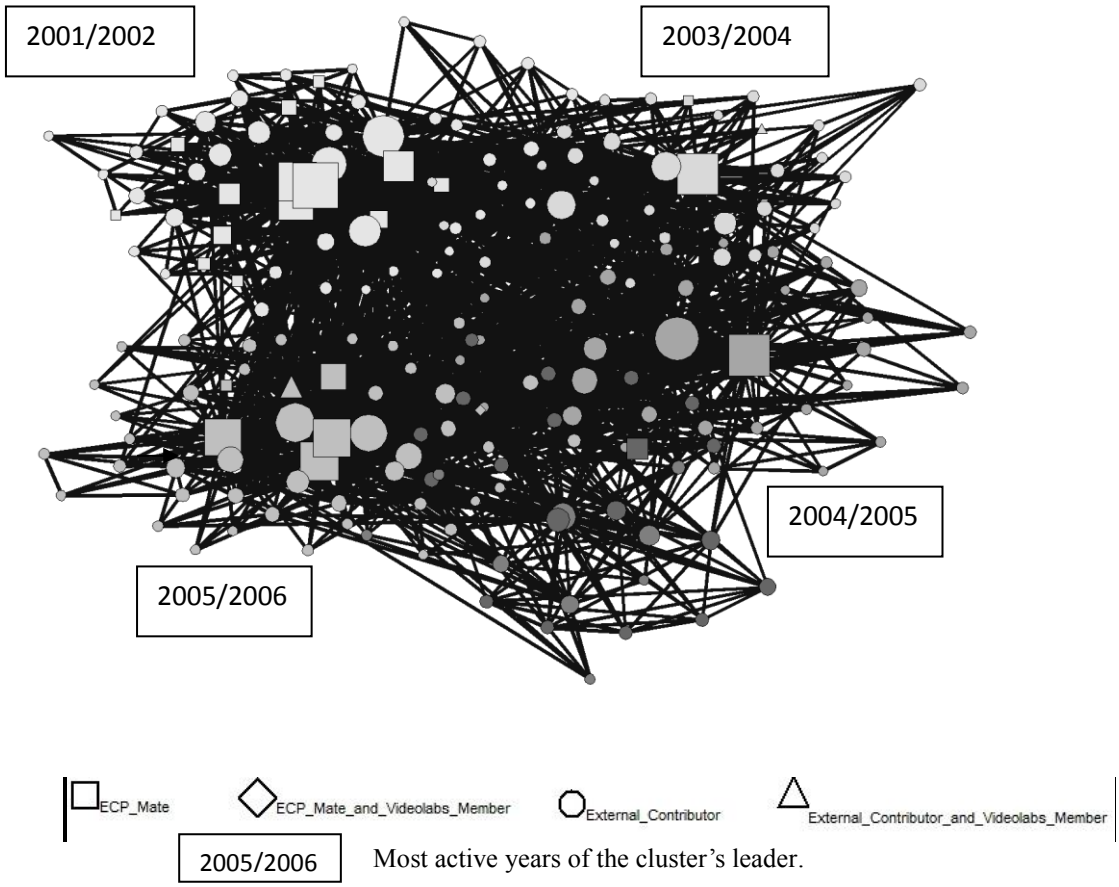

Figure 1 The superimposed community social network[6] (2001/2006, n=1215, Density = 0.00386052)[7]

The network of this first period has structural characteristics. The centrality standard deviation is low and stable compared to the next periods (Figure 2). This frame indicated a less centralised work division than the next two periods. During this early time the community

[6]To show the network's evolution we realize visualization with Pajek software with the merging of networks of the years for each stage. We create partitions in the network through a community calculation with the Louvain method to highlight the subcomunities by taking into account the density between nodes. That technique is taking into account the sum of the weights of links between vertices. If the connection is repeated, the vertices are part of the same subnetworks and painted in the same colour. Furthermore, the Kamada–Kawai layout on Pajek is able to write the network with an optimization inside cluster only. This algorithm makes automatic layout to show easily clusters and regroups the vertices of the same clusters. We add a vector in the layout to highlight the importance of vertices through their degree of centrality. The higher the centrality is, the bigger the vertices should be. Finally, we also add a variable from the profile of the contributors to distinguish the ECP mates, the external contributors and the Videolabs employees.

[7] Network visualization has been reduced to make easier the graph's reading (nodes all degree>5)

is mainly composed by the ECP student turnover. However, some external contributors interested in a multimedia open source project also participate. Between 2002 and 2005, the project experiences fame (award from IBM and Linux Challenge in 2001, from Apple Design in 2003) and the mailing list population quadruple (Figure 3).

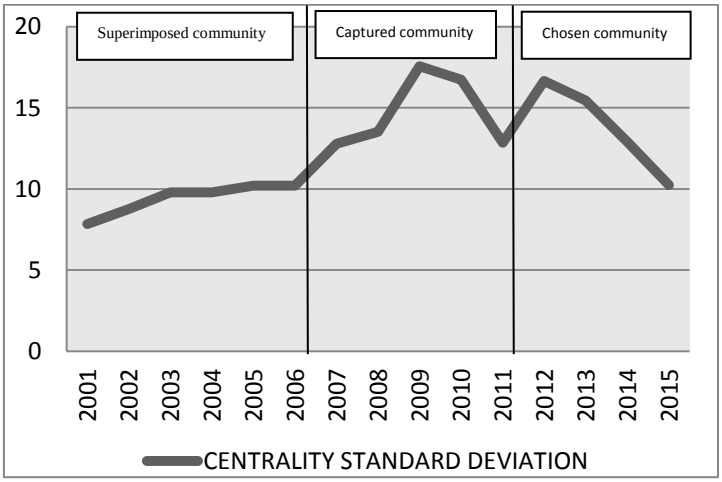

Figure 2 Centrality standard deviation on the mailing list VLCdevel

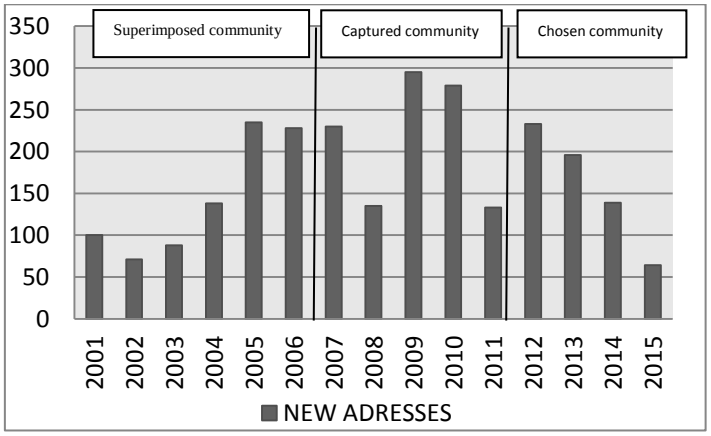

Figure 3 New addresses on the mailing list VLCdevel

During this first period the important presence of external contributors is not completely integrated with the personal relationship build at the ECP. The weight of the links between the externals (amount of mail exchanged between contributors) is strong (Figure 4). In other words, the students do not have the monopoly of expertise until 2006. This centralised organisation with active periphery is reflected in the modular software structure. The Videolan core software is an engine for specialised features (modules), produced by external developers. A contributor explains that the Videolan team ensured that these external features are compatible with their core.

'W*e use fundamental bricks of free software used by almost all projects. For example, QT which is a graphical interface, it is carried by a mobile phone manufacturer, and a team of several hundred people and it is a Linux base.*'

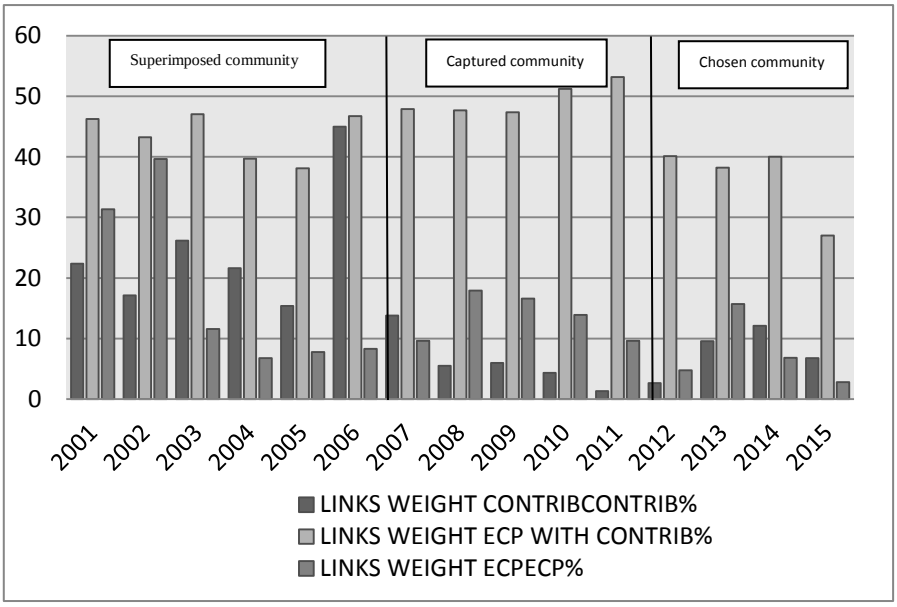

Figure 4 Weight of the links between Contributors and ECP students on the mailing list VLCdevel

The superimposed community is built in two ways. The first one is related to the school context. Students are selected and put together into an institution. The second way is related to the free licences, enabling people external to the core initiator ECP to actively contribute. The first situation creates a personal proximity among the core contributors. They live together at the same place, share the same social and technical features and they have the same goals. However, they didn't decide to meet before the institution put them face to face.

c) The captured community: attraction and legal management

Until 2005 the project had been very dependent on ECP student selection. However, in 2006 the Videolan project was dropped from the ECP curriculum. A contributor tells us during an interview how this new policy affected the project.

'The last years, students were very bad, that's why it stopped. They have no time and no training. It's not that the younger generations level down, they just learn something else.'

This lack of trust is visible in the social network metrics (Figure 5). The rise of core developers is tangible with the social network clustering indicator. In other words, the central contributors are more trusted than the others. During the captured period there is a decreasing number of transversal relationships. This phenomenon starts with the source code upgrade. The situation changes during the chosen community and the transitivity grows. This new

trend highlights a structure more triadic and a spread of expertise and trust in the network after a phase of strong centrality around a small core of developers.

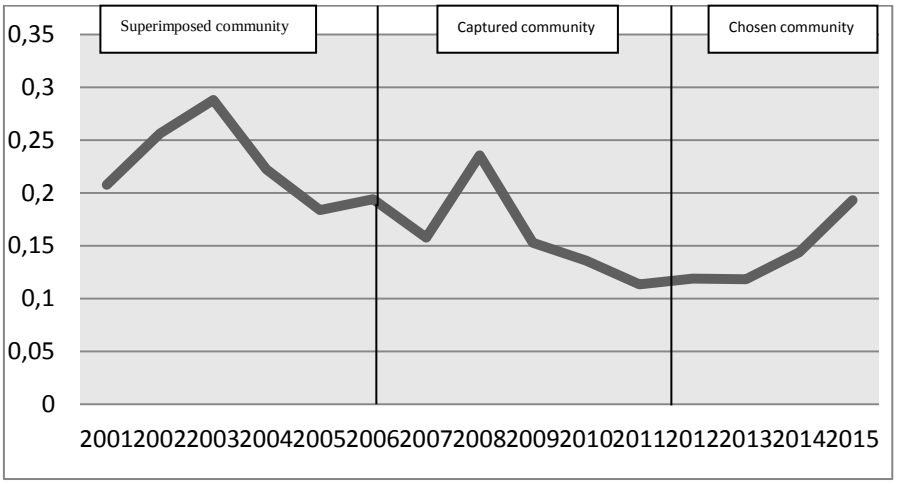

Figure 5 Network Clustering Coefficient (transitivity)

This situation resumes the main characteristic of a captured community: find (good) contributors and improve trust in a virtual team. First the ex-ECP developers had to upgrade the code. A core of contributors reworked the code on their leisure time. Development during the school period created code problems, due to the successive team in charge of the project as a contributor said.

'In fact, the code was messy. Students who came from one year to another, they did something and abandoned, and the following year it was another who did something. So there was a great need to clean. It has been done between 2006 and 2007, 2008. We were 3 or 4. Not all of the code, but part. Now that the code is correct, people can come and work on it quickly. The code is so complicated you need a level that you do not have when you're in school. These young professionals are often former students and they want to continue the project. Now it's very easy to come and add features that are clean and easy to maintain and suitable for people. People can come to projects based on VLC without changing VLC.'

The testimony from this contributor is confirmed by the network data. The improvement of the source code by a small team is followed by the arrival of new external contributors (Figure 3). The demographic increase is marked by the network density diminution (Figure 5**Ошибка! Источник ссылки не найден.**). More topics are discussed by students and external contributors participating in other free software projects or corporations.

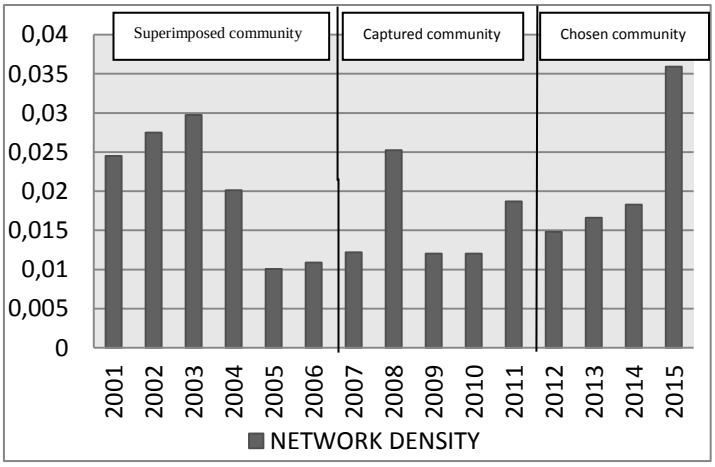

Figure 6 Network density on the mailing list VLCdevel

The captured community has a specific network compared to the previous period (Figure 7). This community is organised by ex ECP mates. In that network the centrality standard deviation is rising (Figure 2). A team of 7 contributors (with 5 ex-ECP) stay highly active between 2006 and 2011. They concentrate expertise on the VLC development. In this network most of the links connect ex-ECP mates to external contributors. The social network layout below shows the cluster around core developers specialised in the software's parts. Once again, only one external developer was able during several years to contribute and lead a cluster mostly dedicate to technical issues. That underlines the institutional roots of the proximity in the project even after the project had left the ECP School.

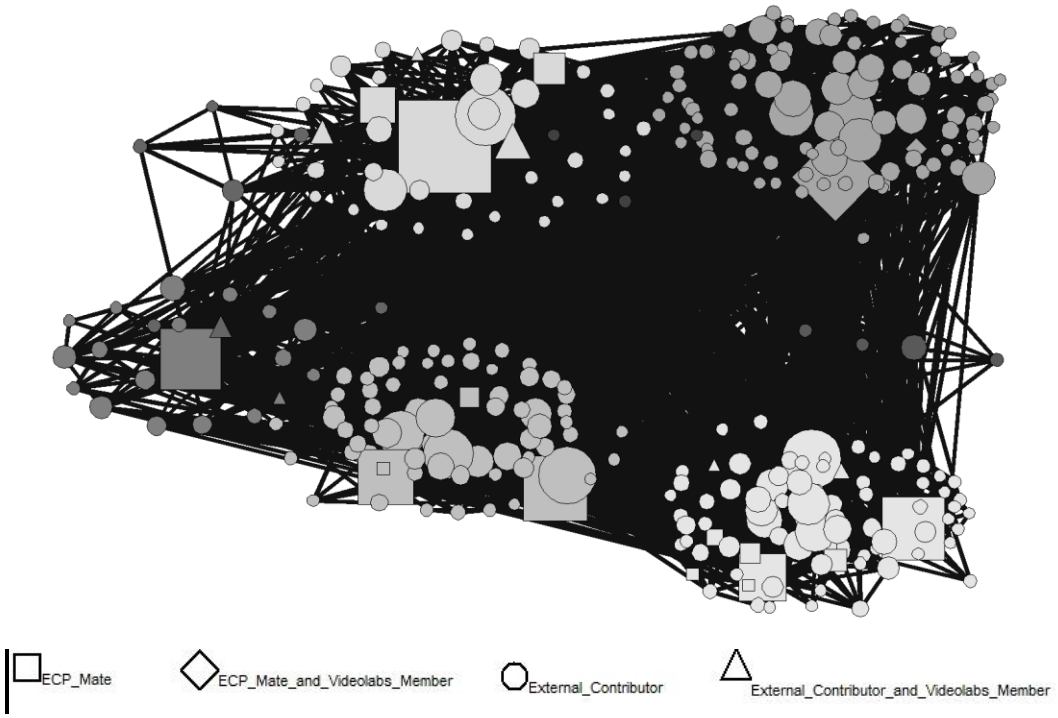

Figure 7 The captured community social network (2007/2011, n=1511, Density [loops allowed] = 0.00407994)[8]

The dynamics of this network are not linear. The arrival of new contributors in the community varies each year. The mailing list attractiveness is related to the upgrade realised on the code between 2006 and 2008. After that, the project catches the attention of new waves of contributors between 2009 and 2010 (Figure 3). However, the multimedia software frightened volunteers and companies. This part of the ICT industry is characterised by complex copyright laws as a core developer from ECP says below.

'In multimedia there is patent everywhere, nobody wants to put money, everyone is afraid of being attacked. It's too dangerous. We are in Europe and we have no money. It is useless to attack us. The free multimedia is European'

The upgrade was not the only way to attract the attention of newcomers. The core has reactivated face-to-face meetings named the Videolan Dev Days (VDD) since 2008. During these events the non-profit organisation Videolan provided accommodation for participants. All developers (even those are not contributors) were invited to discuss during lunch and during the entire workshop in a friendly atmosphere.

Technical frames and community management are not enough to do all the tasks the community needs. The core developer decided to create bounties. Some tasks remained unrealised because of lack of time or skills. These source code contributions are rewarded

[8] Network visualization has been reduced to make easier the graph's reading (nodes all degree>5)

between 250 and 6000 Euros. These funds are dedicated to external contributors and exclude the core developers group.

The captured community was oriented to innovate and produced new features. However, its management was centralised and exposed to unexpected variation as evidenced by new arrivals on the mailing list. That means the expertise was shared among the leaders who have mostly the same background at the ECP. These leaders faced different issues such as: skill management, competition, demographic change, technical upgrades, and copyright agreements. To succeed these strategic periods, the communities need to redesign their technical and institutional environment to facilitative communication in the organisation (Mateos-Garcia and Steinmueller 2008). The contributors use different types of relationship to solve these events.

To stay active this group has to regularly succeed in meeting objectives and in maintaining contributors' excitement. This period implies widening of the cognitive activity. Leaders must be good at the code, but must also get a strong knowledge of law, economics, institutional process, and communication. In other words, leaders graduate limit their exposure to the coding space and invest in management skills far from their first motivation.

Sometimes strong solidarity is needed because of judicial affairs, or deep technical modifications. In these cases, the personal proximity between leaders and contributors is being mobilised through the ex-ECP network. These relationships are created by early or/and intense relationship in the project often through common institutional affiliation. In other circumstances the leaders need to share broadly "boring tasks", add new features to the project, or the community infrastructure requires financial investments. On these occasions the leaders use the social proximity. These linkages are built by temporal contributions or through the external institutional environment.

d) Chosen community: friendship and discipline

Until 2012 the project is led by a chosen community organised around a company of software services named Videolabs. This group of developers has created a company to provide services with VLC. The 17 members of Videolabs are important contributors to the code of VLC and to the community in the mailing-list.

The most important contributor (ex-ECP) to Videolan is not part of Videolabs, but he continues to be the most productive individual in the community at large (he carried out 24% of the code modification). In other words, when individuals were free to choose their partner, they did not necessarily choose on the basis of technical efficiency, but preferred other types

of affinity. Besides, there is a divergence of views with some contributors seeing Videolan as a project realised by volunteers taking care of users' needs rather than employees who address customers' demands.

The network of this period remains similar to the superimposed community in terms of size, but its dynamics are different. The network exhibits decreasing centrality standard deviation implying that the network is focused on a widened developer core. Furthermore, the density is increasing because developers have more exchanges and share expertise in different software parts. There is no isolated expert, but more people (especially those of Videolabs) have deep knowledge of the entire software. The expertise stays in the developers' hands regrouped in Videolabs. In that network, the number of threads where Videolabs people participate increases and the external contributors need their interventions in order to contribute (Figure 8).

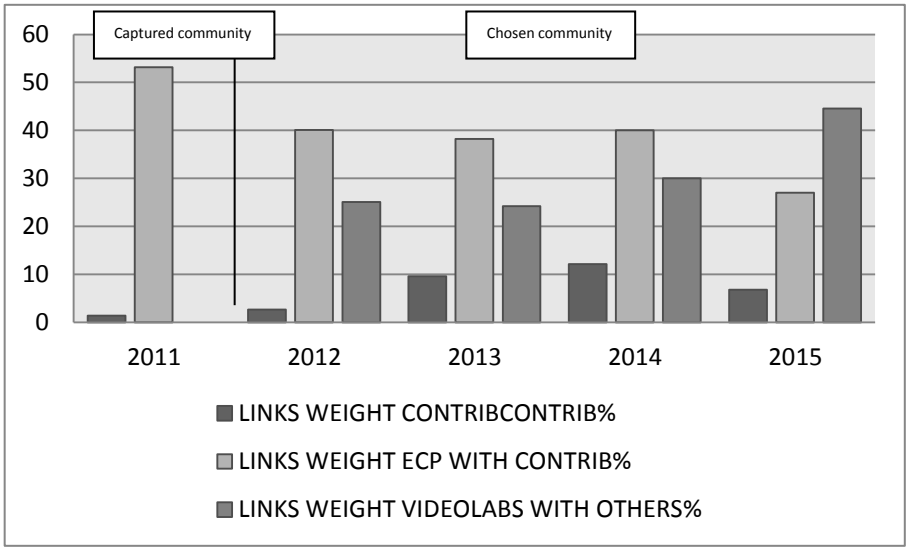

Figure 8 Weight of the links between Contributors and ECP students and the Videolabs employees on the mailing list VLCdevel

The chosen community now illustrates the leaders and their followers' freedom to involve in a common activity. It is also the institutionalisation of their charisma legitimised by their expertise. The remuneration of Videolan contributors is not a new fact. However, previously this phenomenon involved only isolated people. Now Videolabs hires the core community with technical, social and economic resources to improve the software.

The core community has an authority because of its expertise, but also because of its discipline imposed on others. These developers between free software community and a company are criticised, but they keep authority onto the external contributors. The case (presented below from the mailing list) of a contributor who asked the reinstated person of his

code management right highlights the conflict of authority and the discipline imposed by the core developers.

> *'Since the entirety of the board (President, Treasurer and Secretary) are either VideoLABS employees, how do you ensure treating me vs. VideoLABS in a fair manner and separate the interests of VideoLAN versus VideoLABS?'*[External developer, no ECP and no Videolabs]

>> *'Of course there are very obvious and well-known potential issues when a single company has most or all control on an open-source project. But it is up to you, me and anybody else not (yet) affiliated with VideoLabs, to counterbalance it if they see fit. Obviously that will involve spending time on the project.'* [Core developer, Ex-ECP no Videolabs]

>>> *'Read my email again then. You keep doing things as root in the main machine and inside the lxc. You refuse to use the FTP incoming like all other maintainers. […] You need to read the forum, triage the bugs, edit the wiki. You, so far, do none of those. Once again, see my previous email.'* [Core developer, ex-ECP and VideoLabs]

The chosen community is not based on technical efficiency, but on a set of shared norms. The strict respect of that discipline enables to distribute work in a network centralised by the core developers regrouped into a company. This organisation distributes the work and expertise. This strategy reminds the selection way in the superimposed community and the process of attractiveness of talented developers in the captured community.

The clusters in the mailing list social network are no longer only led by ECP students (Figure 9). External contributors are taking charge of most key topics. Some of them are Videolabs employees, but most of the important contributors are not involved in the company. Four of the eleven main topics are framed by Videolabs members. The other clusters are managed mostly by external contributors or ex ECP students still involved. This graph shows that the leading position is not realised by an initiator or a broker but by a group of brokers who drive the collective activities.

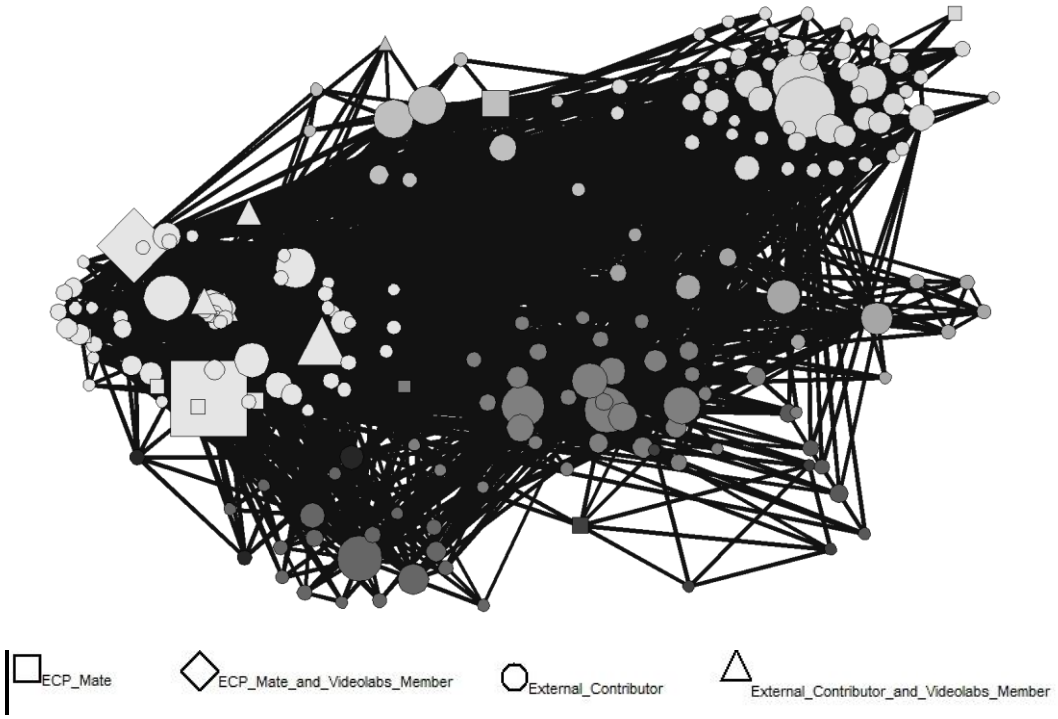

Figure 9 The chosen community social network (2012/2015, n=962, Density [loops allowed] = 0.00647854)[9]

Betweenness centrality shows the networks profiles homogenisation in all the categories (Figure 10). Betweenness converges and signals an intensification of participation by external contributors. This new proximity build outside school relationships highlights new roots of trust to manage the code and licence. People from the contributor group are no longer just asking questions. They also answer other people's questions before the core developers from Videolabs and ex-ECP react.

The first two stages were animated by actors with very specific betweenness rate. That shows the proximity between people is dependent on their institutional embedment. The superimposed community is marked by a dynamic with convergent tendencies but with an important gap between ECP and external contributors. In the captured community, the tendency is non-convergent because the external contributors are not involved durably in the project.

[9] Network visualization has been reduced to make easier the graph's reading (nodes all degree>5)

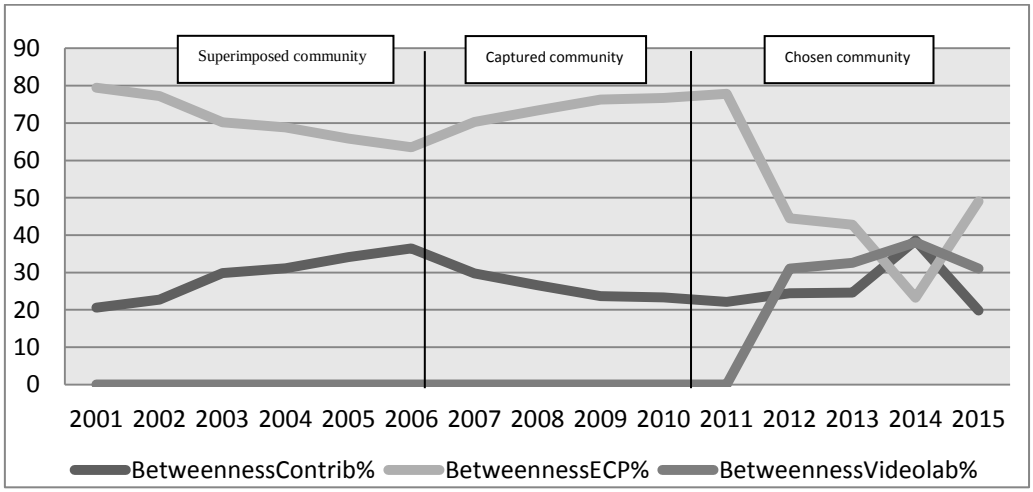

Figure 10 Betweenness centrality shares by profiles of contributors on the mailing list VLCdevel

However, if the profile of people participating actively to the list comes from different origins, the core developers remain as an elite very different from the most of contributors. The continuing rise of the betweenness standard deviation since the project exited the ECP School highlights this fact (Figure 11). During the period of the superimposed community betweenness dips due to the increase of free software community participation from outside the school. Then, when the project is upgraded and driven by a specific team outside of the ECP School, the difference between core developers and the other contributors increases. During the captured community and the chosen community stages the difference in betweenness is due to the progressive settlement of a team regrouped around a company.

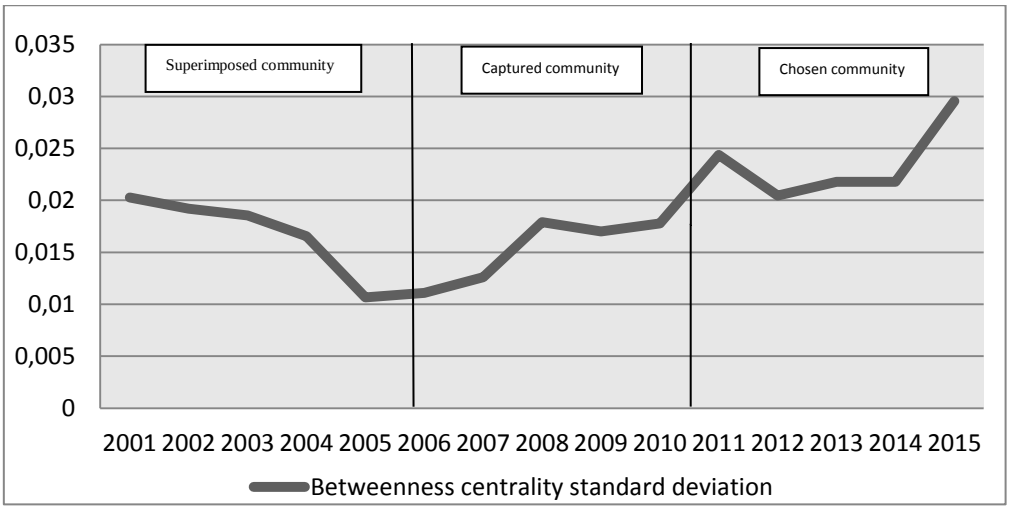

Figure 11 Betweenness centrality standard deviation contributors on the mailing list VLCdevel

Finally, it must be stressed that the chosen community stage is not characterised by a friendlier or anarchic community, but by a chosen set of rules. These rules are not imposed by an external organisation, nor are they created to attract new contributors. They are chosen through collective experience from a set of technical and legal possibilities met by the core developers since the beginning of the project.

4) Discussion

In addition to personal convictions, commitment to open source projects is influenced by the contexts in which individuals find themselves. Far from conforming to the imaginary immaterial land impersonal world of the Web, an open-source community such as Videolan is influenced by the face-to-face interactions and by the personal proximity between lead developers. The involvement of these core contributors implies multiple forms of regulation in relationships (Demazière, Horn, and Zune 2007). Our typology of superimposed (early stage), the captured (middle stage) and the chosen communities (later stage) present different types of organisation between the economic incentive models and the ego management from the meritocratic point of view. In each Videolan project period, the equality and the meritocracy between developers and leaders are thwarted by other norms. The purpose and means of collaboration and the ensuing social networks are shaped by the institutional framework, innovation requirements and collective discipline.

Different types of personal proximity were observed in the three communities (Tab 1). The core developers have personal relationships with each other through different aspects of their private life. During the superimposed community, the students share strong bonds as part of their everyday life at the boarding school. The captured community is animated by the leaders facing strong technical and legal challenges in order to convince contributors from the free software community and IT industry to join the Videolan Project. The involvement implied a strong solidarity because of legal issues imposed by the copyright and the concurrence in the IT industry. In the chosen community, the proximity between the core developers is also strong and personal, taking into account the freedom to choose each other as partner. Most of them are standing developers with a common engineering background and face-to-face interaction.

The core developer community evolves with the global community through an ‘imaginary equality’ due to the free software licences. The two parts have a social proximity

routed in multimedia technical issues (Tab 1). During the superimposed community period, the free software involvement creates an identity that the ECP students, but also external developers, shared through a transversal organisation. The social identity was complemented by the community management used with the Videolan brand during the captured community period. This period is marked by a centralisation of contributions and trust. The creation of an economic model with the VideoLabs Company during the chosen community period institutionalised an extended core of developers with authority and expertise (even if they are not part of the company) on the shared source code.

Tab 1 Proximity synthesis

	SUPERIMPOSED COMMUNITY	**CAPTURED COMMUNITY**	**CHOSEN COMMUNITY**
PERSONAL PROXIMITY	Pre-selection of students Boarding school life Transversal trust	Free software legal issues Software upgrade Centralised trust	Free software legal issues Videolabs company business Strict rules to contribute Extended core confidence
SOCIAL PROXIMITY	Free software rules Multimedia technical issues	Community management Multimedia technical issues	Source code sharing Multimedia technical issues

5) Conclusion

This paper analyses personal and social proximity in open software environments. It contributes to the literature on free/open source innovation in three ways. First, it highlights the continuum of roles played by individual leaders in the open source project, as brokers and/or initiators. Second, the paper targets the evolution of proximity among the members of the core team and highlights the influence of institutional and industrial context on projects organisation. We use the social networks of the Videolan software community to delve deeper into where, how and when leaders are organised in groups and play the role of brokers and initiators. We study leadership emergence over time by taking into account the context of activities. The core developer networks emerge through three successive stages with different social dynamics. By taking into account the process of institutionalisation we understand how a project survives outside its initial environment.

The results of the study could be summarised by three key findings. First, the free software project is not driven by an inflexible organisational structure but it is shared between an evolving leader-broker layout. Second, the proximity of the initiators is rooted in the original institutional belonging even when the project has quit the initial institution. Third, proximity and solidarity can be rebuilt from a common background in technical matters around a common formal institution such as a company.

None of these findings confirms or invalidates the '*imaginary equality*' norms in free software communities. Nevertheless, the institutional roots of the community and the existence of the superimposed, captured and chosen communities highlight the contextual influence on the individual involvement and proximity. In other words, some people have more opportunities to contribute than others. However, the changes in community organisation show that the contributors' profiles and the contribution norms evolved through time, thus limiting the scope of a determinist approach.

Limitations of our work are related to the monographic approach. They point at desirable expansions in our typology. An obvious expansion would be to examine whether results are particular to the specific Videolan case or hold in other open software cases. Studies from other types of open communities could enrich the findings regarding the influence of social context in the community's activities and organisation. Further, the change of centrality distribution and size in the networks indicates the importance of exogenous factors in shaping the community social network. We observed some of them in this article, but looking at a larger list of such contextual factors would see a worthwhile endeavour.

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