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Bottom-up Infrastructures: Aligning Politics and Technology in building a Wireless Community Network

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Abstract. Contemporary innovation in infrastructures is increasingly characterized by a close relationship between experts and lay people. This phenomenon has attracted the attention from a wide range of disciplines, including computer-supported cooperative work (CSCW), science and technology studies (S&TS), organization studies and participatory design (PD). Connecting to this broad area of research, the article presents a qualitative case study concerning the building and maintenance of a grassroots, bottom-up information infrastructure in Italy, defined as wireless community network (WCN). Methodologically, the research is based on qualitative interviews with participants to the WCN, ethnographic observations and document analysis. The aim of the article is to understand the alignment between the technical work implied in building this bottom-up infrastructure and the political and cultural frameworks that move people to participate to this project. Relying on the field of science & technology studies, and in particular on the notions of 'inverse infrastructure' and 'research in the wild', we disclose the WCN's peculiar innovation trajectory, localized outside conventional spaces of research and development. Overall, the presentation of the qualitative and ethnographic data allows to point out a more general reflection on bottom-up infrastructures and to enrich the academic debate concerning bottom-up infrastructuring work and other similar typologies of collaborative design projects in the domain of infrastructures.

Keywords: Information infrastructures, Wireless community networks, Bottom-up infrastructures, Inverse infrastructures, Research in the wild, Qualitative case study

1. Introduction

Civic and grassroots organizations are currently playing a growing role in the shaping of technoscientific innovation processes in a number of contexts, including information and communication infrastructures (Björgvinsson et al. 2010; Callon et al. 2009; Mongili and Pellegrino 2014; Ludwig et al. 2016). Contemporary innovation in infrastructures is increasingly characterized by a close relationship between experts, non-professional designers and lay people, and this phenomenon has attracted the attention from a wide range of disciplines, including computer-supported cooperative work (CSCW), science and technology studies (S&TS), organization studies and participatory design (PD). These perspectives have attempted to understand how cooperative design practices of infrastructures can both

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shape unprecedented trajectories of innovation and enact the democratization of technological development and usage. This occurs especially when collaborative practices and projects are carried out outside conventional environments where technologies are usually elaborated and implemented (Latour and Weibel 2005; Le Dantec and DiSalvo 2013; Teli et al. 2015; Jalbert 2016), such in the case of bottom-up, grassroots or 'inverse infrastructures' (Egyedi and Mehos 2012).

Connecting to this broad area of research, this article contributes to the on-going debate on the cooperative shaping of technoscientific innovations, highlighting how and what consequences the increasing engagement of heterogeneous publics have on the development of bottom-up information infrastructures, as a forum for horizontal co-design and local, mutual learning (Bødker et al. 2017). In this way, by bringing together the debate about bottom-up infrastructures in PD and the empirical and processual sensitiveness, arising from S&TS work, on the manufacturing of technoscience occurring 'in the wild' (Callon and Rabeharisoa 2003; Smith et al. 2017), we aim at fostering the understanding of design-in-the-making of information infrastructures as a crucial topic for CSCW's scholarship.

For this purpose, the article presents and discusses a qualitative case study concerning an emerging typology of grassroots information infrastructure for digital communication, defined as a wireless community network (WCN). WCNs are bottom-up infrastructures characterized by being based on a 'mesh' or 'distributed' network architecture and also by being built and self-managed by 'communities' of voluntary people, including a wide range of social profiles such as hackers and geeks, engineering students, political activists, and interested citizens.

By addressing some of the key features pertaining to the building-up and maintenance of a grassroots information infrastructure, we refer mainly to the field of S&TS, where scholars have developed a conceptual apparatus to theoretically

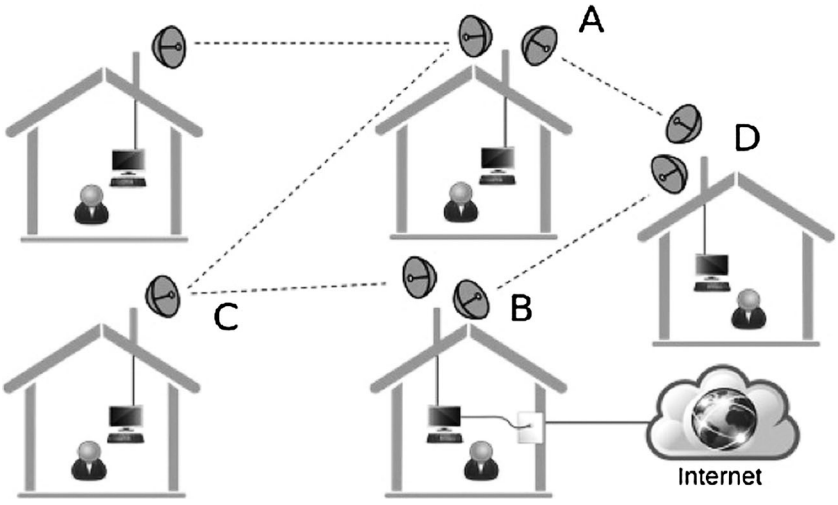

Figure 1. A graphical description of the structure of a WCN (Crabu et al. 2016).

capture issues related to the processual and open-ended dimension of socio-material work in scientific and technological innovation: 'inverse infrastructure' and 'research in the wild'. The notion of 'inverse infrastructure' (Egyedi and Mehos 2012) conceptually emphasizes the increasing relevance of user-driven, decentralized, and self-managed infrastructures that emerge by an 'inverse' trajectory. More accurately, the term 'inverse' reflects the growing relevance of technological and organizational alternatives to the dominant model operating in institutional infrastructures, where public institutions, private organizations, or centrally-controlled governing bodies represent pivotal actors in the design and management of large-scale technical systems (Hughes 1983). At the same time, the concept of 'research in the wild' (Callon and Rabeharisoa 2003), which was originally developed to theoretically capture the public shaping of medical research, is here discussed in guise of promising 'heuristic lens' to address the work of 'infrastructuring' that occur outside the usual boundaries of research and development (R&D) settings, in relation to the shaping of participants' identities and subjectivities involved in bottom-up projects. This analytical sensibility allows to adopt a processual conception of knowledge and technologies as *act of knowing and learning in practices* (Gherardi 2009), enabling to disclose those peculiar trajectories of grassroots innovation, increasingly localized outside conventional and predictable spaces of research and development. In these processes of infrastructuring, specialists, experts, and 'lay-expert' (see Prior 2003) their cultural frames, and material artifacts are interacting with each other in a dynamic of mutual reconfiguration, thus reshaping the conventional boundaries between science, technology and society. In other words, this perspective allows the *processual* and *in-the-making* nature of the technological innovation to be highlighted, as well as to investigate the 'naturalization process' (Bowker and Star 1999) of unpredictable and erratic paths through which infrastructures can be developed in a horizontal, participated, and cooperative way.

To reach this outcome, the article starts with a discussion on emerging patterns of collaboration and design in CSCW, outlining the theoretical perspective adopted in the article. Then, we present a qualitative case study that focuses on the development of a grassroots wireless community network in Italy, originally started in Rome in 2001 and expanded in the last few years in other cities such as Florence, Pisa, and Bologna. This case study is the empirical basis to investigate how contemporary infrastructuring processes are the emerging result of the sociomaterial collaboration occurring through bottom-up trajectories by the mutual engagement of experts, lay people and other actors in unconventional environments of innovation.

The presentation of the qualitative and ethnographic data will concentrate on three main features of this infrastructuring in the wild: i) an outline of the hybrid set of motivations and beliefs that sustained the participation in the work of infrastructuring, paying specific attention to the interaction between technical issues and participants' political instances; ii) the process of the subjectivation, or the identity formation, of participants and the ways in which the work of infrastructuring co-participates in generating an active and legitimate membership, as well as the

political and social meanings of the infrastructure; and iii) the role of material artifacts and technologies, as non-human agents (Callon and Law 1997), in the shaping of motivations, identities, and relationships within the work of infrastructuring.

2. CSCW, Participatory Design, and the Co-Production of Infrastructuring processes

The issue of innovative models of collaboration in technology design has been at the core of the emergence of the CSCW domain, and of its interest toward the investigation of computers and ICT as supporting devices for 'cooperative work arrangements' (Schmidt and Bannon 1992) in various workplace organizations such as firms and offices. According to Bannon's (1991) reflections in a seminal contribution in the field of CSCW, human agents cannot be considered merely ensembles of cognitive 'human factors,' but they rather are social actors carrying specific beliefs, skills, and individual values, which co-define their agency and their positioning within technologically dense contexts. Moving from these reflections, increasing attention has been devoted to participatory design practices, by taking into account the experiential and subjective dimensions of human agents in addressing and actively sustaining participatory design of information technologies, as well as of information infrastructures (Hassenzahl and Tractinsky 2006; Teli et al. 2015).

Precisely, with the aim to understand (Le Dantec and DiSalvo 2013) and, in certain extent, support (Pipek and Wulf 2009; Björgvinsson et al. 2012) collaborative design of technologies and projects — in which technology is co-produced by diverse communities of users and practices — a growing body of research around the concept of infrastructuring has been recently consolidated (Karasti 2014). Indeed, according with Star and Bowker (2006), thinking in terms of infrastructuring allows to overcome a reified vision of infrastructures, thus placing more attention on the processual and generative dimension of design practices.

In line with this intellectual trend, the concept of 'design in the wild' (Dittrich et al. 2002; Rogers 2011; Chamberlain et al. 2012) has been proposed to highlight the increasing centrality by forms of participatory design, in which experts and non-experts cooperate to build new ICT. In this regard, Karasti and Syrjänen (2004) addressed more accurately the topic of design and innovation by non-professional designers, coining the notion of 'artful infrastructuring' — borrower on Suchman's notion of 'artful integrations' (Suchman 2002) — to conceptualise participatory 'design in the wild' as an 'embedded, ongoing, and multi-relational activity' (Karasti and Syrjänen 2004, p. 20). In a similar vein, albeit with the major purpose of improving collaborative design methodology, Pipek and Wulf (2009) elaborated a perspective on organizational information technology in term of 'work infrastructure'. In their contribution, they pay special attention to the infrastructural dimension entailed in organizing information technology systems, thus emphasizing the crucial role of creative activities of ordinary users in the process of collaborative design for

infrastructure improvement. Thus, authors propose a methodology and tool oriented to support infrastructuring in the workplace considering the relevance of such activities in breaking the institutional boundaries between professional designers and ordinary users. Undoubtedly, the crossing of infrastructuring literature with the interest in understanding and supporting participatory design has allowed to deeply analyse and (politically) bootstrap (Björgvinsson et al. 2010) the diverse perspectives in the collaborative design of information technology, primarily emphasizing the horizontal and situated nature of participatory approaches to infrastructuring.

In continuity with this trajectory of thought, this contribution aims at investigating the situated modalities through which 'design in the wild', and especially the bottom-up infrastructuring work, are actually negotiated and materially performed within a specific socio-technical context. In so doing, we question the controversial dichotomy between 'expert designers' and 'lay people,' considering the latter not merely as 'experiential experts' who may join technological innovation process only in the test phase through top-down involvement; but rather as creative subjects, dynamically engaged in the multidimensional practices co-producing knowledge and technology (Callon and Rabeharisoa 2008; Callon et al. 2009). As recent work matured in the field of S&TS has highlighted, the distinction between expert and lay people stems from an alleged asymmetry in the epistemological status of expert and lay knowledge, assuming that lay people are intrinsically ignorant and, consequently, require to be involved by the means of top-down actions of science education (Wynne 1996; Jasanoff 2004; Oudshoorn and Pinch 2003). To disclose the empirical flimsiness of this assumption, particularly pervasive in Western science (Collins 1999), S&TS contributions have shown how non-scientists are increasingly mobilized in collective decision-making actions and innovation processes concerning technoscience (Brown 1992; Epstein 1996).

Indeed, public engagement practices, stakeholders' discussion groups, and public consultations have recently been established as some of the main forms of civic action in technoscientific landscapes to enhance specialists' awareness and understanding in interaction with non-scientists (Delli Carpini et al. 2004; Da Costa and Kavita 2008). According to Sheila Jasanoff (2004), what is at stake is not just an enlargement of the traditional procedures of representation and participation of stakeholders in the innovation processes. As argued by Jasanoff and other S&TS scholars, the 'logic of representation' has been superseded by a more radical 'logic of intervention' (Callon 2012), which allows concerned groups to simultaneously define scientific agendas and actively orient the research process, pooling their own experience and competences (Callon 2003).

Therefore, accordingly to what has been recently remarked by Bødker and colleagues, it seems crucial to revolve attention to the situated engagement of people 'beyond the points of infrastructuring' (Bødker et al. 2017, p. 248), thus to capture the socio-technical organization — in terms of alignment of material and immaterial resources — of social actors in grassroots projects of infrastructure development. The aim of this work is, then, also to explore how the co-production of infrastructuring processes enacted by grassroots groups de-stabilize and de-naturalize traditional

barriers of scientific legitimacy in technology development, by performing cooperation with expert and lay people.

This perspective can be fruitfully developed to investigate the building of information infrastructures, particularly when these are the emerging result of the collaboration of experts with citizens and concerned groups active outside the conventional R&D settings.

3. Theoretical Remarks: Ordering Human Subjects and Technologies in Bottom-up Infrastructures

To understand the emergence of collaborative shaping of information infrastructure, we mainly refer to some works from the field of S&TS, where the issue of co-production in technoscientific processes has been explored over the last two decades, with particular attention to the process of participation, mutual learning and sharing of knowledge. From a theoretical point of view, we outline our analytical posture by highlighting the heuristic power of the notions of *inverse infrastructure* and *research in the wild*.

First, the notion of inverse infrastructure has been introduced by Egyedi and Mehos (2012) to specifically describe bottom-up infrastructure, and alternative to those promoted by private firms or state and local governments, as in the case of Thomas Hughes's Large Technological System approach. Egyedi and colleagues relate to the term 'inverse' to shed light on all those bottom-up strategies, alternatives to the conventional top-down trajectories in infrastructure's construction, care, and maintenance. The examples of inverse infrastructures introduced by the authors mainly regard the sector of information technologies, and include cases such as citizens' Wi-Fi sharing, applications among radio amateurs, early cooperative network services like USENET, or residents grouping together to buy communal TV antennas (ibid., pp. 2–3). The main features of these inverse infrastructures regard:

- the *user-driven* dimension, which means that these infrastructures are designed and managed by the same end-users, while in conventional infrastructures users remain largely invisible;
- the self-organized and *self-management* dimension, that is their government and maintenance are not handled by institutional actors or firms, but rather they are coordinated through the cooperation among the same users, often on a voluntary basis;
- the decentralization or the peer-to-peer way of coordination; this does not imply that they are not coordinated or that tensions related to pressure from the 'center' are not present at all, but rather that this coordination is not based on conventional long-term planning, though predictable institutional arrangements;
- finally, inverse infrastructures present a different balance between top-down and bottom-up influences; while bottom-up inputs characterize in a more significant way this kind of infrastructure, the latter is also shaped by top-down processes, produced by structural and even global constraints and opportunities.

These properties highlight that new models of co-production in the realm of infrastructures are characterized first and foremost by a reconfiguration of conventional structures and influences typical of large and institutionally-driven information infrastructures.

However, while this approach to study inverse infrastructures offers an effective entrance to disentangle the reconfiguration of infrastructures' structure and users' contributing role, we also argue that the mere focus on the 'inversion' of inputs and roles lacks the sensitivity to catch the dynamic and open-ended nature of these infrastructures; it particularly fails to assess how the building of such infrastructures is inextricably intertwined with the whole set of cultural understandings, motivations, and identities that move participants to be enrolled, often on a spontaneous and voluntary basis, into the process of infrastructuring. Moreover, this approach also seems to undermine the role of technologies and non-human actors in the process of defining the bottom-up infrastructure and the fact that these material artifacts became crucial parts in the shaping of both the infrastructure and participants' identities and motivations.

To sensitize and explore these undermined issues, our framework will be inspired by the notion of 'research in the wild', which has been proposed by Callon and Rabeharisoa (2003, pp. 202–203) to analyse how concerned group of people engaged in biomedical landscape 'are both the objects and the subjects of their research' (ibid., p. 203). In their contribution, Callon and Rabeharisoa gracefully discuss how in research in the wild the elaboration of knowledge cannot be disconnected from a dynamic process of reshaping of the same participants' 'social' and 'technical' identities and motivation, as well as from the questions at the core of the research that are actively reframed and developed as a constituent part of the participants subjectivation process. In this way, the authors theoretically capture the increasing tendency, by part of civic or concerned groups, to contest the uncertain boundaries between expert and lay ways of knowing and learning in technoscientific processes (Gherardi 2009).

This perspective allows to adopt a perspective deeply innervated with a processual conception of knowledge and technologies, with the aim to take into account the learning and knowing practices at stake in the infrastructuring process, as well the modalities through which these practices contribute in performing the 'political' and 'technical' trajectories of the subjectivation of social actors (Dunbar-Hester 2014). Under this analytical perspective, bottom-up information infrastructures should be considered not as stabilized technological objects, but rather as ongoing sociomaterial processes, in which cognitive, material, and symbolic strategies intersect one each other (Star and Ruhleder 1996; Mongili and Pellegrino 2014).

In the analysis of our empirical case study, we highlight how bottom-up infrastructuring implies a peculiar form of grassroots participation, intended as a sociomaterial experience of mutual learning and knowing that brings into play heterogeneous capabilities emerging 'from the situated and on-going interrelationships of context (time and place), activity stream, agency (intentions, actions), and

structure (normative, authoritative, and interpretive)' (Orlikowski 2002, p. 253). Adopting this theoretical sensibility in observing the processual dimension of knowledge and technologies, we argue that in the participatory shaping of bottom-up infrastructure social actors are required to learn *how to infrastructure,* or in other terms to perform ordering activities of social, political, technical and material resources in interplay with subjectivation process (Law 1994).

4. WCNs as Bottom-up Infrastructuring Environments

To contribute in an innovative way to the theoretical and empirical debate pertaining to the investigation of bottom-up collaborative infrastructures, we carried out a study on a kind of grassroots infrastructure developed in recent years under different names, such as WCNs*,* alternative mesh networks*,* or even grassroots wireless networks (Hackett and William 2006; Shaffer 2011; Shaffer and Jordan 2013; De Filippi and Tréguer 2016). These WCNs are bottom-up communication infrastructures, generally built up at local level by activists and 'geeks' on the basis of explicit political as well as civic motivations. Technically, a WCN is a decentralized wireless infrastructure for digital communication that allows interconnecting antennas, usually set up on the roof of participants' homes or on those of informal groups. These decentralized networks are fully independent of the Internet, even though in a few countries they became popular as a less expensive alternative to commercial ISP connections (see Fig. 1). WCNs are usually raised by groups of people rooted in media-activism, hacking and technical hobbies, engaged in the implementation of these infrastructures on a voluntary basis, as they commonly share a set of goals and political beliefs, resulting in radical criticisms of the contemporary policy and governance of the Internet. These infrastructures are mostly self-built, as volunteers adapt existing software, hack hardware, set up coordination rules, and, last but not least, materially install antennas on the roof.

For all these reasons, it is easy to recognize how these alternative infrastructures are very good examples of what an inverse infrastructure is**.** Indeed, these WCNs are clearly user-driven*,* as users are the initial and major contributors of the infrastructure, which is therefore raised with a completely different approach if compared to large-scale institutionally supported network infrastructures. Consequently, they are also self-organized*,* as the structure and rules of the network are established by the same users, who usually define them on the basis of their political concerns related to the global surveillance on the Internet and against the conventionally commoditized relationship between providers and consumers in the case of commercial ISPs. Inverse infrastructures are also highly decentralized, both in technical and organizational terms, even if the balance between centralization and decentralization remains a crucial matter of debate in the maintenance of the network (Denis et al. 2015). Finally, these infrastructures are clearly based on a bottom-up approach, as they largely move from volunteers' efforts at the local level; however, they are also dependent on top-down processes in terms of technology development, legal framework, and even mainstream media coverage.

5. The Empirical Research: Case Study and Methodology

The research was mainly carried out in 2014, and the empirical data discussed here were collected through a qualitative multi-method approach. The research focused on the Italian WCN named Ninux.org, which was launched in Rome in 2001, and consists at the beginning of 2017 of more than 360 nodes in about ten Italian cities, the majority of which are located in Rome. First, we decided to extensively gather the existing documentation on the Ninux.org network, including materials produced by the local networks as well as reports and newspaper articles produced by mainstream media. Particular attention was devoted to the collaborative forms of communication used by participants in the community networks and, more specifically, to the discussions on themes related with Ninux.org occurred between January 2014 and December 2015 through the mailing list of the national community. Beside the analysis of documents, we conducted 11 in-depth interviews (Silverman 1997; Wengraf 2001), lasting between 60 and 120 min, with participants of four major local networks and divided proportionally between the different cities. More precisely, we interviewed participants that, due to their active and consolidated participation in the Ninux.org project, can be considered as 'key informants', such as citizens who have gradually become members active in crucial phases, acquiring technical skills through their active involvement in the daily activities of infrastructure management. Many informants, most of them with a strong technical background and a long experience in the Ninux.org community, label themselves in terms of 'home-grown hackers', 'geeks' or 'media-activists' interested in developing more sustainable and democratic digital communication tools (Fuchs 2017).

These interviews allowed us, on the one hand, to reconstruct the trajectories of each local group and, on the other hand, to investigate individual and collective participation in this project, paying particular attention to the discursive elements and the socio-cultural frames shared among participants. Finally, following a 'multi-sited ethnographic approach' (Marcus 1995), we also directly observed three major meetings of the network, such as the national assembly of the whole Ninux.org held in Bologna in June 2014. Empirically speaking, these meetings represented crucial opportunities for the collection of consistent data concerning the multi-dimensional trajectories of the network development. In fact, on such occasions Ninux.org members faced several crucial issues related to technical and social governance of the community, thus offering the opportunity to observe the discursive intertwining between technological, political and social dimensions. The ethnographic field notes and in-depth interviews have been fully transcribed in digital format. The coding of the empirical material, which included also general documents and mailing list conversations, was carried out through Atlas.ti software, following the principles of constructivist grounded theory (Charmaz 2006). A first round of data-coding process guided by a grounded theory approach allowed to engender descriptive labels; then, on the basis of this early analysis, a second coding process has been performed to generate more interpretative and theory-laden labels, which have subsequently adopted in the articulation of the discussion of research findings.

6. Findings

This section is dedicated to the presentation of our case study and the contextual empirical data with the aim to highlight the modalities and forms through which collaborative infrastructuring activities of an inverse infrastructure are performed. With respect to this research interest, which poses original theoretical challenges to contemporary CSCW, a relevant question arises: in the case of bottom-up inverse infrastructures, how do participants' identities and motivations, as well as material artifacts, play a role in shaping and sustaining the work of infrastructuring in unconventional settings of innovation?

To address this question, we first focus our analytical gaze on the genealogy and organizational culture of Italy's largest current WCN, emphasizing how an inverse infrastructure is not just a technological endeavour, but rather a sociotechnical terrain in which political motivations, beliefs, and cultural frames need to be mutually adjusted with technical elements, both material (i.e., wireless antennas and routers) and immaterial (i.e., skills and expert knowledge on network operating systems). Consequently, we will show how the infrastructuring work implies the alignment of both technical and political engagements in the project as well as how the identities and subjectivities of participants are processually reconfigured along with the evolution of the network infrastructure. Finally, we highlight how the work of infrastructuring in the wild entails the reconfiguration and cultural resignification of technologies as political agents, not only for their technical implications.

On the whole, for the purposes of this exposition we focus on the ways in which participants perform this alignment between technological, symbolic, and political elements outside formal organizational structures and procedures, and how the output of this alignment is being embedded in the inverse infrastructure. Coherently with our theoretical framework, this analytical posture allows us to understand the inverse infrastructures as a dynamic and open-ended process emerging from cooperative infrastructuring practices.

6.1. Unfolding the Italian Wireless Community Network Project

The Italian WCN started originally in Rome in 2001 with the name 'Ninux.org,' following other notable similar projects, such as the Seattle Wireless created in 2000 in the Northwest United States (see Maccari 2013; Maccari and Lo Cigno 2015; Crabu et al. 2015, 2016). In recent years, Ninux.org has expanded beyond Rome to other Italian cities, where similar grassroots networks have been launched under the same name. The network in Rome got underway as a technical experiment, thanks to the effort of about ten young people, including informatics students, experts in network operating systems, home-grown hackers, and geeks, some of whom were also participating in the free and open software movement developed in Italy during the previous decade (Gruppo Laser 2005). The pioneer collective originally meet in a

popular local 'nerd pub,' and subsequently in the spaces of leftist non-profit associations engaged in promoting countercultural and artistic activities.

In the early period, the ground-breaking group began to collectively test emerging wireless networking hardware and software, building up experimental connections between wireless antennas (also homemade) installed on their own home roofs. Year after year, thanks to the implementation on the network of services such as file sharing and tools for cooperative writing, the infrastructure attracted a growing number of participants, civic associations, and left-oriented 'squatted social centers' [*centri sociali autogestiti*], thus turning into a relatively wide urban decentralized wireless network.

From a descriptive point of view, the Ninux.org network presents all the major features of an inverse infrastructure, being bottom-up, self-organized, decentralized, and emerging as the result of a process of engagement where end-users and designers substantially overlap. This trajectory has been summed up by one of the funding participants in the network in Rome,

> 'You cannot define our services really as "services", in the sense that normally a "service" implies that there is a supplier for these services. In this case, being completely self-managed, the services have emerged when people, who had a need to do something, put up a solution and offered it to others. So, early things that came out were services to communicate, then chat and do other stuff like file sharing; someone also started to implement a search engine that searches within the files of all hard drives that are around'. [Interview 1, participant in Rome, 26/06/2014]

As it clearly emerges from these utterances, the participants in this inverse infrastructure conceive and describe in a peculiar way the uses of the network, stressing a critical deconstruction of the taken-for-granted relationship between consumers and commercial ISPs, thus questioning the conventional demarcation between end-users and designers.

As reported by several of Ninux.org's members interviewed during the research, a turning point in the extension of the user base took place around 2012–2013, as a consequence of lowering the costs of wireless equipment (antennas and routers) and the increasing importance that the issues of privacy and control over the Internet gained within the public opinion, particularly in the agendas of anti-capitalist protest movements (Milan 2013). In particular, the rise of public concerns about privacy over the Internet — especially generated by the Snowden affair, Anonymous' actions, and Wikileaks' revelations — is a contingent element that substantially contributed to spurring participation and engagement in the construction of this self-managed network, as an alternative to the Internet. As a consequence, in 2013 the Ninux.org project also expanded in other cities, such as in Florence, Bologna, and Pisa in Northern Italy or Cosenza in Southern Italy, where smaller local WCNs have been implemented. These other local networks still remain in an experimental stage,

as each of them have between 5 and 30 antennas connected. Even if these smaller local networks remain technically separated from each other, they share the same name, a common political framework, and tools supporting a collective cooperative work for the development of software, hardware, and protocols. This shared framework is the result of an ongoing collective effort of negotiation, which occurs through online forums and mailing lists, but also thanks to periodic meetings, such as an annual 'Ninux Day' happening.

What specifically characterizes Ninux.org is surely its political frame, as the collective management of the network is guided by a set of principles and motivations exposed in a common online 'manifesto' published on the project's website (http://wiki.ninux.org/Manifesto). This manifesto emphasizes the political relevance of decentralized and mesh network architectures, quoting their contribution to the empowerment and self-determination of citizens; their role as democratizing tool and resources to fight digital divide; their support for freedom of speech over the Internet network; and their alternative to the influence of commercial firms in shaping policy and regulation of the web. These several instances reflect synthetically the set of political concerns sustaining the work of infrastructuring in the wild in this grassroots infrastructure.

From an analytical point of view, as highlighted by Verhaegh and van Oost (2012) in their research on the motivations that push volunteers to maintain and care for a Dutch Wi-Fi community infrastructure, what is crucial to capture participation in these kinds of inverse infrastructures is how infrastructures are not just mere technical tasks to be realized but rather represent 'identity projects' (ibid., p. 154). Thus, the authors highlighted that the work of maintaining the network was strictly related to how volunteers turned this work into a chance to 'perform and enhance their technical identities' (ibid., p. 154). The authors of this study primarily emphasized the dimension of technical experimentation as the driving force behind the construction of inverse infrastructures; however, they failed in recognizing other kinds of dimensions relevant in the participants' performance of their identities.

Unlike this latter case, the participation in Ninux.org mobilized not only a technical interest in experimenting with emerging technology as in the case of user-innovation theory (Von Hippel 2005; Van Oost et al. 2009), but also the collective embodiment of political concerns and practices. This means that the building and maintenance of the network resulted from the intersection between, on the one hand, the participants' technical efforts and competences and, on the other hand, their political beliefs, motivations, and practices; in Ninux.org a culture of technical experimentation (such as the learning-by-doing attitude common among geeks and informatics students) meets issues and practices belonging to political and media activism, incorporating the discourses focused on making digital infrastructures more sustainable, democratic and open to participation. We argue that considering this relationship according to our analytical framework makes us more sensitive to understand the bottom-up infrastructure as an open-ended process of co-construction and co-evolution between technical work, also in its interplay with knowing and learning, and political participation. As we will see now, performing an

alignment between the technical issues and the political grounds represents a crucial dynamic in the cooperative work of infrastructuring in the case of the Ninux.org network, helping in this way to highlight how a grassroots organizational setting was determinant for the evolution of this inverse infrastructure.

The case of the Italian WCN not only offers to the analysis a particular kind of ICT infrastructure, but it also enables to focus on a specific pattern of infrastructuring features characterizing bottom-up infrastructures. We can point out at least three dimensions that make this case peculiar in respect to previous analyses of infrastructuring processes.

On a first level, the case of the Italian WCN, differently for example from the seminal case studied by Star and Ruhleder's (1996), does not focus on an already existing and well-settled infrastructure. Rather, this case focuses on the process of building up an infrastructure in its early stage, thus enabling to bring to light on those driving forces, acts of alignments, managements of conflict that are constitutive of early stages of an infrastructure. In other terms, this case does not aim at making manifest a well consolidated, hidden and scarcely visible infrastructure, but rather it allows to address the heterogeneous issues emerging in its early, visible and at some degree public stage of development.

On a second level, this case addresses the concept of acting 'in the wild' especially by focusing on the grassroots and bottom-up features characterising the process of infrastructuring. Indeed, in contrast with large part of the existing literature on users' involvement in innovative processes (Von Hippel 2005; Oudshoorn and Pinch 2003; Hyysalo et al. 2016), the Italian WCN offers insights on a technology connected with a public issue and on a technical solution that inherently requires to be organized on a collective basis. This means that this case study cannot be channelled through individualistic approaches to innovation and that, consequently, it is able to offer insights into the nature of infrastructuring processes driven by collective motivations.

A third distinctive feature highlighted by the Italian WCN case regards the political ideology that sustains it, and that becomes part of the work of infrastructuring, relying on the larger movement for alternatives approaches to the existing Internet regime. Indeed, both the motivations that help to mobilize the participants and the decisions about technical details in the adoption of a certain type of technology for the infrastructure are heavily influenced by a set of political ideologies shared by participants. These political ideologies not only represent a relevant motivating framework for the enrolment of participants into the project, but they also play a central role in shaping the decisions making procedures and the resulting specific technical solutions to be adapted to the infrastructure. Precisely for this multidimensional centrality, political motifs can be the driver of disagreements and conflicts concerning the ways in which the infrastructure should be developed at large. These three dimensions represent crucial features that characterize the empirical case explored in the next sections, and they will also orient the presentation of empirical data, helping to deepen the processual nature of bottom-up and grassroots infrastructures.

6.2. Infrastructuring Subjectivities: Learning, Conflicts and Politics

The following section addresses how identities and subjectivities of participants involved in the Ninux.org network are articulated in relation to learning, political and technical issues pertaining the participation to the work of infrastructuring. We argue that all Ninux.org members situate their identities both as 'technicians' and 'activists,' aligning together the technical work with issues related to freedom, radical democracy and privacy in digital communication. Therefore, we highlight several examples to make evident how, among Ninux.org's members, politically-oriented visions about information infrastructures are strictly entangled with the technical work of the design and maintenance of the infrastructure.

The identities of the participants of the Ninux.org project, as well as the infrastructure-in-itself, cannot be *a priori* reduced to a mere technical dimension. As emphasised by Callon and Rabeharisoa (2003) in their study on patients' activism, what is at stake is the logic of intervention that enacts grassroots groups to simultaneously discuss their subjectivities, motivations and their expectations: as result, activists' identity and those of the concerned initiative are simultaneously shaped along the development of the project in itself. This means, for example, that for some participants the infrastructure is not important, mainly because it allows them to perform and enhance their technical skills; on the contrary, political motivations are vital elements in sustaining participants' endeavours to build up the infrastructure, and to enact their role of 'media activists,' rather than that of 'volunteers' or 'tweakers.' This process of entanglement between technical competences and political views emerges from the narration of a participant in Florence, who is a university technician in the field of distributed networks,

> 'When I started to be interested in WCN, I had always worked in the university context on mesh networks, in a university laboratory that was inside a company, one of the greatest companies I have ever worked with. And they produced mesh networking applications for all sorts of aims, ranging from civil protection, hospitals, military, etc. And at some point, when I realized that there were alternative experiences applying this technology outside of the laboratory, and outside of the contexts that normally finance this technology, I really liked this idea. Being able to have a network that works, something real and existing, but not funded by the government or the army, is something that has excited me, especially when I got found that it can really work. And this has also put into question the way in which I was working in the university'. [Interview 2, participant in Florence, 10/07/2014]

By adopting a focus on the ordinary and situated work of bottom-up infrastructuring, we are more able to conceive of participants' involvement not as the acting of an established and taken-for-granted technical identity, but rather as a process of questioning the social implication of technoscientific innovation, thus de-

constructing the presumed neutrality of technological infrastructures. Furthermore, as the latter excerpt shows, we can neither assume that participants' identities remain fixed along the whole trajectory of involvement in building the network. When political claims are brought into the picture of the infrastructure, we become more open to understanding how the identities of participants co-evolve and change together with their participation in the project.

This co-evolution becomes further evident, for example, when participants do not own an established set of technical skills before joining a project, but rather these skills are learned as a consequence of their involvement in the project. This clearly emerges in the words of a well-integrated participant in the network in Rome, who did not have a solid technical background when he became involved in Ninux,

> 'No, I'm not an engineer, but here [in Ninux.org] it is not the situation where you're alone, trying to do things. When you approach a community that teaches you all sorts of things, it is easy to learn. So, my interest in mesh networks depends on a series of events that triggered my curiosity. I became interested, I went [to the meetings] and I liked it. I did not understand anything at first, as when I went there it was like listening to someone speaking another language. And slowly, by insisting, I started to learn that kind of language'. [Interview 3, participant in Rome, 28/06/2014]

As a result, the Ninux.org network is not just a space where experts and technicians build, from sketches, a bottom-up infrastructure, but it also serves as a pedagogical/educational setting, where the acquisition of new skills takes place (Fenwick and Edwards 2012; Crabu 2014). In this respect, a crucial dimension in understanding dynamics of participation in the Ninux.org community regards the mutual-learning trajectories of technical knowledge and skills, which are relevant in the self-management of the infrastructure. In order to ensure the sustainability of the CN, the distributed infrastructure requires to growth together with technical capabilities of its users base. In this regard, knowledge sharing and learning are particularly important, since they enable members without technical background to acquire the set of capabilities required to the daily use and management of the network and also to build new infrastructure's nodes and, ultimately, to be fully part of the Ninux.org community as legitimate member able to manage experiential expertise (Akrich et al. 2008). Here, as told by a member of the network in Rome, the collaborative dimension is crucial,

> 'So, Ninux is a sort of "gym" for those who want to learn about networks. Because there are so much things to learn [...] by working in a network as big as that of a [internet service] provider. However, having the tranquillity to do mess, around, you can make mistakes and you can learn new things, and confront

> with many skilled people. So, over the years many people who have crossed Ninux.org or have been heavily involved in it, today they are working in important ICT firms. Because we can say that these people have learned more things in participating in Ninux.org, rather than at the university. This is because at the university you have to learn fairy tales, while in Ninux.org you should put the network in function'. [Interview 4, participant in Rome, 29/06/2014]

This quote allows us to highlight that learning practices and knowledge sharing are of great relevance in managing innovation activities from below, and, in more particular, in co-opting new members in the community. The latter, in fact, is not a static entity, but is performed and reproduced through the transmission of knowledge and skills to interested newcomers, who learn 'how infrastructuring' through observation, listening and situated mentoring by other skilled participants. In more theoretical way, this is an example concerning an enactment of a form of mutual learning: a legitimate collective accomplishment performed by actors involved in a set of sociomaterial practice, as they engage in the production and reproduction of the infrastructure (Orlikowski 2002; Gherardi 2011). Therefore, the learning process, intended as an embedded dimension in the ordinary and situated work of infrastructuring, cannot be reduce to the acquisition of an abstract stock of notional knowledge. It rather circumscribes a process of active participation in bottom-up experimental activities, enabling social actors to be part of a socio-technical environment populated by languages, artifacts and specific knowledge. Thus, mutual learning practices enact skills and capabilities, which are rooted in collective accomplishments performed by a grassroots group of hackers, engineers, citizens passionate about technologies that keep alive and share tacit and explicit knowledge required in building and maintaining the infrastructure. In other words, learning is not an individual concern, separated from the broader infrastructuring process, but it is a collective accomplishment greased by a common attitude centred on democratization of digital technologies through experimentation and tinkering.

This reflection brings us to consider another dimension that is increasingly important in the work of infrastructuring: the role of the temporal evolution and the processual stratification of participation in the infrastructuring practices. As Karasti et al. (2010) have highlighted, the focus on temporal scales, particularly long-term temporalities, is a crucial dimension to study infrastructures' development. In our case study, the fact that members' identities, their skills, and their views about Ninux.org co-evolve over time is crucial to address how the infrastructure develops and is maintained. The relationship between time and competences becomes manifested in the network in Rome, where an early core group with strong technical competences had to include other people with weaker, or with no technical skills. As a key participant told us, this decision produced a shift in the average technical competences required to be active member of the project, thus triggering a conflictual change in the approach the community has in conducting the daily work of development and maintenance of the network.

In this regard, a crucial element to understand the recursive interweaving of participation, competences and temporality is constituted by the tension involving two different dimensions of learning as collective and distributed action: the *exploitation*, or rather the use and implementation of 'naturalized' set of knowledge; and the *exploration*, indicating the experimentation activities, the deviation from and variation of stabilized frame of knowledge, which simultaneous implies generation of new knowledge (March 1991). The relationship between these two dimensions, even in highly innovation-oriented environments, engenders a 'conflicting pluralisation' of visions on the ways in which the infrastructure project requires to be carried out.

This conflictual dimension, involving alternative visions about the possible developments of the network, appears as a constitutive and dynamic element of the process of infrastructuring, as it can be also argued from this excerpt:

> 'At the beginning of the project, people participating had strong skills. Maybe not specific skills in wireless technology, but in any case people with a "technical brain", people with whom it was possible to have a technical discussion. Instead, now more new people are arriving through advertising on Facebook or because they read articles in mainstream newspapers [...], so this has meant that the community now has grown hugely as well as the network has. However, of course the average technical level fell, and this turned into the fact that, when you propose a [technical] change, you could not make this change acceptable to all, as many participants neither understand it, nor they know how to handle it'. [Interview 5, participant in Rome, 21/07/2014]

The empirical richness of this quotation reveals how the bottom-up infrastructure is stratified around different conceptions, sometimes conflicting with each other, regarding the options about the digital network development. The interplay between human actors, knowledge and material resources, that crosses the infrastructuring work, can be located in a socio-technical context characterised, on the one side, by the tension concerning the implementation of 'naturalized knowledge' (considered reliable) and, on the other side, by the risk arising from experimental activities and procedures that might work (or not) in the near future. Alongside a vision of the infrastructure as a place of continuous experimentation and innovation, the WCN's members can however develop attitudes that hinder the construction of new knowledge, privileging instead the network stability and its technical sustainability. The focus on the different levels of skills and on how they circulate among participants helps not only to address the situated and contingent construction of multiple identities, but also to reveal how these multiple identities can therefore be understood as dynamic entities that change and evolve in a dialectic relationship over time.

Another relevant issue in the co-evolution between the infrastructure and participants' identities is regarding how technically-trained participants have been

involved in a process of 'political' subjectivation', a phenomenon that has been already stressed by Dunbar-Hester (2014) observing grassroots communities of FM radio activists. While this point has been partially mentioned at the beginning of this section, now we want to emphasize how, during infrastructuring in the wild, geeks and technicians learn to reframe their technical identities in a dialectic relationship with radical political activism focused on ICT and with an anti-capitalist critique to neoliberal pressures on the Internet (Weiner 2001; Pellizzoni and Ylonen 2012; Chenou 2014). Consider, for example, this discourse by a participant to the local network in Pisa,

> 'Sometimes someone says: "Excuse me, but is it not enough that the Internet is already working? Why is it not enough to request that the municipality put Internet in areas still not covered?" This question is a challenge for all us, and we want to contribute in building a parallel infrastructure, which has grown over time and represents a space of freedom. The central aspect is the possibility of being able to manage your own services, to be able to create from scratch the stuff that the community around you needs. And then, also the fact that more and more, at the global level, the Internet's problems remain a central concern, especially in relation to the development of contemporary capitalism. Therefore, it is important to cultivate an experience that consists of building from scratch a community: a network that works, and at the same time that forces you to question what the challenges are in this great battlefield'. [Interview 6, participant in Pisa, 31/05/2014]

This excerpt helps to highlight the centrality of political views and their relevance in orienting participation in a bottom-up project concerning technological experimentation. In the case of Ninux.org, experts reconfigured and readjusted their skills in relation to specific political views on communication technologies. For participants, the engagement in infrastructuring activities also means bending its own subjectivity towards a radical political setting, thus enacting a proactive membership both on a technical and on a political ground (Hensby et al. 2012). Particularly, Ninux.org's members' political ideas frame the Internet as a centralized and hierarchical infrastructure, in which citizens' privacy and freedom is subordinated to personal data control, and where there is a predominance of profit-based and business-oriented web services over non-profit, participated, and more horizontal platforms,

> 'What we try to do with these community networks is to decentralize the infrastructure. That is, we want to get to a point where the infrastructure that you use to communicate is no longer hierarchical, is no longer centralized and in the hands of someone else. It will be completely distributed and based on a

> community of people. [...] In the philosophy of community wireless networks, we have this fact of using free software, open source software; we have a "sharing attitude" in general'. [ethnographic fieldnotes: public presentation of the Ninux.org, Bologna, 28/06/2014].

As it clearly emerges from this description, the identities of technical experts assume relevance in relation to specific political views and motivations about the technological solutions to adopt in sustaining an infrastructure, for example in the adoption of free software and non-proprietary hardware. In this sense, maintenance and technical choices are never neutral, but instead are mutually shaped in relation to political ideas shared by the community.

This process of alignment is also influenced by the fact that many of the community meetings are often hosted by *centri sociali autogestiti*, which in last two decades have played an important role in the development of a political and critical discourse on technological innovation and ICT (McCaughey and Ayers 2004; Lievrouw 2011; Milan 2013). In these political settings, geeks, activists, and technical experts meet and intersect their trajectories of technical skills acquisition as well as of political subjectivation: expert members and geeks are not simply ICT technicians, but are also 'teachers' of an expert knowledge, which is articulated according to specific political views; political activists and other lay members, on the other hand, learn new skills and techniques and reconfigure their identities on the basis of the technical competences gained during their participation in the wild to the building of the infrastructure.

6.3. Wireless Antennas as Non-Human Agents in Bottom-up Infrastructuring

As we discussed in the previous section, inverse infrastructures like Ninux.org gather a concerned group of people pooled based on a common set of technical and political motivations. During infrastructuring in the wild, the boundaries existing between 'developers' and 'end-users,' as well as between activists and technical tweakers, fade or get at least 'confused' (St. Laurent 2004; Oudshoorn and Pinch 2003). The performance of these multi-dimensional roles, or the management of different political and technical positioning, is also made possible thanks to the mediation of material artifacts. The relevance of materiality as a generative dimension of social processes has been largely addressed by a relevant body of empirical research in the field of S&TS, and particularly in the actor-network theory (ANT) (see Callon 1986; Latour 1992, 2005). Aiming to understand how materiality participates in shaping the worlds we act in, ANT has emphasized how artifacts and technologies are more than organizational elements for social action (Law and Mol 1995) as well as how social action represents the context in which human subjects and non-human entities are tied in a dynamic of mutual reconfiguration. The constitutive entanglement between human subjects and non-human objects is central in the experience of participation in the Ninux.org network. The infrastructuring process, as a set of

socio-material organizational practices (Orlikowski 2007; Orlikowski and Scott 2008), can be considered the outcome of a set of activities performed on symbolic elements, but also on the material components of technical activities.

The clearest example of the generating relationship between artifacts and human subjects in the case of Ninux.org concerns the wireless antennas, their installation and maintenance and how all these activities intersect with the situated modalities of participation and collaboration. Wireless antennas can be considered a material interface between human agents and the network as a whole, as through these antennas the wireless signal propagates, enabling the connection of each member of the network infrastructure. These antennas are not only technical properties of the network; rather their installation and maintenance has direct consequences on collaboration, roles, and the overall regime of participation. All people interested in the project have to assume the responsibility of the antennas installed on their own roofs; as one participant stated, 'below every antenna there must be an active member of the community',

> 'A tacit rule is that below every roof, below every node, below every antenna, there must be an active member of the community. This is because the network is being conceived as something that we do and then we put in common. You cannot imagine building up the network like: "Oh well, I'll come to your house, and I install the antenna... and then everything will be ok and you will never have to worry". The key issue is that, by joining the Ninux network cable that comes down from the roof, you are not just replacing the commercial ISP cable, and nothing more has changed for you. Behind this network there must be people who are aware of how the network works, and therefore there's this tacit rule that for every antenna, there must be a human head'. [Interview 7, participant in Bologna, 5/5/2014]

As this participant has argued, antennas need to be installed, maintained, and set-up, and these activities are essential for the development and efficient working of the network. At the same time, committing themselves to the care of their own antennas has an important symbolic as well as material meaning, as it means participating in and taking care *of* the collective bottom-up infrastructure. Thus, antennas are not just functional technical devices, but rather they are active 'non-human agents' that contribute to supporting the process of subjectification in a grassroots group. In fact, wireless antennas solicit collective participation: their maintenance not only gives concreteness to a technical project, but also materializes in the way a technical activity manages the proper radical discourse that sustains the overall infrastructure.

Regarding the handling of these antennas, it is not required that all members master all the technical knowledge required for their full installation and maintenance, but their owners at least have to know how to manage the basic settings configuring a peculiar interdependence between human actors and material artifacts

in the infrastructure. On the one hand, this limits the possibility of the network's growth, as it is quite difficult to enrol new participants; but on the other hand, this choice reflects a political vision about the organization of the inverse infrastructure, also ensuring more horizontal participation and more effective decentralization of the network's maintenance. Thus, this specific shared configuration involving antennas, their technical maintenance, participants, and their skills is at the core of the process of enrolment and collaboration in the infrastructuring process.

Once more, in the process of infrastructuring observed here, the construction and management politics are quite different from those that can be observed in the case of large technical systems or institutional and commercial infrastructures. The management of antennas in the Ninux.org case reflects the fact that technical artifacts do not merely raise 'technical' matters, but also play a fundamental role in the process of subjectivation of members and in the definition of the hybrid user identities of activist-technicians. In this infrastructure, antennas work 'in the proper way' not only if they are properly connected to the network, but also if they are in a 'dialogic relation' (Vygotskiĭ 1962) with human agents who are responsible for them. This relationship is twofold: taking care of an antenna means learning some technical skills, thus enacting a competent membership; in doing so, members also take care of a political project that is embedded and materialized in the infrastructure, of which the antenna belongs. Hence, the antenna is not only a propagator of electromagnetic radiations, but an active amplifier of the process the shaping of technical and political identities. Conceptually speaking, wireless antennas can thus be considered 'infra-structuring objects' (Crabu 2014), able to activate and sustain the interdependence between human actors and the infrastructure. The antenna, in fact, plays a central role because it contributes to framing the relationship between experts and non-experts, allowing the alignment and mutual subjectivations among geeks, hackers, and political activists. Moreover, we also argue that the active role of material artifacts in the shaping of the infrastructure is peculiarly crucial when infrastructures emerge with an inverse pattern within grassroots organizational environments, rather than in institutional settings; this is because these material artifacts support inclusion, identification, and collective integration, which in traditional settings are assured by the already existing relational and formalised bureaucratic organizational structure (Kunda 2006).

7. Discussion and Conclusive Remarks: Studying Bottom-up Infrastructures

In this contribution we emphasized the growing importance of the multidimensional interaction between civic engagement and technical, political, and material instances in the development of a bottom-up information infrastructure. These kinds of bottom-up initiatives represent an emblematic domain to investigate new emerging and increasingly relevant patterns in the design and maintenance of inverse information infrastructures. In this respect, the article offered a perspective to foster the understanding of unconventional collaborative trajectories of infrastructuring, especially when they occur outside predictable innovation environments.

Moving from the main findings arising from our empirical research on the Italian wireless community network project, we will now point out a few more general points able to expand the academic debate concerning bottom-up infrastructuring work and other similar typologies of collaborative design projects in the domain of infrastructures.

First, our case study highlighted that it is important to focus the analytical gaze not only on activities performed in the technical shaping of the infrastructure, but also on cultural frames, political ideologies, and subjectivation processes that sustain the collaboration between experts and non-professional designers. As it has been already pointed out by Jalbert (2016), grassroots and bottom-up dynamics can alter power relationships and redistribute symbolic resources in multiple ways from the expectations that originally triggered these projects. In line with this reflection, we argued that participants' motivations and identities are not defined *a priori*. On the contrary, as we have shown discussing how the engagement of new participants into the Ninux.org network evolved over time, participants in these bottom-up initiatives are entangled in performing multiple identities during their active involvement in collaborative settings.

Moreover, we noted that often participants' involvement began on a mere technical level, but soon started intersecting with political views and practices rooted in leftist and in part anti-capitalist movements. The hybridization between different technical, political, and cultural instances is a key point in the way this bottom-up infrastructure evolved, thus questioning the traditional models of innovation and collaboration in the work of infrastructuring. In line to what has been outlined by Karasti and Syrjänen (2004), we have shown on an empirical ground how WCN members performed a kind of 'artful infrastructuring' of technologies, organizational models and political visions into an effective participatory process of technology development. Our analysis allowed to recognize the generative relevance of this hybridization and how its dynamic outputs represented crucial resources for the development of the infrastructure on a cognitive, symbolic and material level.

Another major point made through this case study is that this co-evolution of heterogeneous entities represents a disrupting force, able to transform conventional patterns of collaboration for the development and maintenance of information infrastructures. In bottom-up infrastructuring, technical devices, the competences associated with them and their practical maintenance are at the center of a process of alignment and contamination. Thus, the participation in such a bottom-up infrastructure is not just an opportunity to develop technical competences, but can be understood as a complex terrain on which motivations, meanings, and identities are actually shaped, altered, and reinforced.

The analysis also pointed out empirically the process of mutual reconfiguration between the three different dimensions – organizational, social and technical – that has been recognized as crucial in infrastructures community design by Karasti and Baker (2008). The mutual interaction between these dimensions has been highlighted especially by discussing the heterogeneous activities surrounding wireless

antennas, showing how these technologies are not only a technical problem to be solved, but also socio-material devices intervening in the redefinition of participants' identity and in the reconfiguration of driving motivations that mobilize them. Hence, technical artifacts resulted as active mediators between different cognitive and semantic worlds, such as the antennas on the roofs that we have defined as 'infrastructuring objects' at the crossroad between different and previously non-aligned settings.

Therefore, our distinctive contribution to this CSCW special issue consists into addressing novel forms of infrastructuring emerging in an increasingly complex data-driven society, where innovation is more and more often co-produced from below, by unconventional collectives and groups (Smith et al. 2017). More specifically, the qualitative case study discussed here offers a contribution to the debate about bottom-up information infrastructures in PD by emphasizing the situated emerging dynamics of participation, which have been recalled in the article.

First of all, the processes emerged from this analysis emphasize the increasing importance of the dynamics that characterize bottom-up and grassroots infrastructures, allowing to give relevance to a wider trend –operating in contemporary technoscience – consisting in the *co-production* and *co-creation* of technoscientific outcomes through the active involvement of citizens, laypeople and previously unrepresented concerned groups.

Moreover, the Italian community network case allow us to investigate what happens in the early stages of infrastructuring process. In this way, the case considered not only tell us how important is to bring to the foreground the implicit and invisible processes behind the infrastructure, but also to highlight the relevance of the articulation work between cognitive, social, political and technological resources at play.

Additionally, the case presented can serve as an example of how to put together different concepts and approaches to explore empirically bottom-up infrastructuring processes and, especially, to account for the political and collective ideologies that support the emerging processes of infrastructuring occurring outside top-down, established research and development organizations.

Finally, by adopting a processual and *in-the-making* perspective, we argued that it is not enough to focus on the bottom-up trajectory of infrastructures or to merely recognize how end-users acquire increasing centrality in their building and maintenance. Rather, we have explored how new infrastructuring trajectories challenge conventional representations of the relationship between technical expertise and the broader social and cultural motivations and ideologies that contribute to enabling innovation processes themselves.

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