The Theory of Actor Interactions Shaping Innovations in Digital Infrastructure:

The Case of Residential Internet Development in Belarus

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ABSTRACT

This paper examines how digital innovation develops in ecologies of distributed heterogeneous actors with contesting logics, diverse technologies and various forms of orchestrations. Drawing on the insights from the emerging theory of digital innovation augmented by an institutional logics perspective, we study how over 20 years residential Internet infrastructure was coshaped by the interplay of self-organized residential communities, corporate Internet service providers (ISPs), and a state ISP. Our analysis led to the identification of four types of interactions that shape the trajectories of digital infrastructure development which are beyond direct actor interplays and competition or collaboration relationships. We label these interactions as symbiotic generative, symbiotic mutualistic, parasitic complementary, and parasitic competitive and explain the processes and conditions of their development as well as their innovation outcomes. Drawing on these findings, we develop a model of symbiotic and parasitic interactions shaping digital infrastructure development and identify key characteristics of the ecologies where these emerge. Our study contributes to the growing field of research on complex and nonlinear paths of digital innovation development constituted by the dynamics of its distributed agency and concludes by highlighting avenues for future research in this area.

Keywords: digital innovation, infrastructure, symbiotic and parasitic interactions, ecology of games, communities

INTRODUCTION

Studies on digital innovations (DI) in technologies and infrastructures have highlighted distinctive properties and dynamics of these development processes. Such innovations, in particular, develop by distributed collectives of unprompted sets of actors (Dougherty and Dunne 2011; Lyytinen et al. 2016; Nambisan et al. 2017; Yoo 2013), which build on diverse and often contesting logics of organizing and

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technology framings (Barrett et al. 2013; Berente and Yoo 2012; Garud et al. 2013; Hultin and Mähring 2014) and interact in both synchronized and orchestrated but also in emergent and serendipitous manners (Boland et al. 2007; Garud et al. 2008; Hanseth and Lyytinen 2010). The complexities of DI development processes have led researchers to call for studies that shed light on the non-linear dynamics of distributed DI agency (e.g., Nambisan et al. 2017; Oborn et al. 2019; Tilson et al. 2010) and suggest the value of ecological perspectives in this regard (e.g., Dougherty and Dunne 2011; Lyytinen et al. 2016).

Across disciplines, ecological perspectives generally assume a multiplicity of heterogeneous actors with complex symbiotic and parasitic relationships. These relationships are not simply cooperation/competition-driven, as they can be mutually beneficial (e.g., flowers and bees), beneficial to only one side (e.g., spruces that benefit from neighboring trees that protect them from the sun and cold), or parasitic (e.g., leeches and viruses that feed off of and degrade other organisms). Such relationships also change dynamically over time (e.g., spruces that compete for nutrients with the trees that protected them), coevolve via "prehensible, opportunistic, ready to yoke unlikely partners" (Haraway 2003, p. 32), and have ecological impacts beyond direct actor interactions (Margulis and Sagan 2007).

Previous studies have begun to examine how DI develops in ecologies of heterogenous actors which rely on orchestrated and deliberate actions (Dougherty and Dunne 2011). However, our knowledge on the development of DI in less orchestrated ecologies, where actors rely on serendipity, improvisation and opportunism (Oborn et al . 2019) or deal with various temporal, resource, capability and spatial asynchronies (e.g. Ansari and Garud 2008; Garud et al. 2013; Oborn 2019), has remained undertheorized. Furthermore, while research has discussed how multi-actor DI unfolds under the umbrella of particular technology projects (Boland et al. 2007; Oborn et al. 2019; Tuertscher et al. 2013) we know less about DI development in ecologies where actors use diverse technologies.

To address these gaps, this paper complements research on the diverse logics of actors in IT development (e.g., Barrett et al. 2013; Constantinides and Barrett 2015; Berente and Yoo 2012; Gawer and Phillips 2013; Hultin and Mahring 2014) with the insights from growing studies on digital innovation and digital infrastructure development (Boland et al. 2007; Hanseth and Lyytinen 2010; Lyytinen et al. 2016; Nambisan et al. 2017; Oborn et al. 2019; Tuertscher et al. 2014; Yoo et al. 2012). Based on the insights, we describe how heterogenous actors in Belarus, such as self-organized residential communities, corporate Internet service providers (ISPs), and a monopolist state Internet service provider (ISP), developed Internet infrastructures while following diverse logics and technologies and operating under various changing degrees of orchestration. Our findings reveal four types of symbiotic and parasitic interactions that help explain the distinctive paths of DI development in such complex ecology. We label the identified types of interactions as *symbiotic generative*, *symbiotic mutualistic*, *parasitic complementary*, and *parasitic competitive* and explain the processes and conditions of their development as well as their innovation outcomes.

Our findings make several valuable contributions to our knowledge on DI development. First, our findings on symbiotic and parasitic interactions extend existing knowledge on diverse forms of interactions within the distributed DI agency (Boland et al. 2007; Lyytinen et al. 2016; O'Mahony and Becky 2008; Tuertscher et al. 2014). Second we identify and detail the processes, shaping characteristics, and innovation outcomes for each type of the identified interactions and develop a model of symbiotic and parasitic interactions shaping DI developments. These insights might be generalizable to the development of other DI (e.g. blockchain, Internet of things, digital platforms) that assume interactions of multiple actors with diverse institutional logics and multiple technologies. Third, our study is among the first to examine the interplay of multiple technologies in the DI development by highlighting how DI might successfully develop via various combinations of digital technologies with diverse degrees of confluence. In this regard, our findings contribute to understanding the role of technology in DI development (e.g. Boland et al. 2007; Nambisan et al. 2017) by illustrating that actors' multiple diverse technologies enable various and often unlikely technology combinations that act as a gateways integrating innovative developments from heterogenous actors into a DI that would be unlikely to emerge around single technology. Forth, our study is among the first to incorporate institutional logics into the analysis of DI development and suggests both its value and novel insights. Thus while previous studies have discussed that actor logics enable and constrain actors in building on certain rules and resources (Berente and Yoo 2012; Carlile 2002; Garud et al. 2013; Hultin and Mähring 2014), our findings illustrate that the interplay of multiple diverse technologies provides DI actors with insights into rules and access to resources beyond the repertoires afforded by their dominant logics.

The following sections begin with a review of existing research on DI agency and its interaction dynamics, noting gaps in our knowledge and providing a background to study the shaping of DI innovation within ecologies of multiple heterogenous actors that operate on multiple technologies. We then describe the details of our methodological approach, the research setting, and our research findings. The article concludes with a proposed model of symbiotic and parasitic interactions shaping DI development and a discussion of theoretical and practical implications of our findings along with their limitations and areas for future research.

THEORETICAL BACKGROUND

DI in general and digital infrastructures[3] in particular are characterized by unique openness to number and types of users (Monteiro et al. 2014; Nambisan et al. 2017) as well as "the number and heterogeneity of included components, relations, and their dynamic and unexpected interactions" (Hanseth and Lyytinen 2010, p. 1). The development of these digital artifacts occurs in emergent collectives of *multiple*,

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[3] A) The literature has used multiple terms, including information infrastructure, IT infrastructure, e-infrastructure, etc. Following Henfridsson and Bygstad's (2013) analysis of variety of infrastructure studies, we use "digital infrastructure" throughout the paper. B) While research on digital innovation and infrastructure studies are two distinctive areas, studies in both streams often refer to infrastructures as constituted by digital innovations (e.g., see Hanseth and Lyytinen 2010; Henfridsson and Bygstad 2013; Nambisan et al. 2017; Yoo et al. 2010).

continuously *evolving*, and *heterogeneous* actors with different logics and capabilities (Boland et al. 2007; Lyytinen et al. 2016; Nambisan et al. 2017; Tuomi 2002; Yoo et al. 2012). In this regard, Nambisan et al. (2017, p. 225) define DI agency as *distributed*, i.e., a "collection of actors with diverse goals and motives—often outside the control of the primary innovator… [who] can opt in and out while their goals change, new competencies are needed, … new constraints and opportunities emerge, or varying contributions become recognized." Most relevant to our knowledge on DI development by distributed DI agency with multiple logics and technologies are studies that discuss the role of actor logics, the role of technology, and the dynamics multi-actor interactions.

The Role of Logics in DI Development

The distributed nature of DI agency implies an extended diversity of meanings attached to developing innovations (Abbate 2000; Constantinides and Barrett 2014; Hepsø et al. 2009). These different meanings, conceptualized by a variety of terms, such as ideologies, frames, and logics (Barrett et al. 2013; Berente and Yoo 2012; Gawer and Phillips 2013; Orlikowski and Gash 1994), provide distinct understandings of how a technology works and may be used (Abbate 2000; Hultin and Mähring 2014; Orlikowski and Gash 1994). Actors' different meanings inform innovation processes since they enable or constrain actors capabilities and resources (Constantinides and Barrett 2014; Tuomi 2002), and might lead to conflicts (Carlile 2002; Lyytinen et al. 2016; Raymond 1999; Tuomi 2002), complex coadaptation strategies (West and O'Mahony 2008), and legitimacy risks (Barrett et al. 2013; Garud et al. 2002).

This paper addresses the calls to incorporate the interplay of diverse actors' meanings to the analysis of development of digital infrastructures (Constantinides and Barrett 2014; Hanseth and Monteiro 1997; Sahay et al. 2009; Schultze and Bhappu 2017). We build on an institutional logics perspective as a metatheoretical and multilevel framing for analyzing the interrelationships among heterogenous actors such as institutions, individuals, and organizations (Friedland and Alford 1991; Thornton et al. 2012). We define institutional *logics* as "the socially constructed historical patterns of material practices, assumptions, values, beliefs and rules by which individuals produce and reproduce their material subsistence, and provide meaning to their social reality" (Thornton and Ocasio 1999, p. 804). For instance, free and open-source software communities follow *community logics*, based on trust and commitment to reciprocity, unity of will, commitment to community values of shared resources and intellectual property rights, group membership, and reliance on social capital as a coordinator (Barrett et al. 2013; O'Mahony and Lakhani 2011; Raymond 1999; Thornton et al. 2012). Community logics are distinct from *market logics*, where actors seek to maximize their profit and rely on price and economic transactions to coordinate their behavior (Eisenmann 2008; Thornton et al. 2012), and also from *state logics*, where the state is a source of rules and goals and a distribution mechanism for resources, and where backroom politics and bureaucratic rules guide actors' behavior (Dunn and Jones 2010; Lounsbury 2007; Ouchi 1980; Thornton et al. 2012).

Since institutional logic instantiate in the technology (Gawer and Phillips 2013) actors with different logics will develop different technologies or use these differently adapting or neglecting certain features (Berente and Yoo 2012). In turn, change in the material practices of innovation conditions the evolution of actors' institutional logics (Berente and Yoo 2012; Gawer and Phillips 2013; Hultin and Mähring 2014).

At the same time, the interplay of binary logics is prioritized over insights into the interplay of multiple logics (Schultze and Bhappu 2017) and the role of community logics has been overlooked in organizational theory and institutional logics studies (Thornton et al. 2012; O'Mahony and Lakhani 2011). This is an important gap in the context of DI, where there is a lack of studies on how different actors' logics interact in the interplay of collectives shaping DI (Nambisan et al. 2017) and where research calls for more studies on how digital infrastructures are shaped by heterogeneous actors with asymmetrical power, resources, and contested meanings (Constantinides and Barrett 2014; Edwards et al. 2009; Hanseth and Monteiro 1997; Sanner et al. 2014).

The Role of Technology in DI Development

The literature on DI and digital infrastructures has highlighted that technology helps coordinate interactions and contributions from heterogeneous actors (Boland et al. 2007; Oborn et al. 2019; O'Mahony and Lakhani 2011; Tuomi 2002). An important specificity of digital instrastructure is that it can grow by building on not only tightly coupled architectures with highly integrated innovative developments but also when building on loosely coupled and integrated developments (Henfridsson and Bygstad 2013; Tiwana et al. 2010). In this way, IT can become a "boundary object" for diverse and continuously evolving actors' interpretations (Boland et al. 2007; Lyytinen et al. 2016; Nambisan et al. 2017; Thornton et al. 2012; Tuomi 2002) or a "trading zone," (Boland et al. 2007) where alternative beliefs and different knowledge bases of multiple actors are negotiated. IT can also act as an orchestration tool that connects contributions from heterogenous actors by matching those with solutions to those with problems (e.g., the Uber algorithm) (Afuah and Tucci 2012; Nambisan et al. 2017).

The above studies have generated valuable insights for understanding the role of technology for coordination of heterogenous DI actors. However, their focus has been centered on DI developing under the umbrella of particular kinds of technologies and services such as 3D CAD/CAM systems in architecture, engineering, and construction industries (Boland et al. 2007), mobile money payment services (Oborn et al. 2019), and a particle detector system (Tuertscher et al. 2013). This creates an important gap in our knowledge about the paths of DI development through the interplay of multiple and diverse technologies.

Multi-Actor Interactions Shaping DI Development

Research has begun to examine forms of interactions within the distributed DI agency (Boland et al. 2007; Lyytinen et al. 2016; O'Mahony and Becky 2008; Tuertscher et al. 2014). For example, Lyytinen et al. (2016) discuss anarchic networks where innovative contributions and resources of heterogeneous actors become dynamically identified and mobilized under an umbrella of a common innovation project but in the absence of hierarchical control. Complex innovation projects, such as Frank Gehry's construction projects (Boland et al. 2007) or the creation of a particle detector at CERN (Tuertscher et al.

2014), provide a common ground where distinct emergent contributions of multiple actors become unpredictably interwoven. For example, Boland et al. (2007) discuss how heterogenous firms interacting under a common project produced multiple distinct innovations that occasionally interacted with each other and fed back into the project, stimulating further innovations in a staccato fashion.

Gulati et al. (2012, p. 7) propose a concept of *meta-organization* to account for multiactor networks where "each agent has its own motivations, incentives, and cognitions … a multitude of individual organisms that coexist, collaborate, and co-evolve via a complex set of symbiotic and reciprocal relationships which together form a larger organism." Meta-organization generates a mutually profitable ecosystem where participants might use material, cognitive, network, or legitimate resources from outside their boundaries by orchestrating or cultivating the behavior of their partners. Such symbiotic ecosystems can make the behavior of heterogenous actors highly coadaptive, such as when big software companies like IBM, Apple or Oracle integrate OSS software into their products, cultivate OSS communities, and encourage their personnel to participate in these (Gulati et al. 2012; Lakhani and Panetta 2007) or when industry and community actors with divergent interests collaborate through the creation of a boundary organization (O'Mahoney and Becky 2008). Reflecting a multiplicity of actors with diverse loci of control, contemporary digital infrastructures increasingly follow a complex canvas of *mesh networks*, where some components have centralized control, while others are decentralized (Rodon and Silva 2015), or rely on tight control while being flexible (Lyytinen et al. 2016; Tilson et al. 2010a).

While previous studies have emphasized the importance of orchestrating and coordinating contributions of heterogeneous DI actors (Dougherty and Dunne 2015; Henfridsson and Yoo 2014; Nambisan et al. 2017), our knowledge on DI developing via less orchestrated interactions has remained relatively limited (Oborn et al. 2019). Low degrees of orchestration between DI actors might occur due to diverse rhythms on which the DI infrastructures, resources, capabilities, and participating actors develop and operate (Ansari and Garud 2009; Garud et al. 2013), as well as asynchronies between the global and local innovation spaces (Oborn et al. 2019). Specifically, low degrees of orchestration might condition a variety of complex indirect and not necessarily reciprocal actor interplays that have remained largely undertheorized. For example, DI actors might develop alternative innovations for unaddressed or excluded users as solutions that co-exist in parallel, not directly interacting markets (Jack and Suri 2011; Morawczynski and Pickens 2009; Sahay et al. 2009; Van Oost et al. 2009). Moreover, the orchestrated relationships change over time (Aanestad and Jensen 2011; Ansari and Garud 2009; Tilson et al. 2010a), such as when initial collaboration interactions develop into threatening ones (Constantinides and Barrett 2014; Sahay et al. 2009) or when centralized and tightly coupled networks evolve into a more loosely coupled system (Rodon and Silva 2015). Finally, the unavoidable deviation of actor interactions from deliberate to serendipitous, improvised and opportunistic requires investigation of non-orchestrated DI paths (Oborn et al. 2019).

To summarize, research on DI and digital infrastructures has made significant steps forward in understanding the role of actor logics, technology, and interaction dynamics during DI development. However, actor interactions that take place within less orchestrated ecologies and build on multiple contesting logics and diverse technologies have remained undertheorized.

METHOD

This analysis is anchored in a longitudinal case study of residential Internet infrastructure development in Minsk, the capital of Belarus. Several reasons underpin this choice of this case (Siggelkow 2007). First, the focal phenomenon is ultimately the unfolding of digital infrastructure over 23 years (1994–2017), which is nationally bounded but also parallels infrastructure that has developed across the world. Tracing the longitudinal development of Internet infrastructure over a 20-year time horizon was particularly valuable for investigating the ecological interplays between multiple heterogeneous and continuously evolving innovation collectives (Nambisan et al. 2017; Tilson et al. 2010b; Yoo et al. 2012). Second, the development of residential Internet infrastructure in Belarus reached a relatively high level, being considered one of the top ten countries worldwide for speed of IT development (ITU 2016; Rybik 2012;

Seklickiy 2000; Zabrodskaya 2013) and also providing one of the world's most affordable Internet services relative to GNI per capita (ITU 2014, 2016) (see Figure 1).

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Third, since Internet infrastructure in Minsk was cocreated by communities, corporate and state-owned ISPs, and government, the setting enabled us to study an innovation constituted by multiple heterogeneous actors (Hanseth and Lyytinen 2010; Tuomi 2002) with diverse contesting logics, including the undertheorized community logics ((Thorston et al. 2012; O'Mahoney and Lakhani 2011). The heterogenous actors also operated on distinct goals and power positions (Constantinides and Barrett 2014; Nambisan et al. 2017; Sahay et al. 2009), and diverse technologies. In this case, communities, called HomeNets, were among the core actors in this process. These emerged in the mid-1990s as communities of residents who linked their home computers together with cables and other equipment to create an initially offline version of a local Internet. Starting from the 2000s, they cocreated residential Internet infrastructures with corporate ISPs and became among the largest and most vibrant online communities in the country, with more than 800 HomeNets, each with between several hundred and several thousand members, with 22,000 users registered at the national HomeNet website (Figure 2). HomeNets also became the major means for residential Internet access as residential areas became literally entangled with cables (Figure 3). Starting from 2010, some HomeNets developed into successful ISPs themselves. The case therefore provided an opportunity to investigate how bottom-up and top-down efforts to build infrastructure as well as tightly and loosely coupled infrastructures coexist and interact dynamically when being coshaped by heterogeneous actors over time (Henfridsson and Bygstad 2013; Rodon and Silva 2015).

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Data collection. This study relied on in-depth interviews, documents and archival data. Ninety-seven interviews (40 minutes each on average, ranging from 20 minutes to 3.5 hours; 80 perecnt audiorecorded and transcribed verbatim) were conducted as part of an unpublished PhD dissertation by the lead author (July 2010–April 2011) and a subsequent updating study (November–December 2016) focused on targeting an extended set of actors (ISPs, Beltelecom, experts in the field, HomeNets ISPs) and their interrelationships. Out of 97 interviews, 89 were conducted face to face, five by phone and three by Skype. Interviews with HomeNet members focused on how and why they developed and built up their infrastructures, how these changed over time, and what relationships they developed with ISPs and government bodies. Interviews with ISPs focused on how they developed collaborative relationships with HomeNets and other ISPs as well as how they developed technologies for residential Internet access, how these evolved over time and the nature of their relationships with the government and Beltelecom. Interviews with Beltelecom focused on how the company developed residential Internet access over time, and its relationships with ISPs, HomeNets and government. Finally, interviews with HomeNet ISPs focused on how they evolved from HomeNets, the services that they provided and competed on over the years, and their relationships with other ISPs and HomeNet ISPs. Appendix A provides samples of interview questionnaires for each type of actor in each phase of the study and Table 1 provides details on the interviews and respondents.

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To enhance the reliability of the interviews (due to legal restrictions imposed by the government on HomeNets since 2010) we used a snowball sampling method for locating hard-to-reach populations (Biernacki and Waldorf 1981; Goodman 2011; Heckathorn 2011). Because HomeNets were constantly evolving (Faraj et al. 2011; Faraj et al. 2016), with multiple individual communities growing and merging with one another, we considered the set of HomeNets as one actor. We controlled data sampling to ensure representation of the whole set of HomeNets, despite their variety (in terms of size, time of creation, and city area). This decision was supported by our analysis, which revealed similar actions and organizing principles across HomeNets. For example, they pursued remarkably similar goals and strategies.

The study also incorporated analysis of various secondary data sources (listed in Table B1 in Appendix B), including a variety of HomeNet accounting records, statutes, maps of users and infrastructures, photos and videos, news and blogs about their practices, development, and services; books, research articles and government laws and regulations related to Internet development, statistical indicators (e.g., number of Internet users, home computers, average salary), news portals and websites specializing in IT and Internet development since 2000; official ISP websites.

Systematic procedures were used to safeguard the study from any retrospective biases (Golden 1992, 1997; Huber and Power 1985), including the collection of data from multiple respondents with diverse backgrounds, triangulating data sources to capture the accurate unfolding of formal and informal processes, and structuring interviews around major events and observation of the actual behavior of actors. The interviews were spread over a period of six years that minimized the potential for a particular single event of the interviewees' past to determine their views. In addition, the case narrative and actors' case descriptions were revisited through clarifying interviews with nine participants from each of the corresponding groups (e.g., three with HomeNets; two with ISPs; three with HomeNet ISPs and one with Beltelecom), ensuring that potential inconsistences and the retrospective biases were minimized.

Data analysis. Our analysis followed an "abductive" process (Hanson 1958; Kelle 1995; Peirce 1958; Richardson and Kramer 2006), aiming to explain new and surprising empirical data through the elaboration of the relevant concepts from the literature review (Kelle 1995; Thietart 2016). In line with Hendfridsson and Bygstad (2013), we developed a four-step approach for analyzing the collected data. First, we analyzed our data to identify events contributing to the development of residential Internet in Belarus. To do so, we created a textual summary of the chronology of important events for the Internet's development (Table C1 in Appendix C), by triangulating the data from interviews and secondary sources (Figure 1). This step was important for understanding the key technologies of the evolving Internet infrastructure (dial-up, HomeNet DIY infrastructures, asymmetric digital subscriber line (ADSL), and fiber-optic), the key actors and their interplays. Based on the chronology, we analyzed the breakthrough events (Langley 1999) that introduced innovative technologies; we also identified four main phases in the infrastructure's evolution (Figure 1) and created detailed descriptions of residential Internet infrastructures for each phase. This step was helpful in understanding socioeconomic and political context shaping infrastructure development (Abbate 2000).

Second, based on the first step , we created a list of key interactions shaping the development of residential Internet infrastructure at each phase. These are summarized in Table C2 in Appendix C. Our analysis identified 24 diverse interactions some of each continued across diverse phases (e.g. see interactions 4,5, and 8 in Table C2). Reflecting on this analysis, it was apparent that multiple interactions were played in parallel (e.g., between HomeNets and Beltelecom), where actors were impacted by but often ignoring/ unaware of each other's interactions and technologies.

Third, to better understand actor interactions in this regard (e.g. how and why the actors created, accepted, or neglected infrastructural technologies and formed (or amended) different coalitions), we detailed the motivating logics of each actor. To do so, we built on interviews, secondary data and analysis of key events and technologies from the first step to identify the organizing principles, assumptions, and identities (Thornton and Ocasio 2008) of the key actors and how these framed actors' technologies, resources, and capabilities (Berente and Yoo 2012; Hultin and Mahring 2014). We summarize actors' logics in Table 2 and provide illustrative examples of these in the findings section.

Our final step focused on creating a narrative description of the interplay between actors' interactions and logics and how it contributed to infrastructure development during each phase (see Table C3 in Appendix C). This analysis resulted in the elaboration of four types of actor interactions, which we detail in the findings. We concluded the analysis by revisiting and comparing the key contextual conditions and actors' technology interplay (based on the data analyzed in step one) for each identified interaction type which we summarize in Table 3.

FINDINGS

Residential Internet infrastructure in Belarus emerged as a result of an unfolding interplay between multiple heterogenous actors (HomeNet communities, ISP firms, a state-owned ISP Beltelecom). These actors used multiple diverse technologies (e.g. dial-up, ADSL, DIY infrastructures, optic fibre, mesh-network intranets, game portals). Actors' orchestration and coordination were also dynamically changing, varying from non-existent to strict government regulation, and from independent to highly interdependent actor contributions. The actors also relied on contesting logics. That is, Beltelecom operated on state logics, ISPs operated on market logics, HomeNets operated on community logics, and those HomeNets that transformed into ISPs after 2010 operated on hybrid logics. We summarize the distinctive organizing principles and assumptions, actor identities, technology framing, and resources and capabilities of each logic in Table 2.

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Incorporating actors' logics into the analysis helped us to explain how actors' actions, technology framings, and interactions shaped and why actors ignored other actors, their motives, and technologies. What might have seemed irrational to one actor was rational and natural to others involved in interactions shaped by different goals and underlying logics of action. In this way, the nature and variety of actor interactions that we analyzed significantly exceeded the traditional direct actor interactions based on competition and collaboration and incorporated complex and non-linear DI development.

Our findings illustrate that interactions of DI actors with heterogenous logics and multiple technologies were not only complex but also dynamically changing due to certain dynamically evolving processes at the ecology level (e.g. emergence of new technologies, introduction and changes of government regulations). To explore the processes and innovative outcomes of such complex and dynamically changing interactions of DI actors we focused on the following key dimensions characterizing DI development. First, we sought to understand the actors' key interaction pattern characterizing how the interacting DI actors used own and other actors' resources: either based on actors' mutually adaptive and collaborative use of resources (i.e. *symbiotic* pattern) or based on exploitation and domination of other actor's resources (i.e. parasitic pattern). Second, we explored the type of ecological interplay that draw the development of DI to understand how actor's actions and contributions could be impacted not only by direct interactions but also by contributions of the ignoring and non-interacting actors operating on contesting logics. In this paper, we distinguish between direct ecological interplays (labeled as *mutualistic* and *mutually competitive)* and indirect ecological interplays (labeled *generative* and *complementary*). Third, we explored how the development of DI infrastructure was shaped by the interplay of disjointed or shared and interdepended technologies. Finally, we explored how various regulations of actor behavior or their absence shaped the development of DI infrastructure.

Our findings identify that combinations of the above shaping characteristics led to four different interaction types that shaped distinct paths of the residential Internet infrastructure development: *symbiotic generative*, *symbiotic mutualistic*, *parasitic complementary*, and *parasitic competitive*. Table 3 summarizes key processes, shaping characteristics and innovation outcomes for each type of the identified interactions while following sections discuss these in details.

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Infrastructure Created by Symbiotic Generative Types of Interaction (1994–1999)

Infrastructure developed via *symbiotic generative interaction* emerges as an alternative DI solution created by an emergent DI actor who is shaped by indirect ecological interplay and distinctive technology to adapt to the existing DI agency that is non-orchestrated, relies on contesting logics and disjointed technologies and fails to generate the innovative DI solution itself.

In the Belarus case, a state-owned Beltelecom and private ISPs who failed to develop residential Internet infrastructure for various reasons. Private ISPs failed to recognize the importance of a residential Internet service following the rationale of market logics (see Table 2). As Table 2 illustrates, the ISPs' decision-making and firm capabilities were profit-driven and relied on market analysis. Respectively, technology development focused on the needs of dominant users and existing market demand. Given this market logic, the high costs of building residential infrastructure for residential clients at that time, who had limited buying capacity, made this irrational. Instead, these ISPs focused on higher-value B2B markets, ignoring the needs of residential users.

Likewise, the logics and related technology framing prevented the state-owned Beltelecom ISP from developing residential Internet infrastructure. Created in 1995 and fully owned and funded by the state, the company operated on a state logic (see Table 2) that implied vertical authority and a top-down planning of its goals and priorities:

> The government is planning on its behalf … not in money indicators but in the number of services to provide: e.g. in 2016 Beltelecom needs to install X fixed phones and connect Y new Internet users. [Beltelecom engineer 3]

> You fulfil a plan – you get promoted. You don't fulfil a plan – most probably, you get fired. [Beltelecom engineer 3]

Following its logics and the identity of a national telecommunication operator that "*guarantees and develops technologies important for the government*,"[4] Beletelecom focused on prioritizing services to government organizations and enterprises. The company's first residential dial-up service appeared only in 1999 and was based on a problematic billing system (calculated as 1/30 of a $600 monthly cost of the allocated line, e.g., $20/hour, when an average monthly salary was $60). The innovation was met with resistance from top management, since the company aimed to fulfill the top-down performance indicators, which in this case was measured by "*the number of fixed telephone users and not Internet users*":

> We [engineers] would regularly come to the marketing department and try to persuade [the marketing director] to have flexible services for residents based on traffic consumption. And they would answer "we do not need this." [Beltelecom leading engineer]

Thus, despite access to exceptional resources and capabilities (e.g., government funds; monopoly on a highly developed residential telephone lines), Beltelecom chose to ignore the potential for the development of residential Internet infrastructure since the pursuit of the innovation was not rational in its logics. The coaction of ISP and Beltelecom's logics and interactions led to the situation where residential

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[4] https://beltelecom.by/o-kompanii

users "*were simply excluded from the Internet provider–user chain*" (ICTD-UNDP expert), which conditioned the emergence of a new DI actor, HomeNet communities.

Ignorance from ISP and Beltelecom motivated residents to self-organize into an *emergent DI actor*, HomeNets. Based on the generativity of IT available to them, i.e., their home PCs, HomeNet members collectively developed new capabilities and addressed their unsatisfied needs to access services that are typically provided by an Internet infrastructure (e.g., file exchanges, multiparty games, chats). Unexpectedly, some universities, including leading IT universities in the Minsk capital, who were not involved directly in any specific interactions with other actors, contributed to a broader understanding among residents about "*what the Internet looked like*" (HomeNet user) and what residents might use it for by providing cheap Internet access for thousands of their students living in dormitories (Minevich and Richter 2005). Thus, while the HomeNet idea of shared Internet access and services originated in IT student dormitories, it moved quickly to the residential sector, motivating intensive HomeNet creation from 1994 through 1996, developed primarily by young residents (16–18 years old):

> One day, my neighboring fellows called me and said: "listen, there is a cool thing – local networking – and you can join" They told me that we can play games together, share films, etc. and that it is very cheap to join, just a cost of a piece of cable to my computer and switch. And I thought: "Why not?" [HomeNet user]

> The HomeNet in our building started spontaneously … A bunch of us were hanging out chatting and we got the idea about developing a "makeshift" Internet. Nobody knew what to do, we just came with the idea and made it work. [HomeNet administrator]

HomeNets provided multiple services, such as chats, forums, and access to radio, media galleries, and local news updates, which offered a low-cost (members paid only the connection and maintenance fee) and immediately useful solution (Hanseth and Lyytinen 2010) for residents. These HomeNets were driven by a community logic (see Table 2) that enabled the pooling of member resources, volunteering, reciprocity, and community decision-making:

> If equipment that connects a certain member breaks down, then this member, or a couple of his neighbors, pool some resources and change it. However, because it was often the case, we soon created a fund of shared resources to support the process. [HomeNet administrator]

> Users helped on the volunteer basis because it was interesting for them to contribute… [HomeNet administrator]

> Our HomeNet included eight [multistory] buildings and … eight people were responsible for managing it. [HomeNet user]

Being an offline and bricolage hand-made version of the Internet, HomeNet infrastructures were not joined with ISP solutions. Notably, HomeNets sought not to challenge the ISP ecology but to adapt to it with what was affordable and feasible within a separate but coexisting informal market:

> HomeNets then were filling the vacuum … built on pure enthusiasm and no money at all … they were not in business; they were on a different side. [Beltelecom engineer]

Nevertheless, HomeNet infrastructures rapidly grew in scale (Huang et al. 2019). Administrators and ISPs pointed to the rise before 2000 of several large networks with over 1,500 residential users each and dozens of smaller networks, which accounted for a large proportion of the total residential computer user population[5] and stimulated further development of the residential Internet infrastructure.

Infrastructure Created by Symbiotic Mutualistic Interaction (2000–2006)

Infrastructure developed via *symbiotic mutualistic interaction* emerged as a result of a new regulation stimulating an unlikely actor partnership into a metaorganization where actors maintain their own authority and follow their own motivations, and logics, while developing mutually dependent capabilities and relying on shared and interdepend technologies (see Table 3). In the Belarus case, a new residential infrastructure for more than a million users developed around a symbiosis of ADSL technologies provided by ISPs and residential infrastructures provided by HomeNets.

In 2001, a new law granted Beltelecom a monopoly right to resell Internet traffic to other ISPs. Deprived of the possibility to sell and exchange Internet traffic with each other, and seeking profit in line with their market logic, ISPs focused on serving high-end corporate clients instead of building their own residential infrastructures. To provide ADSL access to residents, ISPs had to rent telephone infrastructure from Beltelecom, and set up the price too high for the residential ASDL market to develop. With an average salary in Belarus in 2000 of $82 (59,000 Blr), corporate ISPs offered ADSL access for $99 (E115) per month and required a one-time connection fee of $700 for new clients.[6] Moreover, lacking residential clients, ISP traffic was used at only 30 percent of its capacity during the day and not at all during night hours.

In 2002, Beltelecom became one of the first adopters of the ADSL technology, primarily for its own company's clients in government. The company could easily have become the main provider of the residential Internet at that time, since ADSL relied on the infrastructure of landline telephone lines and automated telephone stations (ATS). Beltelecom was the monopoly owner of these, with a very high penetration level across Belarus (the highest of the former states of the USSR). However, following its state logic of fulfilling top-down performance indicators, measured by the number of connected *telephone* users (and not the number of *Internet* users), Beltelecom ignored the opportunity. The company also ignored HomeNets. As the company engineer stated:

> Indeed, we [employees] knew about HomeNets. Many used them at home but they existed in a "parallel" reality … Beltelecom's official position was that HomeNets are not legal organizations. It's not a good thing for a respected state company … to support any unofficial developments. So Beltelecom never had any dealings with HomeNets.

The situation motivated ISPs to engage in an unlikely coadaptive alliance (O'Mahony and Bechky 2008) with HomeNets. They formed a metaorganization (Gulati et al. 2012) where each actor maintained its own authority and followed its own motivations and logics while building on both its own and its partners' material, cognitive, network, and legal resources.

The initiative to collaborate came from HomeNets that developed into large communities of several thousand members. In particular, HomeNet's scale, along with member experience of using ADSL at work or hearing about it from friends and relatives, led some administrators to realize that

[6] http://www.e-belarus.org/news/200105301.html, https://42.tut.by/3975

community infrastructures could be used to help provide an inexpensive approach to ADSL-based access. Trying to link HomeNets into the existing ISP network (Sanner et al. 2014), they visited all ISPs and proposed ways to collaborate with them. Initially, it was only one ISP, Solo, that "managed to see a rationale in our idea." (HomeNet administrator). Soon other ISPs realized that a HomeNet could bring as much profit as their targeted corporate clients and engaged in developing a collaborative infrastructure with HomeNets:

> In 2004–2005 all providers placed offers for HomeNets at their websites. By doing this, providers officially recognized their existence. [Sales manager of a large ISP]

Each collaborating party was following its own distinctive goals (e.g., obtaining Internet access for entertainment and community resources through HomeNets, and maximizing their profit in the monopolistic conditions dictated to ISPs by Beltelecom) and acting within its own logics (i.e., market for ISPs and community for HomeNets). At the same time, they together achieved elements lacking in their own network by coadapting and codeveloping their technologies and operational processes. In essence, HomeNets provided the last-mile infrastructure to residential users that ISPs were lacking:

> Intensive night consumption of Internet by HomeNet users … was a huge bonus for providers … HomeNets [thus] were offered big bonuses. [ISP manager]

HomeNets were also maintaining this last-mile infrastructure, connecting new and supporting existing Internet end users who were members of their community. In line with market logics, ISPS now invested in HomeNets as their main clients, providing them with bonuses that stimulated their growth, such as a free modem and Internet bonuses for administrators:

> Our criteria for collaboration were at least five people in a HomeNet. This is all. The HomeNet would receive a free modem, free installation, they were our main customers then. Naturally, such offers motivated their development. [ISP Marketing manager]

HomeNets and ISPs also coadapted their existing technologies and business processes. For example, ISPs developed new billing systems and supporting services to calculate and receive payments from HomeNet members (e.g., payments by Internet, infokiosks, at the post office, and by prepaid cards). They also hired experienced administrators as managers specializing in HomeNet communication, and created technical support centers for HomeNets. In turn, the HomeNets restructured their infrastructure to incorporate many new members who wanted to join in order to gain Internet access and technically found ways to better support multiple Internet access from their shared modems. They also developed new roles for communicating with ISPs and selling prepaid cards to community members.

Two platforms, one created by HomeNets (HomeNets.tut.by) and another created by ISPs (intranet services), facilitated access to each party's expertise and capabilities. Thus, the national HomeNet website, HomeNet.tut.by, emerged in 2002 and soon became the main platform for diverse HomeNets to communicate, develop their own mini-websites, and share their news, inquiries, and experiences, including those related to particular ISPs (see Figure 2). The website also contained a ranking of all ISPs by polling of HomeNet members. As stated by an ISP manager:

> All ISPs were active at the [Homenet.tut.by] website. They explained the company strategy, resolved emerging customer issues, provided feedback, promoted services, monitored each other's offers … Daily communication with users at the website was a part of my job.

Furthermore, following their market logics, ISPs invested in IT serving the needs of HomeNets as their dominant users and regularly updated it. As an ISP marketing director stated in interview, *we made four updates to our infrastructures with HomeNets in three-year period.* Thus, ISPs developed a variety of intranet services, such as media galleries, with films, music, and games. They also monitored members' interests and implemented innovative services (Authors 2016), and tested their own new services via intranets by "*observing how members consumed these*" (ISP manager).

Nevertheless, as specified by Gulati et al. (2012), each party in the metaorganization maintained a degree of autonomy. For example, HomeNets introduced a number of additional ISPs to their infrastructure to prevent one from taking over the community:

> We thought it would be better if there will be several providers in the HomeNet so that they would compete with each other rather than dictate their conditions to us. The advantage of the first provider was that it had a file server, a second one was offering the cheapest Internet, yet another offered really speedy Internet. [HomeNet administrator]

Thus, HomeNet members had a possibility, easily and for free, to switch on a day-to-day basis between different ISPs depending on their needs (e.g., connecting to an ISP with cheaper night Internet access or to another ISP with more expensive but higher-speed Internet). This stimulated competition between ISPs for HomeNet users and led to a variety of new ISP services and special offers, such as FTP servers with films, and game servers (e.g., http://media.aplus.by, http://banana.by, now closed).

HomeNet–ISP collaboration also changed the political dynamics (Sahay et al. 2009) by transforming HomeNets and their technologies from marginal and local into central:

> … people started joining not because of HomeNet resources but because of the Internet … A profile of a HomeNet user became very diverse: there were tax inspectors, firemen, even KGB officers but also simple shop assistants, students, those who recently moved to Minsk … This idea started to be supported by many people. [HomeNet administrator]

Soon, residential Internet access through ADSL–HomeNet infrastructure became the dominant form. Some experts estimated that about 90 percent of all home computers in Minsk during 2002–2009 became connected to the Internet via HomeNets (Scherban 2010).

Infrastructure Created by Parasitic Complementary Interaction (2006–2009)

Infrastructure developed by *parasitic complementary interaction* develops between the primary innovator who proposes a technologically advanced, but ultimately unsuccessful in reaching end users infrastructural innovation, and another DI actor who develops a complementing parasitizing IT solution on the primary innovation. The parasitic complementary interaction allows the innovative infrastructure to scale beyond the tipping point but outside the control of the original innovator in a largely unregulated area and develop as an unprompted mesh network.

In the Belarus case study, such parasitic complementary interaction led to the development of a an unprompted mesh network (Rodon and Silva 2015) linking a new branch of centralized residential Internet infrastructure created by Beltelecom to be complemented by a parasitizing decentralized bottom-up innovative solutions from HomeNets (see Table 3). As described below, these developments unexpectedly changed the political dynamics in the field in ways that led to an increase in the credibility and power of Beltelecom (Constantinides and Barrett 2014; Sahay et al. 2009).

The development of a new branch of residential Internet infrastructure by Beltelecom was motivated by two national programs, "e-Belarus" (2003–2010) and the Telecommunications Development Program (2006–2010), which announced its aim to increase the number of Internet users.[7] In line with these, Beltelecom's performance indicators changed to the number of *Internet* users, which led to a shift in the prioritized technologies. Residential ADSL technologies developed by a group of enthusiastic Beltelecom engineers, but neglected for years, suddenly received approval:

> For developing this [ByFly] service I received a monetary bonus to my salary and my boss received his desired promotion. [Beltelecom engineer]

This is how, in 2006, Beltelecom introduced "ByFly" – an unprecedented option for residents to receive *unlimited* Internet access. Being the monopolist in the provision of an Internet channel and ATS, Beltelcom was the only ISP that could offer truly *unlimited* ADSL Internet access. Driven by the state logics of fulfilling the goal of increasing the number of Internet users, the company introduced its first ever commercial advertising[8] for its ByFly service and gave ISPs a hard time by increasing the rent for Internet channels by over 30 percent.[9]

However, despite its technological superiority and unique offer, ByFly's infrastructure initially failed to enroll and attract users because of its high cost. ByFly's monthly fee was more than ten times a collaborative HomeNet ISP solution, and was therefore it was only purchased by the very high-end customers. Moreover, driven by state logics, Beltelecom was not sensitive to its customers' needs, providing a "zero-level" customer service:

> Beltelecom's most important thing is to fulfil the plan, they not care a straw about people. [Director of a HomeNet ISP]
>
> This giant's Byfly is an intelligent and technically-savvy solution. If they their CRM would be at the same level the majority of ISPs would soon become bankrupts. [ISP Director]

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[7] http://www.e-belarus.org/article/egov03.html; http://www.e-belarus.org/news/200610311.html
[8] http://byfly.by/sites/default/files/video/22110.page_publ.byfly1.mpg
[9] http://www.interminsk.com/news/7.html

Some HomeNet members found ways to transform this expensive and technically superior ByFly innovation into a low-cost solution available to far more users. Some residents started buying a ByFly service and then using existing HomeNet infrastructure to share their Internet access:

> We used the existing HomeNet [infrastructure]. Just instead of using the provider who operated in our network we shared my ByFly access through it. [HomeNet administrator]

In other cases, households gained lower cost access to the Internet by jointly sharing the costs of ByFly. For example, some groups of neighbors, who did not previously use the Internet, created mini-HomeNets for few as two to five people, the instructions for doing so widely available through Homenet.tut.by. This strategy was accelerated by the arrival of Wi-Fi:

> With the emergence of WiFi it became a really mass phenomenon … Neighbors living at the same floor would usually form a network and … use the Beltelecom's Byfly and share Internet costs. [It was] natural to do. [HomeNet administrator]

In this way, ByFly innovation was complemented by innovative uses of HomeNet infrastructure, albeit with relatively inferior performance, given reliance on a multiplexed channel capacity that would often reduce signal quality.

The emergent ByFly–HomeNet infrastructure was based on a mesh network where parasitizing solutions complemented insufficient capabilities of the original innovation in unprompted ways. The centralized ByFly service was enhanced by services that imitated services that were popular within HomeNet–ISP infrastructures, such as multiparty games, media download services, online radio services, forums, and chats, and included these free with the ByFly Internet service. The services were developed and included into Beltlecom's intranet by young IT specialists in Beltelecom. Being graduates from some of the best national IT universities, and active members of local game and open-source coding communities, they were developing these services "*at their own risk*" to push IT progress in the country:

> The game was to develop and launch cool services out of the top-management [bureaucratic] control and then, when they worked well, present them as good achievement for reaching the company goals. [gameplanet.by administrator]

While the services were hosted by Beltelecom, administrators for these were chosen from local enthusiasts and hobbyists.

The development of the unprompted ByFly – HomeNet mesh network allowed the ByFly infrastructure to scale and influence other major actors. For example, in 2008, Beltelecom started hosting the biggest game server in the country, with a major impact on other ISPs providing similar services:

> The majority of the gamer community switched to the ByFly game project http://gameplanet.by. Their forum was one of the central and most numerous among ByFly users. This is why many game servers of other ISPs ceased to exist. [ISP sale manager]

Official Beltelecom statistics indicated that the number of its ByFly users grew dramatically, from 3,000 in 2006 to 190,000 by 2007 and 520,000 or more by 2009.[10]

However, following the state logics of ignoring HomeNets as unofficial actors, Beltelecom managers began to see HomeNets as competitors and an obstacle in fulfilling top-down indicators. The company started to literally cut down HomeNet cables. As a Beltelecom engineer explains:

> Using their ranks and some illegality of HomeNets, some Beltelecom managers sent workers to cut HomeNet cables, e.g. "since we are not advancing in selling Byfly but need to connect 1000 more users by the end of the year quarter". It wasn't an elegant solution but if was a part of their reality: they get salary bonuses when fulfilling the plan and might be fired if they don't.

In 2006, the Ministry of Communication announced that HomeNet infrastructures were illegal.[11] By 2008, a program to eliminate HomeNets was approved by the government and a working group was created, which consisted of Beltelecom, Minsk television, the information networks organization, tax inspection, and the police. This generated hot debates on mass media outlets[12] and HomeNet.tut.by. Following these top-down initiatives, local municipalities received an order to inspect and remove illegal residential HomeNets. This resulted in strong opposition by HomeNets. At the same time, many municipalities unofficially supported HomeNets since thousands of their workers and family members used HomeNet services as the most affordable means. As a result, they often pretended "not to notice any

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[10] http://web.archive.org/web/20130118011141/http://belstat.gov.by/homep/ru/publications/yearbook/2012/yearbook_2012.rar
[11] http://www.e-belarus.org/news/200610311.html
[12] https://42.tut.by/178813, http://providers.by/2009/05/news/chinovnik-nazval-ceny-legalizacii-domashnej-seti/

cables" and warned HomeNets beforehand in a case of verification works from the city council, in some cases even misleading the latter, such as by guiding the commission to "safe" locations.

One consequence of the above interactions was that Beltelecom was gradually developing a leading position in ADSL access. By 2008, ByFly held 35 percent of the market in the capital, Minsk, and about 70 percent in other cities, where ISPs did not have a developed ADSL infrastructure.[13]

Infrastructure Created by Parasitic Competitive Interaction (2008–2015)

Infrastructure developed by *parasitic competitive interaction* emerges when heterogeneous actors compete with one another with a new technology, for which they develop idiosyncratic technology frames and disjointed innovative solutions. Intensive actor regulations in the field further stimulate actors' direct interactions based on exploitation and domination. This leads to the dissolution of some organizational actors as well as the emergence of new actors. The resulting infrastructure consolidates around providing similar technological solutions by the competing multiple heterogenous actors. As explained in the rest of the section, the competitive parasitic interactions unfolded around the introduction of fiber-optic technology and strict government regulations, leading to the dissolution of HomeNets, the emergence of HomeNet ISPs, and infrastructure consolidation around three main technologies (fiber optics (leading the market), ADSL, and wireless solutions) provided simultaneously by the competing Beltelecom, ISPs and HomeNet ISPs (see Table 3).

In 2008, ISPs became interested in developing their own infrastructure based on new fiber-optic technologies, instead of using the monopolistically owned Beltelecom landline infrastructures to provide the ADSL services. Originally, HomeNets were considered important partners in the project, providing the last-mile connection and enabling ISPs to decrease costs of building fiber infrastructure. Revenues from new fiber Internet were planned to come from Ethernet services, such as IPTV, games, and media

[13] http://www.e-belarus.org/news/200810021.html

services, that ISPs had been developing in collaboration with HomeNets. However, the interplay of ISPs and Beltelecom changed all actor interactions in the field to parasitic and led to HomeNet dissolution.

Thus, driven by the state logic to gain national leadership[14] and impressive performance measured by the number of Internet users, Beltelecom competed with ISPs on the bureaucratic and technical capacity sides:

> as soon as ISPs … negotiated with Beltelecom that it won't damp the prices any more, it increased the width of its [Internet] channel. For the same money a Beltelecom user now gets twice the speed. [ISP director]

Beltelecom used the support from the government actors as redistribution mechanism (Thornton et al. 2012) to exclude ISPs from resources necessary to developing fiber infrastructure. Thus, in 2007 the government introduced a new innovation fund, created by a new tax that required all ISPs to pay 1.5 percent of their monthly profit. The fund announced access for all ISPs on the basis of a bidding scheme. However, "*de facto this is only Beltelecom who gets money from it*" (UNDP consultant). To oppose this, in May 2010, nine major private ISPs signed an open letter to Parliament, the National Ministry of Connection, and the National Ministry of Economy, calling for the demonopolization of the industry. The government answered with the introduction of a new state ISP, the National Traffic Exchange Center, in September 2011, with the avowed purpose of demonopolizing the industry.[15]

Following the market logic and seeking to compete with and bypass Beltelecom on the market, ISPs invested heavily in the development of fiber-optic Ethernet infrastructure submitting innovative project applications to win permission from the City's executive committee, Ispolkom. However, unexpectedly, the Beltelecom subsidiary, Minsk Telephone Lines, joined the Ethernet market and challenged Ispolkom's rights to grant permission on its territory in Minsk. This led Ispolkom to block all Ethernet applications (except from Beltelecom) from 2007 till 2009. The Association of Belarussian ISPs

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[14] http://forum.onliner.by/viewtopic.php?t=413579; http://www.interminsk.com/archive/beltelecom
[15] http://www.e-belarus.org/news/201212141.html

(formed in 2001) intensively negotiated and successfully resolved this issue only at the end of 2009,[16] when Beltelecom was already in the process of preparing its fiber-optic infrastructure in line with a new national program, "Electronic Belarus" (2011–2015), where its leading role had been specified.

Seeking to generate profit and find resources to develop fiber infrastructure in such conditions, ISPs started looking for ways to appropriate HomeNet infrastructures and users. A great opportunity came from a new government Internet law, N60. Issued in February 2010 in preparation for the December 2010 presidential elections, the law introduced the obligatory identification of all Internet users, thereby effectively inhibiting shared HomeNet Internet access:

> Suddenly, HomeNets "turned" into a place where potentially dangerous content could be spread … Officially, HomeNets became illegal organizations. [ISP manager]
>
> [After the law] HomeNets continued to exist but … not in open way. [HomeNet user]
>
> Before the law, HomeNets were widely discussed everywhere – in Internet, press, on ISP websites; after the law, they "disappeared", became "grey" networks. [HomeNet administrator]

Following the law, ISPs redefined their long-standing collaborative relationships with HomeNets to one that was parasitic. Thus, big ISPs started actively proposing to "help" legalize HomeNets by offering incorporation of the community infrastructure and making an individual client agreement with every member, while also allowing clients the right to use their HomeNet infrastructure free of charge.[17]

Following the market logic, ISPs offered monetary bonuses to HomeNets, such as by hiring their administrators as managers, offering individual "lifelong" reductions in Internet price, or purchasing the HomeNet infrastructure for a negotiated sum. In some cases, the strategy worked:

> Initially [we paid] 25 dollars for each user… Later, we understood how much it had cost to attract the same member with our own means and the price became lower. [Sales director of a big ISP]
>
> Out of all ISPs, Solo [ISP] had the most liberal conditions. As everyone else, they were fully incorporating the HomeNet infrastructure but proposed to hire administrators. But they became the legal owners after this. [HomeNet administrator]

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[16] http://providers.by/2009/05/news/razreshenie-na-sozdanie-seti-poluchit-nevozmozhno

[17] http://providers.by/by-providers/lans/; http://providers.by/2009/05/news/chinovnik-nazval-ceny-legalizacii-domashnej-seti

In other cases, this generated conflicts with the community logics of HomeNet members:

> No way! We built it with our own hands! [HomeNet user]

Many ISPs developed special strategies for incorporating HomeNets:

> We tried to conquer their minds in order to incorporate. We knew their difficulties well: members leaving because of legal restrictions, breaking HomeNet infrastructures, lack of time and assistants. [ISP manager]

> We put notes that we were going to build a high-speed Internet highway in the distinct with invitations for every potential user to call. In reality, we were not going to build anything … but it disoriented administrators who thought of investing into developing their HomeNets into ISPs and we got contacts of those who might potentially leave. [ISP operational director]

As a result of such parasitic interactions, the majority of HomeNets were either incorporated into ISPs or dissolved. Some HomeNets where "*administrators were smart and strong enough to reject the arguments about the pessimistic future of their networks*" (ISP operational manager) survived and developed into competitors (Sahay et al. 2009) by transforming into a new organizational species, called HomeNet ISPs (e.g., Unet,[18] Flynet,[19] Onenet[20]). These new actors relied on a hybrid logic (see Table 2), being community-driven market players generating profit. Developing Internet infrastructures to serve residents' needs, they competed with other ISPs while delivering many services to each other:

> We provide the billing systems to other HomeNet ISPs … on a friend-to-friend basis… We do not compete with each other … They are all friends who are in the same conditions. [Director of HomeNet ISP]

HomeNet ISPs focused on developing fiber-optic infrastructures to provide high-quality Internet and on original intranet services to build on their well-established relationships with users/community members. This enabled these HomeNet ISPs to occupy the six top positions in the national ranking of ISPs based on customer reviews in 2017 (leaving Beltelecom 38th out of 47 providers; http://providers.by/rating).

To take the lead in the number of Internet users, Beltelecom changed telephone landlines in all residential properties from copper lines to fiber-optic ones, connecting its two millionth Internet user in

[18] https://unet.by/about
[19] https://flynet.by/about
[20] http://onenet.by/o-onenet

2015 and eliminating the technical possibility for other ISPs to provide ADSL there. Beltelecom thus focused on gigabit passive optical network (GPON) fiber-optic, enabling the individual connection of every household, complemented with standard digital TV and landline phone solutions, and provided ADSL and wireless connections as alternatives, in cases where its GPON was not available. Monthly prices (December 2017) of unlimited GPON-based Internet access were as low as $3.5 (7 Blr)-$7.5 (15.5 Blr)[21], including unlimited Internet, interactive HD TV, fixed telephone line being (with average monthly salary being $400). Many ISPs acknowledged in interviews in 2016 that customer service was the only area where they could beat Beltelecom:

> We are lucky that they [Beltelecom] do not know how to sell. [ISP marketing director]
>
> Beltelecom is our main competitor. The company is shameless in dumping prices and impose its services to everyone. Taking into account that it is also the monopolist on selling Internet highlines – it's extremely difficult to compete with. [ISP director]

In contrast with Beltelecom, ISPs focused on fiber to the building (FTTB) solutions and copper lines to individual households, being less expensive to repair and providing more equity in speeds and input/output data flows (which are important for intranet services). However, in the face of high competition (with Beltelecom but also, following the market logic, between themselves), the two biggest ISPs disappeared. In 2015, Solo (the oldest corporate ISP and a pioneer in HomeNet–ISP collaboration) was purchased by Atlant. In December 2016, Atlant was purchased by a cell phone operator, Velcom.

In this way, as summarized in Table 3, the innovative Internet residential infrastructure developed via similar DI solutions (e.g. different combinations of the fiber optic, ADSL, and wireless technologies provided by multiple heterogenous actors with contesting logics.

DISCUSSION

[21] https://www.beltelecom.by

Our study examined how DI infrastructure develops in ecologies with multiple heterogeneous actors operating on contesting logics, diverse technologies and various orchestration levels. Our findings illustrate that DI development follows complex non-linear paths and four types of symbiotic and parasitic actor interactions through which the DI shaped and evolved. Based on these, we develop a model of symbiotic and parasitic interactions shaping DI development and discusses the theoretical and practical implications of our findings.

A Model of Symbiotic and Parasitic Interactions Shaping Digital Infrastructure Development

Generalizing our insights, we develop a model of symbiotic and parasitic interactions of DI agency shaping digital infrastructure development. Our model theorizes that the four identified types of symbiotic and parasitic interactions develop in the ecologies with the following characteristics: a) multiple heterogenous actors with contesting logics; b) multiple technologies with different degrees of confluence; c) various types of ecological interplays; d) diverse and changing levels of actor orchestration (see Figure 4).

--- Insert Figure 4 here ---

The model illustrates that the combination of factors, such as technology confluence, type of ecology interplay, and orchestration, shapes the DI path. *Technology confluence* describes interdependencies between diverse technologies used by multiple heterogenous DI actors. We distinguish between *low levels of technology confluence*, whereby the innovating actors rely on separate diverse or similar technological solutions, and *high levels of technology confluence*, when the innovating actors build on shared or partly shared technologies. The integration of diverse levels of technology confluence is important for capturing diverse ways in which digital infrastructure can develop. As discussed above, the specificity of latter that distinguishes it from other infrastructures, such as roads, is that it allows expansion not only via tightly but also via loosely organized (Henfridsson and Bygstad 2013; Tiwana et al. 2010) integration of new innovative solutions. In this way, residential Internet infrastructure in Belarus was able to grew on an alternative innovative solution developed by HomeNets from affordable DIY technologies which were relatively independent and disjointed from infrastructural technologies of other actors (ISPs and Beltelecom) but served a similar need.

Type of ecological interplay characterizes how the diverse interaction strategies adapted by the heterogenous actors interplay at the ecology level. This characteristic suggests that, as actors adapt, exploit, dominate or ignore other actors they can interplay via *direct interactions*, i.e. based on reciprocal interplay and awareness, as well as *indirect* interactions, i.e. taking place via ecological impacts and/or without reciprocal awareness of the involved actors. Incorporating both direct actor interactiosn and indirect ecological impacts into the analysis provides valuable insights for following the nonlinearity of digital infrastructure development and understanding how indirect ecological impacts might shape the development of the infrastructure paths.

Finally, *orchestration* refers to the coordination and regulation of actor behavior in the ecology, such as state laws regulating particular actor interactions and cultivating or otherwise deliberately influencing the behavior of other actor. Based on these factors, we distinguish between *high and low levels of orchestration*, i.e., intensively and nonintensively coordinated and regulated behavior of DI actors.

The model suggests that the combinations of above ecology-level factors conditions the four diverse modes of symbiotic and parasitic actor interactions, which lead to different paths in DI development. As Figure 4 illustrates, *symbiotic generative type of interaction* of the distributed DI agency develops when the behavior of heterogeneous actors in the ecology is not orchestrated, is motivated by non-direct ecological interplay and relies on separate technologies with low technology confluence. In such case, actors' logics and interactions are structured around *separate diverse technologies* whereby each actor satisfies the specific needs of a narrow set of users. DI in this case emerged as an isolated alternative solution created by a new actor (i.e. HomeNet communities), who developed an unprompted innovation (HomeNet infrastructures) to adapt to the existing ecology of actors.

Symbiotic mutualistic interaction develops in ecologies where actor interactions are orchestrated (i.e., new state regulation enables private ISPs to sell Internet to individual and business clients but not to other ISPs) and where previously unconnected actors become intensively engaged via a new technology that enables confluence between their existing distinct technologies. DI solution in this case emerged based on shared technologies that were collectively developed in a metaorganization by HomeNet and ISPs, despite the actors' diverse technologies, logics and motives (see Figure 4).

Parasitic complementary interaction develops when actor interactions around new technology are not orchestrated but where the technology enables confluences and direct interplay between previously unconnected actors. This stimulates some actors to engage in opportunistic behavior and develop unprompted mesh networks by parasitizing on novel technological solutions developed by other actors. As a result, interactions unfold around a novel DI developed by one actor (HomeNets) based on partly/ unintentionally shared IT innovation owned and developed by another actor (Beltelecom) (see Figure 4).

Parasitic competitive interaction develops in ecologies with high degrees of actor orchestration, intensive actor interplays and low degrees of technology confluences. The logics and interactions of heterogeneous actors organize around competing and parasitizing on each others' resources and capabilities while developing separate similar DI solutions (i.e. fiber optic services).

Notably, we found that symbiotic interactions developed in ecologies where the orchestration of actors' interactions and technology confluences were aligned (i.e., being both either of high or low degrees) (see Figure 4), since this led to fewer conflicts and more mutually adapting actor interactions. In contrast, parasitic interactions developed in ecologies with diverse degrees of orchestration of actors' interactions and technology confluences (i.e. low and high combinations). This effect might arise because new technologies with high degrees of confluence between previously unconnected actors combined with low degrees of actor orchestration might stimulate some actors to engage in opportunistic behavior (e.g., illegal shared Wi-Fi connections based on HomeNet infrastructures). In a similar vein, high degrees of actor orchestration combined with low degrees of technology confluence stimulate actor parasitizing mutually competitive behavior.

Furthermore, our findings suggest that changes within the types and trajectories of actor interactions that lead to novel DI development are triggered by *new technologies* and *regulations*, and their combinations. Thus, new regulations change the ongoing paths of DI development because they influence strategic actor choices with whom to interact, amend the interaction rules and intentions, and challenge existing interactions and power balances. For example, government laws changed the paths of residential Internet infrastructure development by obliging ISPs to buy Internet channel from Beltelecom and motivating them to consider an otherwise unlikely alliances with HomeNets, stimulating Beltelecom's highly interactions with other actors by introducing the priority on the number of its Internet (instead of telephone) users, and disturbing the long-lasting HomeNet-ISP alliances. Without such regulations, the unfolding dynamics of residential Internet infrastructure development could be very different, leading to a different enactment of opportunities emerging from new technology and different interaction dynamics and infrastructural paths. For example, introduction of a new ADSL technology in the absence of the monopoly law on Beltelecom exclusive right for re-selling the Internet channel would make ISPs the major actors ignoring the value of HomeNet infrastructures and developing more centralized infrastructures with fewer variety of customer services. Likewise, the absence of 2008 and 2010 government Internet regulation laws would allow the residential infrastructure to develop mainly through the HomeNet – ISP metaorganization leading to greater diversity of Ethernet services and peer networks, instead of infrastructure consolidation around similar DI solutions. At the same time, regulations are important but not exclusive triggers of DI development and change.

New technology extends possibilities and ways in which each actor in the ecology can react to regulations or their absence and provides new opportunities and platforms for actor interactions that previously were inexistent, unlikely, or hard to achieve. In particular, new technologies provide tools via which actors with contesting logics can instantiate their logics in new ways that might enable previously non-existent interactions. In this regard, considering the interplay of multiple technologies (e.g. technology confluence) is particularly fruitful for understanding how potentially unlikely or non-linear actor interactions develop through a variety of disjointed (e.g. initial HomeNet DIY infrastructures), interdependent or partly shared technology solutions. For example, introduction of ADSL technology enabled the previously inexistent confluence between diverse HomeNet and ISP technologies and their otherwise unlikely collaboration via metaorganization. Likewise, combination of new unlimited (ByFly) Internet service and WiFi technology with existing HomeNet infrastructures led to the development of a partly shared innovative mesh network enabling an otherwise unlikely interplay of HomeNets and Beltelecom.

The principal novelty of our model is that it incorporates the interplay of multiple actor technologies, a variety of ecological interplay (including both direct interactions and indirect impacts) and variety of actor orchestration degrees. In this regard, the model differs significantly from existing ecological frameworks that prioritize deliberate and orchestrated (e.g., Dougherty and Dunne 2015) which focuses on orchestrating deliberate actions of multiple participants. As we illustrate in the paper, emergent and non-orchestrated interactions were particularly important for the development of HomeNet infrastructures in symbiotic generative interactions and residential Wi-Fi infrastructures building on ByFly solutions in parasitic complementary interactions. In this regard, the model provides value for understanding a variety and non-linearity of DI development paths beyond those highlighted by traditional cooperation and competition interactions. The model is also illustrative of a profoundly collective nature of processes and outcomes of DI development, suggesting that even in ecologies where potentials for confluences of actors' diverse technologies are low and actors are not orchestrated, DI can be co-shaped by logics and interactions of multiple actors via non-direct ecological impacts (e.g. DI emerging via symbiotic generative interactions). We discuss the theoretical and practical implications of our model below.

Implications for Theory and Practice

Our findings make several theoretical contributions. First, our findings on symbiotic and parasitic interactions complement emerging research on new forms of multiactor networks and the processes of collective shaping of DI by the distributed innovation agency (e.g., Boland et al. 2007; Garud et al. 2008; Lyytinen et al. 2016; Nambisan et al. 2017). Specifically, our findings contribute to and extend existing knowledge on diverse forms of interactions within the distributed DI agency (Boland et al. 2007; Lyytinen et al. 2016; O'Mahony and Becky 2008; Tuertscher et al. 2014). The identified symbiotic and parasitic interactions, their processes, shaping characteristics and innovative outcomes (detailed in Table 3 and discusses in the proposed model in Figure 4) might be generalizable to the development of other DI in settings that assume interactions of multiple actors with diverse institutional logics and multiple technologies. In particular, we suggest that research on blockchain, Internet of things, digital platforms, smart cities, 3D printing, and car manufacturing (that builds on open software solutions and spans industrial boundaries) can benefit from the proposed model in developing insights on the variety and non-linearity of interaction shaping DI developments, as well as their processes, conditions and outcomes.

Second, our study is among the first to examine the interplay of multiple technologies in the DI development. Previous studies have discussed that collectives of distributed actors succeed in DI development either under an umbrella of a common project, services or sociotechnical system (e.g., Boland et al. 2007; Tuertscher et al. 2013; Oborn et al. 2019) or by excluding multiple versions of digital infrastructures (e.g., Constantinides and Barrett 2014; Aanestad and Jensen 2011; Sahay et al. 2009). A common argument in these diverse studies is that a specific technology serves as a coordination tool for matching contributions from highly diverse multiple actors. Our findings importantly extend these insights by highlighting how DI develops via combinations of multiple technologies that might interplay in diverse and unpredictable manner and with various degrees of confluence, including separate and independent (as in symbiotic generative interactions), shared (as in symbiotic mutualistic interactions), partly shared (as in parasitic complementary interactions), or similar coexisting solutions (as in parasitic competitive introductions). The interplay of multiple diverse technologies contributes to DI development not by serving a coordination and orchestration tool (e.g. Nambisan et al. 2017) but by enabling various and often unlikely combinations of diverse technologies to act as a gateways integrating innovative developments from heterogenous actors into a DI that would be unlikely to emerge around single technology.

Third, our findings support recent arguments by Oborn et al. (2019) about limitations of orchestration strategies for DI development and illustrate the importance of incorporating both orchestrated and nonorchestrated actor interactions and, specifically, the role of indirect and nonreciprocal actor interactions, in the analysis. In this regard, our findings support and extend existing studies about nonlinear ways of DI development (Gulati et al. 2012; Lyytinen et al. 2016; Nambisan et al. 2017) by detailing how actor interplays might be mutually shaping without direct interactions and contribute to complex and emergent DI development beyond the original intentions, resources, and capabilities of a solo innovator (Garud et al. 2008).

Forth, our study is among the first to incorporate the interplay of contesting logics of multiple heterogenous actors into the analysis of DI development and suggests its value and novel insights in this regard.. Thus, the concept of *institutional logics* is helpful in capturing diverse ways in which heterogenous actors think about their rules and resources in the field (e.g., see Table 2). and explaining how and why actors intentionally or intentionally neglected and downplayed innovative opportunities offered by new and emerging technologies because of the different organizing principles, assumptions and technology framing in their meaning systems (Barrett et al. 2013; Garud et al. 2013), such as in the case of Beltelecom, which neglected the development of residential Internet infrastructure despite having resources to do so. At the same time, while previous studies have discussed that actor logics enable and constrain actors in building on certain rules and resources (Berente and Yoo 2012; Carlile 2002; Garud et al. 2013; Hultin and Mähring 2014), our findings challenge this assumption. In particular, our findings suggest that the interplay of multiple diverse technologies might provide DI actors with insights into rules and access to resources that are not typical of the repertoires afforded by their dominant logics. Thus, while previous studies have argued that actor logics instantiate in the technology (Gawer and Phillips 2013), we argue that the interplay of actors' multiple logics, diverse technologies and various ecological impacts condition synergies into the collective DI development processes and outcomes that exceed the sum of resources, rules and capabilities of individually contributing actors. The cases of symbiotic mutualistic and parasitic complementary interactions are illustrative in this regard.

Fifths, the four identified symbiotic and parasitic types of interactions nuance our knowledge on a possible repertoire of nonlinear paths of DI development (Garud et al. 2013; Hanseth and Lyytinen 2010) and extend our knowledge on asynchronies associated with non-linear and non-orchestrated DI development. Studies have pointed to diverse nonlinearities that characterize the processes of DI development across time (Ansari and Garud 2009; Garud et al. 2013) and space (e.g., Oborn et al. 2019). Our study builds on and extends these findings by highlighting the variety of nonlinearities and complexities that act as "generative forces that are required to sustain innovations" (Garud et al. 2013, p. 801), including asynchronies/ignorance in actors logics, disjointed technologies and the emergent interplay of direct and indirect ecological impacts. These nonlinearities and complexities were crucial for enabling the residential Internet infrastructure in Belarus to develop as open innovation systems incorporating a variety of unprompted actors and unanticipated processes and consequences (Lyytinen et al. 2016; Zittrain 2008).

Finally, our findings suggest a need for researchers to rethink the role of regulations, power and control in actor ecologies shaping DI development. Our findings on the important role of regulations support studies that have argued for incorporating political and institutional regulations into the analysis of the development of digital infrastructures (Aanestad and Jensen 2011; Constantinides and Barrett 2014b; Sahay et al. 2009). Furthermore, our findings support and extend some recent studies arguing that control becomes decentralized in multiactor DI networks (e.g., Lyytinen et al. 2016). Actors that historically were not in power in the particular context (such as ISPs and HomeNet communities) and were dominated by traditionally powerful actors with distinct logics (such as Beltelecom and the state) used the capacities of IT to generate a distinctive source of power based on an ability to achieve technology confluence. Our findings thus suggest that in the ecologies of heterogenous actors with diverse logics and technologies the sources of power shift from pure regulative and legitimate capacities to the ability to generate idiosyncratic solutions enabling one to symbiotically adapt, parasitize, or otherwise complement and build on distinct technologies and infrastructures created by other actors.

Our study offers several practical implications. First, our findings illustrate a need for DI regulators and curators to consider that privileging or excluding certain actors can lead to shifts and unexpected reconfigurations of the whole infrastructure, beyond the intended and focused regulations imposed on a limited number of actors. Second, our findings suggest that those under regulations might be mindful of cooperative opportunities with unexpected and unprompted partners as these might provide successful opportunities to develop IT capabilities in novel ways. Third, our findings motivates innovators to explore and leverage opportunities of linking diverse technologies from previously unconnected actors. While this will require certain openness to other actors' distinct logics and forms of organizing, our findings suggest that such alliances might take place without a need to scarify or significantly modify actors' own logics and enable access to resources beyond those available within their boundaries and logics. Finally, our findings suggest that actors with fewer resources and less power (such as HomeNet communities) can develop into key contributors to and central innovators in DI development when they are sensitive to emergent IT capabilities and networking with actors with distinct forms of organizing and contesting logics.

Future Research

Our findings provide several avenues for further research on DI development constituted by distributed agency. First, they illustrate a need for further research to go beyond the focus on direct actor interactions and consider a broader variety of actor interplays, including indirect ecological impacts. Second, taking into account the significant role of technology in shaping diverse actor interactions, it would be interesting to explore technology as an active coshaping non-human actant (e.g. Callon 1986). Our findings highlight a need for further research to incorporate a broader view on the role of technology and the aspects of confluences of multiple technologies in the ecologies comprised of multiple heterogenous actors. In particular, future research on multiactor interactions needs to better understand the role and interplay of technologies which are not only commonly shared by also partly shared and separate/disjointed. Finally, as digital technology redistributes control and provides continuous opportunities for actors to use and modify it in novel ways (Lyytinen et al. 2016; Nambisan et al. 2017; Oborn et al. 2019; Yoo 2013), further insights are needed to understand the dynamics of ecologies where DI actors might engage in a variety of prehensible and opportunistic relationships with unlikely partners (Haraway 2003). It would be particularly interesting to investigate whether and how the identified symbiotic and parasitic interactions hold true across a diverse scope of actors, technologies and a broader set of institutional logics.

Limitations

There are several limitations of this study. First, the logics of the actors involved in DI development were mostly pure (as Table 2 indicates, only HomeNet ISPs relied on hybrid logics). Research studying actors operating with a greater variety of hybrid logics might reveal different actor interactions and their combinations not captured in this study. Second, we limited our analysis to actors involved in the development of landline residential Internet infrastructure and excluded mobile ISPs (which have been quite active in Belarus since 2012). Research comprising even greater variety and multiplicity of technologies might find different patterns of technology confluences and underlying actor interactions. Third, the regulative aspects in our case study were quite radical (e.g. either absent or strict). Research on industries with milder regulatory modes might discover other types or variations of interactions. Finally, residential Internet technologies in our study were of a relatively low cost, This enabled multiple and heterogenous actors to join the interplay, instantiate technology differently and increased the scope of available DI solutions. Research on technologies with higher costs could find a limited repertoire of participating actors and generated DI solutions which could generate limited types of technology confluence. These limitations provide opportunities for further studies to refine and extend our findings.

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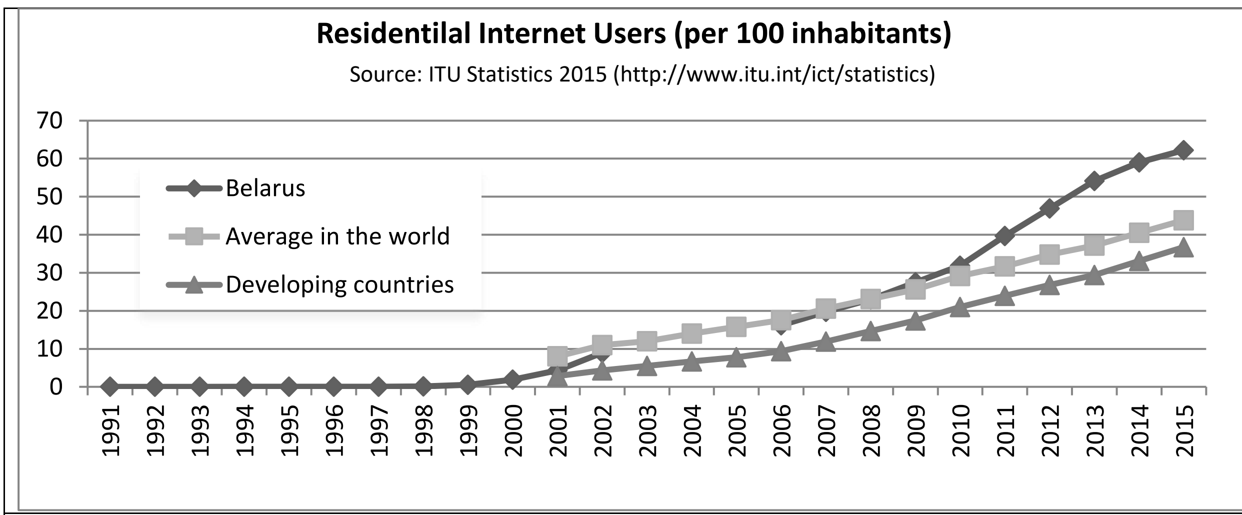

Major Events in the Belarusian Residential Internet Industry

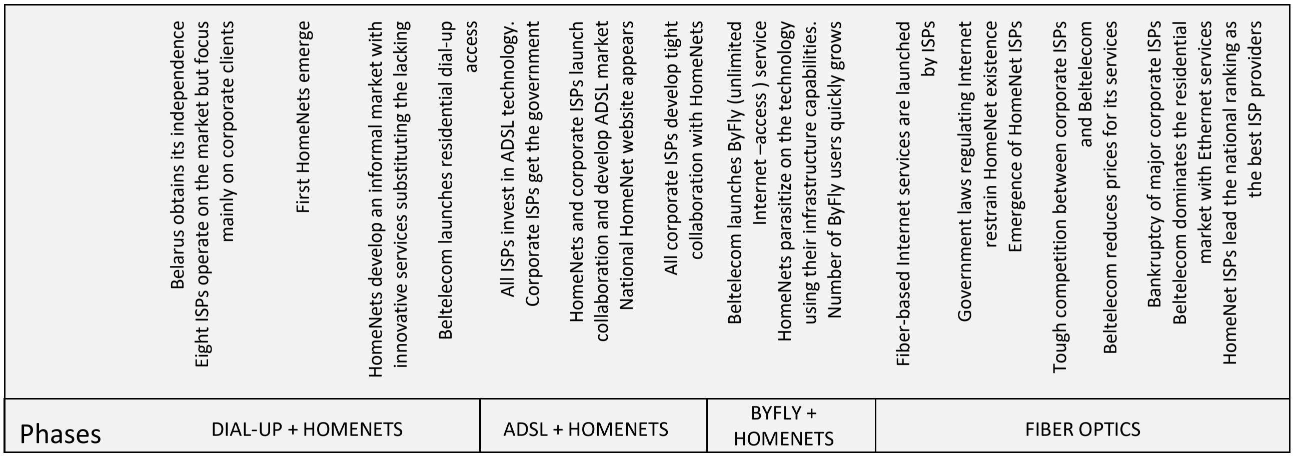

Figure 1. Development of Residential Internet Infrastructure in Belarus

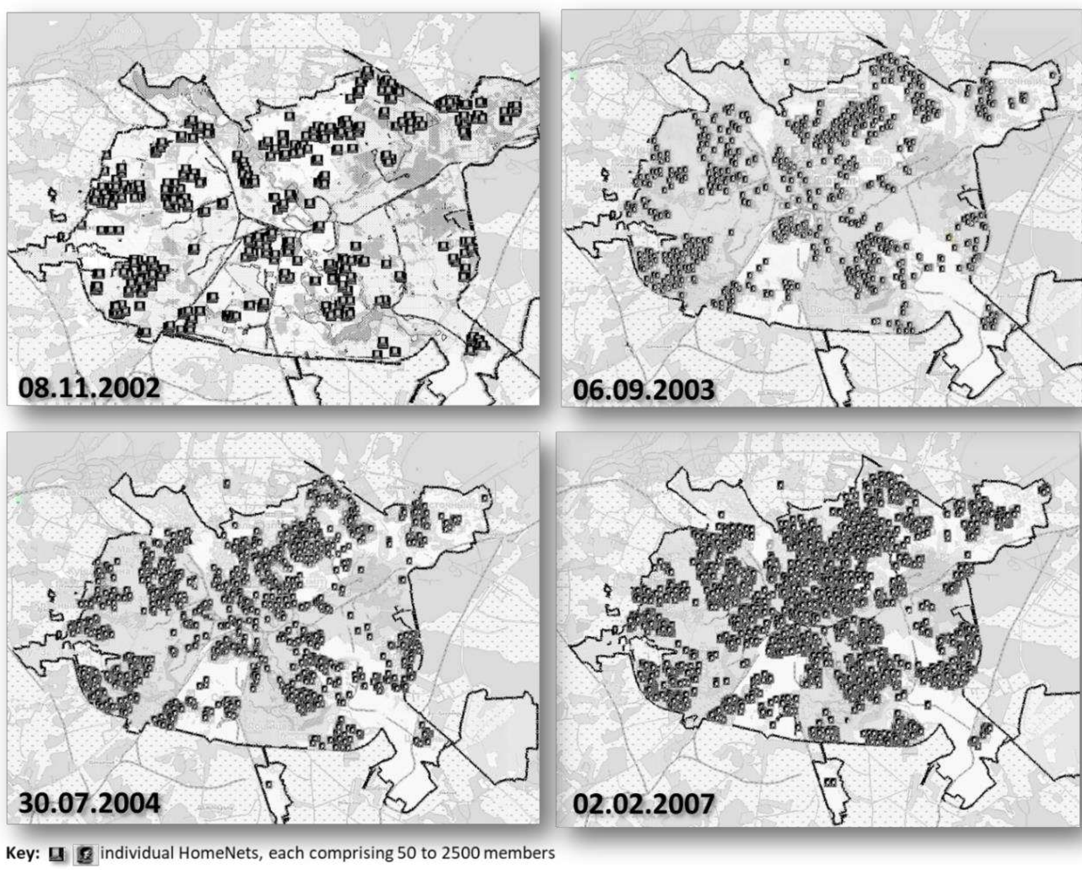

Figure 2. Dynamics of HomeNets Registered as the National HomeNet Website within the City of Minsk (source: HomeNets.tut.by)*

Figure 3. Residential Wired Networking in Minsk

Table 1. Interviews

Respondents	Details			
	July 2010–April 2012		Nov-Dec 2016	
HomeNets	Administrators 37	Users 22	Administrators 5	Users
7Net	*1*	*1*	-	-
AllOff,by	*1*	*1*	-	-
B&B	*1*	-	-	-
Damavik	*1*	-	-	-
Digital Home	*1*	-	-	-
NRM	*1*	-	*1*	-
Dom 7	*1*	*1*	-	-
Gaya.net	*1*	*1*	-	-
GURT	*1*	-	-	-
Home	*1*	-	-	-
Home-net	*1*	*1*	-	-
InterLAN	*1*	*1*	-	-
JamCrew	*1*	-	-	-
J-NET	*1*	*1*	-	-
KIEVSKAYA	*1*	*1*	-	-
Legion 2	*1*	-	-	-
Lorien	*1*	*2*	*1*	-
LSD	*1*	*1*	-	-
MassNet	*1*	*1*	-	-
Neshta	*1*	-	-	-
Never,net	*1*	*1*	-	-
N-Net	*1*	*1*	-	-
Noname net	*1*	-	-	-
NRC	*1*	-	-	-
Open.net	*1*	-	-	-
Ruslanaga	*1*	*1*	-	-
S.K.Y	*1*	*1*	-	-
Serebrianka	*1*	*1*	*1*	-
Skynet	*1*	*1*	-	-
ST	*1*	-	-	-
STONENET	*1*	-	-	-
StreamLine	*1*	*1*	-	-
ThunderNet	-	-	*1*	-
Unified Network Home	*1*	*1*	-	-
Vostochka.net	*1*	*1*	*1*	-

WestLAN		*1*	*1*		-	-
XSpider		*1*	-		-	-
Zizeron		*1*	-		-	-
HomeNet ISPs	4			7		
UNET			-			*1*
FlyNet			-			*1*
OneNet			-			*2*
Domashnaya Set'			*1*			*1*
LifeNet			*2*			*1*
Netberry			*1*			*1*
Corporate ISPs	10			4		
Solo			*3*			*1*
Atlanttelecom			-			*1*
Aichyna			*1*			*1*
ADSL.by			*1*			*1*
НИКС			*2*			-
Next			*1*			-
IP TelCom			*1*			-
Delovaya Set'			*1*			-
Beltelecom	2			2		
Engineer 1			*1*			-
Marketing director			*1*			-
Engineer 2			-			*1*
Engineer 3			-			*1*
Experts in the field:	-			4		
S Jay, creator of Homenets.tut.by			-			1
Alex K, popular blogger on ISP and HomeNets from 2005-2011			-			1
UNDP consultant for Internet in Belarus for 20 years, author of e-belarus.org	-					2
	75			22		
Total		97				

Table 2. Heterogeneous Actors' Logics

Key actors and logics	Organizing principles and assumptions	Identity	Technology framing	Resources and capabilities
Beltelecom *State logics*	Strongly relying on top-down planning, vertical authority and decision-making Reluctant to changes and innovations unless they are state-approved Seeking to dominate other ISPs as potentially threating the company performance leadership and access to government distribution of resources	"National" provider Conflicts with actors from different social groups (e.g., market and community)	Technologies serving the needs of citizens declared by the government Innovations and technologies requiring top-down approval	Relying on government as a distributor of funds and resources Using expensive resources that enable the company monopoly Adjusting capabilities to fit the evolving state performance indicators
ISPs *Market logics*	Decision-making based on market analysis Organizing and selecting partners based on profit maximization Seeking to increase market shares	Market players driven by profit	Technology serving the needs of dominant users Technology investments based on the market demand and competitive aims	Resources generated by profit Developing capabilities to generate competitive advantage

			Adjusting infrastructure to maximize profits from serving users' needs	Using platforms in attracting resources beyond the original ISP boundaries Orchestrating the behavior of partners to increase profit
HomeNets *Community logics*	Based on volunteer contributions and self-selected roles Group membership Seeking to generate innovations to create social value Community values of reciprocity, trust, and unity of will	Community of residents	Technology serving the needs of residents Profoundly social nature of innovations and infrastructures IT services and infrastructures are collectively owned, developed and used	Shared resources and costs Resources generated by bricolage and collective funding of community members
HomeNet ISPs *Hybrid (community and market) logics*	Firms with community values Seeking to be competitive while relying on community values	Community -driven market players	Technology serving the needs of residents Innovations that is both competitive and valuable for members	Shared resources between community members and with other HomeNet ISPs Intensive member participation in resource and capability creation

Table 3. Key Processes, Characteristics and Outcomes of Symbiotic and Parasitic Interactions

	Interaction description	Factors driving the interaction development	DI agency	Actor technologies	Type of ecological interplay	Orchestration between participating actors	DI outcome
Symbiotic generative interaction	Interactions of existing actors in the ecology are non-orchestrated, rely on contesting state and market logics and disjoined coexisting diverse technologies that serve specific group of users while ignoring others. Such ignorance generates a new DI actor via indirect ecological impacts: the ignored users rely on a distinctive disjointed technology and a contesting community logics to collectively develop an innovative infrastructure to adapt to the lack of existing IT solutions	Indirect ecological impacts generates an emergent new actor who develops DI	Self-organized DI actor relies on distinctive community logics and disjointed technologies *Ex.:* HomeNet communities	Diverse separate technologies specific to each actor *Ex:* dial-up technologies by Beltelecom; satellite-based Internet access by ISPs; dial-up DIY infrastructure by HomeNets	Indirect interactions between the generated actor and other actors in the field *Ex*: no direct interactions between HomeNets and other ISPs and Beltelecom	No orchestration and coordination between actors, no laws coordinating actors' interactions, asynchronies in actors' capabilities and resources	Adaptive alternative and disjointed DI solution by an emergent DI actor *Ex.:* HomeNet residential infrastructures
Symbiotic mutualistic interaction	A new regulation introduced on one of the actors opens its strategy to a nontypical partner based on a new technology. The ecology of metaorganization emerges in the course of an unlikely partnership where actors develop an innovative DI solution through mutually dependent capabilities and shared technologies yet maintaining their authority and following their own motivations and logics	New state regulation introduces interdependencies between previously unconnected heterogenous actors New technology enables confluence between diverse technologies of previously unconnected actors	Metaorganization of actors with contesting community and market logics and diverse shared technologies *Ex.:* HomeNet – ISP networks	Codeveloped, commonly shared and interdepend technologies *Ex.:* ISPs and HomeNets build on codeveloped but independently managed HomeNet services, ISP intranets, services through shared modems provided by ISPs	Direct collaboration between actors in meta-organization *Ex:* HomeNets and ISPs intensively interact	Mutually adaptive interactions in metaorganization and regulations stimulating an unlikely actor partnership into a metaorganization *Ex.:* ISPs and HomeNets orchestrate and cultivate each other's behavior; ISP dependence on Beltelecom infrastructure following the state regulation	DI solution based on shared and codeveloped technologies by a metaorganization *Ex.:* HomeNet – ISP residential infrastructures

Table 3 (cont'd)

	Interaction description	Factors driving the interaction development	DI agency	Actor technologies		Orchestration between participating actors	DI outcome
Parasitic complementary interaction	Emerges when a technologically advanced but ultimately unsuccessful in reaching end users, infrastructural innovation that is developed by the primary innovator gets complemented by a parasitizing IT solution by another DI actor. This allows innovative infrastructure to scale beyond the tipping point but outside the control of the original innovator in a largely unregulated area	New technology (e.g. WiFi) enables confluence between technologies of previously unconnected heterogenous actors with contesting logics	Parasitizing interplay of two heterogenous DI actors with contesting logics whereby one actor feeds on innovative solution developed by another actor	Unprompted mesh network that builds on actors' partly shared technologies *Ex.:* HomeNet members share ByFly Internet access via Wi-Fi networks and HomeNet infrastructures to access Internet and community services (e.g., games and chats)	Indirect interactions based on partly shared/ technology parasitizing another actors' innovation *Ex:* Internet from ByFly WiFi networks shared via HomeNet infrastructures	No regulations between the parasitized and parasitizing actors *Ex.:* No specific regulations of the interplays between Beltelecom and HomeNet actors; no specific Wi-Fi network regulations by the state	DI solution based on parasitizing (making partly shared) another actor's IT innovation *Ex.:* Beltelecom Internet solutions latently shared via HomeNet infrastructures
Parasitic competitive	Emerges when a heterogeneous set of actors compete for leaderships and domination in a new technology that has idiosyncratic value in their logics and games and stimulates independent innovative solutions. Regulations further stimulate actors' independent strategies, leading exploitation and dissolution of some organizational actors as well as the emergence of new actors	New technology enables independent solutions; Intensive regulations stimulate independencies	Heterogenous actors with contesting logics who develop similar innovations while competing and feeding on each other	Coexisting similar technologies with no interdependencies *Ex.:* Coexisting multiple Internet access options (fiber optic, ADSL, and wireless) proposed by Beltelecom, ISPs and HomeNet ISPs	Direct mutually competitive interplay between all actors Ex.: ISPs, HomeNet ISPs and Beltelecom competing with similar technologies	Exploitative interactions between all actors in the ecology *Ex.*: Strict regulations of Internet infrastructure development and intensive government interventions into the interplay of Beltelecom, ISPs, and HomeNets	Similar DI solutions developed by multiple heterogenous actors *Ex.:* Actors develop similar fiber optic, ADSL, and wireless infrastructure with similar services

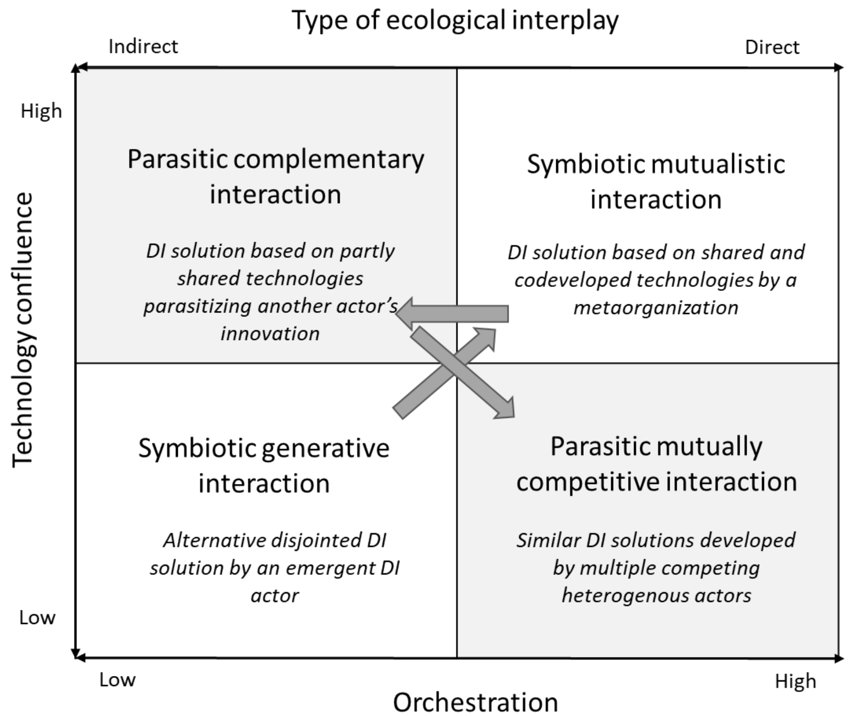

Figure 4. Model of Symbiotic and Parasitic Interactions Shaping Digital Infrastructure Development by Heterogenous Actors with Contesting Logics and Diverse Technologies