How to create innovative solutions in an extensive multi-industry innovation network: A case study on the formation process and innovation activities

A competitive paper submitted to the IMP2014 Conference, Bordeaux

Special Track: Welfare innovation

Authors

Leena Aarikka-Stenroos

Department of Marketing and International Business, Turku School of Economics, University of Turku

E-mail: leena.aarikka-stenroos@utu.fi

Tel. +3582 3339 229

Address: Turku School of Economics, FI-20014 University of Turku, Finland

Tiina Mäkitalo-Keinonen

E-mail: tiina.makitalo-keinonen@utu.fi

Address: Turku School of Economics, Pori Unit, FI-28101 Pori, Finland

Abstract

Innovations are increasingly being developed and commercialized within networks. Few firms have the capability to manage innovations internally; success often requires cooperation between organizations in visioning and developing and commercializing innovations. Research emphasizing inter-organizational networks (particularly the IMP school) has shown that the innovator firm can intentionally activate its diverse network relations with suppliers, distributors, and customers in order to advance innovation success. Additionally, the strategic network approach suggests that innovative firms' strategic networking creates new business fields for innovations. We assume that diverse network actors' resources and collaboration facilitate visioning, developing, and commercializing innovative solutions in many ways. Moreover, collaboration and networking for innovations presents many business opportunities but also challenges. Our research questions are as follows: How does an innovation network comprising diverse actors from different industries with vague goals emerge and elaborate? What new business opportunities and challenges emerge in a network during innovating activities at different relationships levels (network, dyadic relationships, and firm level)? In the empirical section, we use a case strategy to examine an extensive multi-sector network of 16 firms and numerous other organizations, including public organizations that cooperate to develop and commercialize hygiene technology solutions. The contribution of this paper is that it structurally analyzes in detail the type of opportunities and challenges that may emerge within an extensive multi-industry network pursuing the development of innovative solutions. The paper also develops new knowledge actor interactions in innovation processes and the inter-organizational consequences of emergent innovations related to health care and welfare.

INTRODUCTION

Innovations are increasingly being developed and commercialized within networks. Few firms have the capability to manage innovations internally; success often requires cooperation between organizations in visioning and developing (e.g., Håkansson & Waluszewski, 2002; Story et al., 2009, Rampersad et al. 2010) and commercializing innovations (Aarikka-Stenroos et al 2014). Since a single company is rarely capable of developing and generating successful diffusion in commercializing an innovation, the network aspect is crucial. Therefore, *innovating in networks* (see Freytag & Young, 2014) is an increasing tendency; firms use collaboration and networks throughout the innovation process from visioning and development to commercialization. Research emphasizing inter-organizational networks (particularly the IMP school) has shown that the innovator firm can intentionally activate its diverse network relations with other firms, suppliers, distributors, and customers in order to advance the innovation success (Aarikka-Stenroos and Sandberg, 2012; Partanen et al. 2011; Perks & Moxley, 2011, Story et al. 2009; Story et al., 2011). A large network of diverse stakeholders supporting an innovation tends to resemble ecosystems (Chiesa & Frattini, 2011; Aarikka-Stenroos et al. 2014). Additionally, the strategic network approach suggests that innovative firms' strategic networking creates new business fields for the innovations (Möller & Svahn, 2009; Möller & Rajala, 2007).

Innovating in a network throughout the innovation process presumably creates opportunities and challenges. We assume that diverse network actors' resources and collaboration facilitate visioning, developing, and commercializing innovative solutions in many ways. Firms may lack financial and competence resources, and therefore, collaboration might be essential. Moreover, firms with complementary resources, products, and channel relationships may create new markets through collaboration (Möller and Rajala, 2007). Actors collaborating on a novel product often need to generate ideas and focus on the best ones, but if the concept is very new and vague, it may be difficult to discuss the details of the co-operation clearly (Möller and Svahn, 2008). Firms also need to mobilize and coordinate the activities of other relevant actors and orchestrate actors from several different fields (Möller et al. 2005). However, there are empirical notions that the more complex the networking for innovation due to different industries, technologies, goals, and target markets, the more problematic it is finding a common consensus and goals for collaboration (Aarikka-Stenroos & Sandberg, 2012). There is evidence of diverse management and trust conflicts in innovation networks from development to commercialization (Heikkinen et al., 2007; Aarikka-Stenroos & Sandberg, 2012). This research suggests that managing innovation networks is difficult: For example, Heikkinen et al.'s (2007) findings on how a new-product-development network broke up during commercialization because of diverging goals indicates that the evolution of innovation activities raises specific management challenges in innovation networks.

Innovation networks often comprise firms, research organizations, and universities working together to achieve shared innovation goals (e.g., Rampersad et al., 2010). Innovating in networks can be conceptualized with diverse network approaches that have different thematic emphases and background assumptions. In this paper, we rely on industrial networks (the emphasis on interactive relationships between the networked companies; the basic assumption is that networks cannot be managed, e.g.. Håkansson & Ford, 2002), strategic networks (the basic assumption that networks of companies can be managed toward a shared goal, e.g., Jarillo, 2006; Gulati, 1998; Möller & Svahn, 2009, Rampersad et al. 2010), and innovation networks (with the emphasis on managing networked firms for R&D, e.g., Dhanaraj & Parkhe, 2006).

Recently, researchers investigating innovating in networks have studied organizations' strategic and operational collaboration for innovation (e.g., Perks & Moxey, 2011; Möller & Rajala, 2007; Partanen et al., 2011). The research on innovating in networks, however, concentrates mostly on one innovation activity, such as research and development: for example, investigating resource combinations for product development (e.g., Ritter and Gemünden, 2003) or commercialization (Aarikka-Stenroos et al. 2014). Only a few attempts have been made to study network relations throughout the innovation process and

investigate how networks change and network relationships transform when firms experience different kinds of innovation activities during the innovation process (e.g., Aarikka-Stenroos & Sandberg 2012, Perks & Moxley, 2011; Story et al. 2009; Story et al., 2011). However, these studies did not focus on what kinds of conflicts and opportunities emerge between actors in the innovation networks during the entire innovation process or analyze these aspects empirically in detail. Research concerning strategic value and innovation nets suggested how diverse organizations together may provoke new business through innovating and creating new business fields based on new values (e.g., Möller & Svahn, 2009), but researchers have not empirically studied how this happens: how this collaboration between very heterogenous actors who have similar strategic goals and ideas of future values emerges. Moreover, the increasing tendency is to encourage multi-sectoral innovation networks (Rambersad et al. 2010), but the extant studies have also found that such multi-industry innovation networks tend to face crucial challenges in management that hinder innovation success (see Hopkins et al. 2011; Heikkinen et al. 2007, Aarikka-Stenroos & Sandberg 2012). The dissimilarity of actors in business logics, knowledge, and cultures in particular complicates such innovating through collaboration (Nissen et al. 2014). This indicates that we need more understanding of underlying management and other challenges faced by extensive multi-sectoral innovation networks that comprise diverse dissimilar actors pursuing parallel goals.

Based on these notions, in this research we investigate how one extensive innovation network emerges, goes through visioning, research and development, and commercialization activities in order to innovate a new value creating concepts, and what kind of challenges and opportunities such collaboration brings in. Based on the discussion above, we assume that collaboration and networking for innovations provide many business opportunities but also challenges throughout the innovation process and at different network levels. Therefore, our purpose is to analyze in detail a multi-industry innovation network, its formation, and innovation activities. Given the centrality of inter-organizational collaboration to the innovation success, it is vital that contemporary researchers generate a deeper understanding of both the benefits and problematic tensions originating from collaboration in innovation networks.

Our research questions are the following:

- How does an innovation network comprising diverse actors from different industries with vague goals emerge and elaborate, i.e., how does an extensive multi-industry innovation network evolve during the innovation process?
- What new business opportunities emerge in a network that aims to develop and commercialize new solutions and how do they emerge at different relationships levels (network, dyadic relationships, and firm level)?
- What challenges and problems emerge at different relationship levels?

In the empirical section, we use case strategy to examine an extensive network of 12 firms with numerous other collaborating firms and organizations that aim to develop and commercialize hygiene technology solutions.

The contribution of this paper is that it structurally analyzes in detail what kind of opportunities and challenges may emerge within an extensive network that pursues the creation of innovative solutions during the entire innovation process. Through our analysis, we develop new knowledge of problematic tensions and challenges that may hinder innovating in networks as well as opportunities that originate from collaboration and therefore enhance innovation in networks.

Some of the key concepts are defined next. In the literature, the term ‘innovation’ has been used to describe radical, breakthrough novelties and incremental, modest novelties (Mohr, 2001; Garcia and Calantone, 2002). We use the term innovation in its broader sense, that is, encompassing radical and incremental novelties; the latter are often referred to as new products or services.

Our paper is structured as follows. First, we discuss innovation activities throughout the process, innovating in networks, network resources and actors, and the management of relationships on different levels. In the next section, we explain the methodology used and the case. A case analysis and key findings about opportunities and challenges in network relations in innovation activities follow. In the

final section, we discuss the theoretical conclusions, the potential contributions, and the managerial implications.

INNOVATING IN NETWORKS AND POTENTIAL CONFLICTS, TENSION, AND OPPORTUNITIES

COLLABORATION FOR DIVERSE INNOVATION ACTIVITIES THROUGHOUT THE INNOVATION PROCESS

Innovations are increasingly developed within networks, and thus, research on how networks and collaboration may contribute to the entire innovation process is increasing. The tendency to develop innovations within R&D networks is becoming stronger because of the high complexity and costs, and technological interconnectedness (e.g., Ritter and Gemünden, 2003, Rampersad et al. 2010). Recently, researchers have also noted that networks and relations also enhance commercialization (Aarikka-Stenroos et al. 2014). Based on these notions, diverse network actors such as customers, distributors, research institutions, and competitors can contribute to innovation development (Ritter and Gemünden, 2003) and commercialization (Aarikka-Stenroos et al. 2014). These actors can support innovating in various ways. Story et al. (2011) identified several tasks for the network actors involved in innovating: They support other actors by performing *innovation tasks*, such as articulating, funding, developing, prototyping, producing, and by performing *networking tasks* such as connecting, integrating, and endorsing.

The innovation process per se includes multiple innovation activities, conventionally conceptualized as visioning, development, and commercialization/marketing activities. According to the linear view, the process begins with an idea, proceeds with product development, and ends when the product actually creates wealth. However, an increasingly popular non-linear approach emphasizes that the ideation/visioning, product/technical development and marketing/commercialization activities are more interactive and interlinked (e.g., Prenkert, 2012). Existing studies have increasingly noted that many decisions and activities of the front end, technical development, and commercialization interact and evolve in parallel throughout the innovation process (see Prebble, de Wall, & de Groot, 2008; Prenkert, 2012). For example, the initial visioning and early decisions concerning the market and concept made at the front end influence further activities and innovation success (Markham, 2013; Reid & de Brentani, 2012). Thus, we follow the perception according which visioning, technical product development, and commercialization are not stages but activities of the innovation process that are complementary, concurrent, and mutually linked. These activities may also overlap. In this paper, we assume that network relations and collaboration can provide contributive resources as well as challenges for these innovation activities. They are discussed in detail next in relation to the network approach.

OPPORTUNITIES AND CHALLENGES THAT INNOVATING IN NETWORKS CREATES

There are multiple reasons why firms need collaboration and resources through networks throughout the innovation process. Small firms in general may lack financial and competence resources that enable them to turn their innovative product and service visions into commercialized concepts. Network relations with suppliers, distributors, and customers help small, new innovative firms acquire resources for creating incremental and radical innovations (Partanen et al. 2011). Collaboration between innovative firms with complementary resources, products, and channel relationships may create future demand and new markets (Möller and Rajala, 2007). New ventures in particular need high-profile partners in order to establish credibility (Zott and Nguyen Huy, 2007); relationships with reputable companies tend to increase the credibility of their partners (Anderson, Håkansson and Johanson, 1994), which is particularly important in the innovation business. Furthermore, innovator firms can combine resources in their networks to enter new foreign markets (Tolstoy & Agndal, 2010). Commercialization of the novelty requires resources to bring a new product to market. Then collaboration for commercialization can assist in creating demand, markets, and distribution channels, communicating with end-users, accessing and developing market and customer information, and facilitating adoption among users, complementors, and intermediaries (Harrison and Waluszewski, 2008, Story et al. 2009, Aarikka-Stenroos et al. 2014).

When linking the changing innovation activities during the innovation process and collaboration through networks to conduct these activities, the change in and complexity of relations and innovation activities become apparent. Since the innovating firm needs different resources for commercializing than for R&D, the firm must renew existing relations or create completely new ones (Aarikka-Stenroos & Sandberg 2012). Different innovation activities presumably lead to changes in resource requirements and thus changes in network relationships (e.g., Heikkinen et al., 2007). Furthermore, due to the interconnectedness of market actors and technologies, interrelated organizations and individuals often reciprocally influence each other's behavior, which has consequences in innovating activities. Market players will not switch to manufacturing or using a new product or service unless they are convinced that most of the other players will, a situation that is typical in some industries (see Chiesa and Frattini, 2011).

Innovating in networks generates opportunities and dilemmas. Collaboration through networking increases capabilities and ideas but may result in coordination difficulties. It may reduce the costs of innovating but increase a need to invest in network projects, and even though collaboration may provide access to new markets, at the same time it may lead to the emergence of future competitors (Millson and Wilemon, 2008).

Innovating in networks may help companies reach diverse goals and thus provide opportunities. The firms may gain aligned strategies; potential growth and profit; access to new business relationships, information, ideas, and markets; learning; an enhanced reputation; support for complex and novel offerings; and negotiation power (Harrison and Waluszewski, 2008; Ritter and Gemünden, 2003; Aarikka-Stenroos & Sandberg, 2012).

In addition, several aspects generate particular challenges for innovating in networks. For example, if the firms do not have a common history, a lack of trust often hinders collaboration on innovations (Story et al., 2009). Therefore, trust is a critical component when parties want to avoid opportunism and competition. Similarity in strategies, technologies, products, markets, or cultures often facilitates knowledge transfer and predicts cooperation success. In particular, choosing partners with similar values fosters trust (Dhanaraj and Parkhe, 2006; Jarillo, 1988), and therefore, dissimilarity of actors provokes challenges for innovation networks (e.g., Nissen et al. 2014). Problems arise when partners in the innovation process belong to different systems and logics (Biemans, 1991; Nissen et al. 2014). However, opportunities can also arise from dissimilar actors in innovation networks. It is often advantageous to collaborate with dissimilar actors who bring in more new and different insights, compared to collaboration only with conventional, homogeneous actors that provide similar ideas (Granovetter, 1973; Möller and Rajala, 2007). In summary, the similarity and dissimilarity of network actors generate positive and negative outcomes for innovating.

Furthermore, interconnectedness and network effects create opportunities and challenges. On one hand, they facilitate the use of resources within the network, but on the other hand, they also constrain further networking through lock-ins (Anderson et al., 1994; Håkansson and Snehota, 1995; Ritter and Gemünden, 2003). Thus, firms aiming to create innovations in networks may become locked into cooperating with each other and locked out of cooperating with others.

Innovating in networks causes dynamics and changes in business relationships. New interaction between some firms will be created, existing collaboration between some firms may transform, and some interactions between firms may cease (see, e.g., Håkansson and Snehota, 1995; Halinen et al., 1999; Aarikka-Stenroos & Sandberg 2012). Even though these changes often occur in a dyadic relationship, they tend to spread to other relationships in the network as well. For example, if two actors start to collaborate, this change may lead to a network change if other actors consider this collaboration important or as a threat and respond to it by tying up new collaboration (Håkansson and Snehota, 1995, Aarikka-Stenroos & Sandberg 2012). Moreover, creating innovations requires often developing novel resource combinations, which often requires the deformation of earlier conventions of doing collaboration (see Håkansson and Waluszewski, 2002). Thus, when firms start to innovate in networks, there will be changes that have consequences, that is, positive opportunities or negative threats.

ACTORS THAT INNOVATE IN NETWORKS

Actors comprising R&D or commercialization networks can include diverse organizational and personal actors, such as complementors, distributors, buyers and users, experts and consultants, suppliers, research institutes and universities, government agencies, and industry associations (Möller et al., 2005; Ritter and Gemünden, 2003; Aarikka-Stenroos et al. 2014). These actors can provide diverse contributions. Vertically linked actors provide distribution resources, whereas horizontally or diagonally related competitors or partners fortify pushing/pulling the new product through or create markets together (Möller and Rajala, 2007; Story et al., 2009). Public organizations and educational institutions can bring a neutral expert perspective, support, and consultancy throughout the innovation process (Troshani and Doolin, 2007, Aarikka-Stenroos & Sandberg 2012). Users are also important network actors since they can improve product modifications of innovation and launch (Harrison & Waluszewski, 2008). Lead users, expert opinion leaders, and hub persons accelerate or block the innovation success (Goldenberg et al., 2009; Harrison and Waluszewski, 2008). Together, these actors comprise an ecosystem that supports innovation and facilitates its success (Chiesa & Frattini, 2011; Aarikka-Stenroos et al. 2014).

FORMING AND ORGANIZING INNOVATING IN NETWORK

Because innovating in networks brings together diverse similar and dissimilar firms with diverse histories, businesses, and goals and includes diverse innovation activities, collaboration requires management or orchestration. Manageability of networks is the subject of strong discussion. According to the IMP approach, business networks are not under the control of an individual firm but are within the sphere of influence of all actors involved through direct and indirect relationships, whereas according to the resource-based view and strategic network approach, large firms intentionally create and control the network (e.g., Håkansson and Snehota, 1995; Möller et al., 2005). This study rests on the premise that innovating in networks requires co-ordination and the ability to provoke, mobilize, and organize collaboration in order to vision, develop, and commercialize.

THE PROCESS OF FORMING AND ORGANIZING AN INNOVATING NETWORK

Initiation activities are required when a firm identifies potential partners, since inter-organizational relationships do not start on their own (Ritter & Gemünden, 2003). In innovation networks, usually the hub firm acts as the initiator, that is, the prime mover (Dhanaraj & Parkhe, 2006), but in low-central multi-sector networks, one or several initiators launch negotiations for collaboration on shared goals. Partanen and Möller (2012) suggested a clear process for forming a strategic network comprising phases such as determining the value-creation activities for the end customer, determining the value-creating system, determining the objectives and activities, conducting preliminary partner assessment, and negotiating with partners and launching inter-firm collaboration. However, we assume that if the process concerns a more vague and innovating multi-sector network, a clear process is not feasible, and the process of forming a net is a more elaborate probing cycle.

To provoke innovating in networks and to form an innovation network, firms must identify potential contributing partners, and motivate them to integrate their resources by revealing the resources they have and indicating the potential benefits of collaboration (Ritter, 1999). The resources of actors in an innovation network can be related through technical competence, knowledge, customer knowledge, market knowledge, and relations. Firms benefit not only from direct ties but also from the ties of the actors to whom the firms are connected; a direct relation to another actor offers an indirect relation through other actors' relations, and these indirect and direct relations can provide access to the technological or knowledge resources of their counterparts (Håkansson & Snehota, 1995; Ritter, 2000; Gulati et al., 2000). Some preconditions such as initial trust and shared goals are required (e.g., Aarikka-Stenroos & Sandberg, 2012).

When firms plan to collaborate closely to create innovations, expectations are discussed and cleared, and early cooperation is launched. Then, as expectations and procedures begin to form, the actors set additional common goals and start to organize collaborative activities (Partanen et al., 2011, Aarikka-

Stenroos & Sandberg, 2012). The formation of such a network can be intentional if the actors in a network intentionally seek a certain type of collaborator or more evolutionary if collaboration for innovating is randomly elaborated. Furthermore, in order to innovate, actors must share knowledge and be able to view value activities and changes in them from each other's perspective, reflected in a "what can we do for them – what can they do for us?" attitude (Möller et al. 2005). The innovation capability of each firm is manifested in an actor's record of product improvements (e.g., improved functionality or lower costs), and of production and delivery process innovations.

Firms seeking to vision, develop and commercialize novel value combinations must first ideate and generate ideas and goals and focus on the best ones. However, if the concept is very new and vague, it may be difficult to outline and discuss the details of the co-operation clearly (see Möller and Svahn, 2008).

The forming process may differ depending on whether it is conducted by a hub firm or equal actors. In high-central innovation networks, the hub firm can impact the network constellation through the strategic choice of partners (Dhanaraj & Parkhe, 2006), but in low-central innovation networks, firms tend to widely monitor the competencies, ideas, and activities among their potential partners (e.g., Aarikka-Stenroos & Sandberg, 2012), and the formation and organizing should be perceived as a group activity that shapes the "rules of the game" (see Melo Brito, 1999), and high-level interaction replaces the active coordination of a central player (Dhanaraj & Parkhe, 2006). However, there may still be confusion about the roles of orchestrator and other network actors. In innovation networks, reciprocity, trust, and coherence in goals tend to be more important in steering collaboration than formal agreements (Dhanaraj and Parkhe, 2006). Moreover, power aspects create dependence and even tension between networked actors (Hoholm & Olsen, 2012; Olsen et al. 2014); for example, smaller or otherwise dependent firms often need to adapt to the wishes of a more powerful firm that can more freely choose its options (see Ritter et al., 2004).

DISTINGUISHING LEVELS IN INNOVATION NETWORKS

To investigate innovating in networks and its formation and organization throughout the innovation process, we use Möller et al.'s conceptualization on network levels. Möller et al. (2005) identify four levels of management in innovative networks: (1) industries as macro-networks, (2) strategic net, (3) relationship portfolio, and (4) relationships. On the macro-network level, collaboration and visioning in particular are complex. They require understanding how all network players affect each other's business. Only really large companies can have impact and management power at this level. At this level, large corporations can try to shape the development of entire industries and influence the beliefs, goals, and behavior of other key actors through "orchestration" (Möller et al.2005).

The second level concerns a subset of the larger network often termed "strategic net," "value net," or simply "net," referring to an interrelated group of actors pursuing shared goals (Heikkinen et al. 2007, Ritter & Gemunden, 2003, Rampersad et al. 2007). At the level of strategic nets, management of relations refers to actions with which firms aim to mobilize and coordinate the value activities of other relevant actors. The aim might be to improve operational efficiency or leverage of existing capabilities or developing new capabilities. Management at this level often includes visioning, actor evaluation, creating direction through agenda setting and motivation, and coordination and control among different actors. A key aspect here is the ability to identify the roles, capabilities, and goals of other important actors, and to modify one's strategy to match the network situation. Since firms are generally involved in several different and overlapping nets, management faces a complicated optimization challenge concerning which strategic nets to operate and how. Therefore, firms often ponder the future importance of the net in terms of its business potential (Möller et al. 2005).

SUMMING UP: HOW A NETWORK EVOLVES AND INNOVATION ACTIVITIES OCCUR

To conclude the theoretical section, we suggest conceptualizations that structure and integrate the key elements of our analysis.

To study how an extensive innovation network emerges and evolves, we analyze the process of

forming and organizing innovation activities relying on the literature discussed above. This knowledge is used in the next section in which we describe and analyze the case of an extensive innovation network and its formation process.

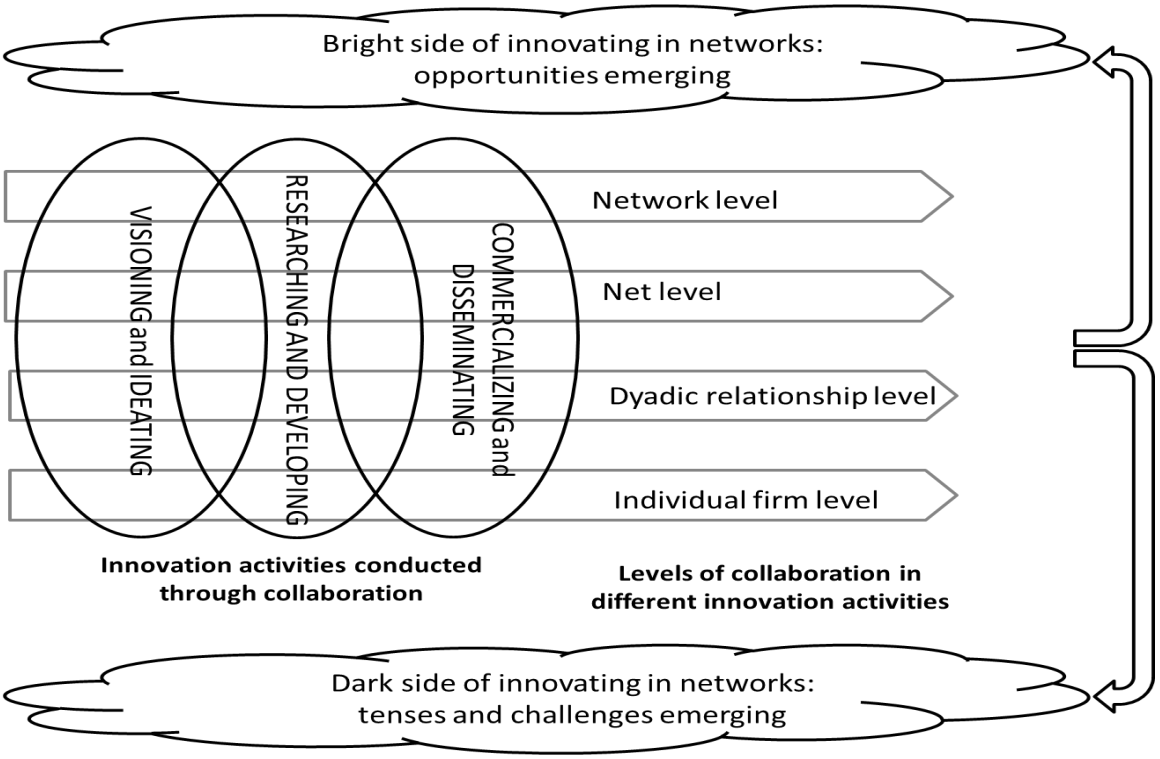

Fig. 1. Framework for the innovating activities and their positive and negative outcomes in an extensive innovation network.

To study how innovating in networks triggers opportunities and challenges in different levels of networking, we use the framework in Fig. 1; this framework includes innovating activities (visioning and ideating; researching and developing, and commercializing and disseminating) that happen and provoke positive opportunities and negative tension. All this concerns the entire network, a particular net, a dyadic relationship, or a particular firm (see Fig. 1). This framework is used in the next section in which we analyze innovating in an extensive innovation network.

METHODS

To conduct an empirical analysis, we chose a case-study strategy since it facilitates holistic understanding of complex phenomena that are not easily separable from their context (Halinen and Törnroos, 2005). The unit of analysis in this study is a network of innovating organizations. Our case is a longitudinal single case study since we followed an extensive project network of 12 firms aiming to vision, develop, and commercialize "a HYGTECH concept" on a general level and individual hygiene technology solutions specifically; we followed the case from 2012 until 2014. During this period, the case network was transformed in the following way. Originally, the network was based on the R&D network of several firms (see H1 in Table 1), then it extended to a larger entity with the goal of developing and commercializing "the HYGTECH concept" (see H2 in Table 1), and finally, it resulted in a "spin-off net" (see S in Table 1) as additional firms and some of the original network members started to collaborate with a narrower focus.

The study was longitudinal and relied on retrospective and real-time multisource data. To capture the process of innovating in networks empirically (see Hoholm & Araujo, 2011), the researchers followed the

process during which the innovation and innovation network evolved and participated in the innovation activities that had features of ethnographic research: communication and observation concerning the firms' products, their installation, use, and related research results during the entire project (2012-2014).

The primary dataset for this paper consists of nine individual interviews, five group discussions with multiple firm representatives, one network workshop, two spin-off net meetings, and 10 project group meetings.

The main data-collecting method was semi-structured interviewing, which provides formality for analyzing complex phenomena and allows unexpected issues to emerge (see Wengraf, 2001). Interviews were conducted from October to December 2013. All the firms were interviewed or involved in group discussions. The respondents included CEOs, sales and product managers, technical directors, external experts, and consultants representing the firms and other organizations involved in the R&D and commercialization activities. The interviews were conducted face-to-face at the firms' head offices or on the university premises.

The main questions were the same for all respondents, but there were separate questions about the specific roles of the respondent and follow-up questions on emergent issues. All interviews covered the following aspects: 1) background of the interviewee(s); 2) the firm's products, services, customers, and competitors; 3) the firm's product/service(s) related to the HYGTECH concept; 4) the firm's project goals and background in the HYGTECH network; and 5) opportunities, challenges, and pursued role related to the creation of the HYGTECH concept. The interviewees were asked to address these themes from their perspective. The length of an interview varied from 1 to 2 hours. All interviews were recorded and transcribed for further analysis.

To get broader understanding of the innovation network and the surrounding ecosystem, other relevant actors, such as a heating ventilation air-conditioning (HVAC) and electrical design software developer's technical director was interviewed as an interest group representative in March and April 2014. The researchers also participated in two spin-off net meetings held in January and March 2014 that built further knowledge related to network formation and co-operation related to HYGTECH as well as an individual firm's goals and business plans.

The diverse datasets consolidated the intention to follow closely, longitudinally, and in real-time the activities of the network actors and the elaboration of the innovation activities. In addition to interview data, the case data includes group discussions documented through field notes from the project network workshop in January 2014. The case data includes memos from 2012 onward on the project steering group meetings and several Living Labs observations and follow-ups. Furthermore, telephone discussions and e-mail correspondence often complemented the interviews and memos. Important data sources included a scientific article (Z), project reports and several theses (Y) related to the products of the case firms, and a Living Lab test performed during HYGTECH 1. In addition, extensive archival internal and media-originated data on the firms and their products were used, such as technical documents, annual reports, firms' marketing materials, research articles, newspaper articles, and firms' websites and other web pages concerning the products, the companies, and their focal markets.

The first step of the analysis was to create an overview of the case from all data sets. We identified and ordered events and constructed them as a flow of linked activities, and thus structured the process of forming and managing a HYGTECH network and its innovating activities. We also analyzed each firm's role and relevant relationships in the network. The next step was a detailed analysis with the framework. We organized the data in themes displayed in the theoretical framework (innovation activities, network levels, positive and negative outcomes). In this analysis phase, we identified diverse opportunities and challenges that had emerged during the innovation activities at different levels.

Table 1
The firms and organizations and data sources of the case.

Actor	*Size*	*Industry*	*Type of the actor*	*Formation phase*	*Data type and informants*
A	1400	faucet manufacturing	firm	H 1&2	group discussion & workshop - Manager, Technical Sales Support & Customized products supervisor
B	200	copper tube manufacturing	firm	H 1&2	interview - Sales and Marketing Director workshop - Communications Manager
C	390	copper manufacturing	firm	H 1&2	interview – Head Company Physician workshop - Product and Chemical Stewardship Specialist
D	<5	organizational activities	other organization	H 1&2	group discussion, workshop & 2 net meetings – Director
E	850	manufacturing of locks and hinges	firm	H 1&2	interview, workshop & 2 net meetings – Industrial Designer
F	<5	technical services	firm	H 1	interview - Founder, Chief Technologist
G	200	copper sheets and strips manufacturing	firm	H 1&2	interview, workshop & 2 net meetings - Application Engineer, Architectural Products
H	<5	wholesale of machinery, equipment and supplies	firm	H 1&2	interview – Sales Director
I	430	manufacturing of machinery and equipment	firm	H 2	group discussion – R&D Manager & Product Manager
J	<20	agents involved in the sale of machinery and industrial equipment	firm	H 2	interview – Managing Director
K	5800	conglomerate; waste collection, treatment and disposal activities; materials recovery	firm	H 2	interview – Development Manager workshop & 1 net meeting – Service Administration Manager, Facility Services
L	<20	manufacturing of clothing	firm	H 2	interview, workshop - R&D Engineer, Electronics
M	22	wholesale of other machinery and equipment	firm	H 2	interview – Director, Sales
N	80	computer programming, consultancy and related activities	firm	OS	2 interviews – Technical Director
O	460	manufacturing of furniture	firm	S	1 group discussion & 2 net meetings – Development Manager (3), Director, International Development Projects (2), Director, occupational health care services (
P	130	manufacturing of medical instruments	firm	S	2 net meetings - CTO & Global Business Director (2), Product Development Manager (1)
Q	<5	professional, scientific, and technical activities	firm	S	1 net meeting – Managing Director
R	20	manufacturing of other fabricated metal products	firm	S	1 net meeting – Managing Director
S		technology center	users and other stakeholders	H 1&2	living lab research results
T		assisted living facility	users and other stakeholders	H 1&2	living lab research results
U		education	users and other stakeholders	H 2	living lab research results
V		day care	users and other stakeholders	H1&2	living lab research results
X		health care	users and other stakeholders	H2	living lab research results
Y		education and research	other organization	H 1&2	project workshops and other project material

	(technology)			
Z	research and development (water)	other organization	H 1&2	project workshops and other project material
Å	education and research (technology)	other organization	H 2	project workshops and other project material
Ä	education and research (business)	other organization	H 2	project workshops and other project material

H1 = project 1.4.2012-31.7.2013, H2 = project 1.8.2013-31.10.2014, S = spin-off net, OS= other stakeholders

Multiple analytical tools and tactics enhanced the analysis. We organized aspects of the framework in multiple tables to structure the analysis of the case and firms, and drew network pictures that displayed the firms' relationships. NVivo software was used to analyze interviews since it facilitates managing and decreasing multiple and broad datasets, enables systematic but flexible analytical processes and multiple categorizations, and enables the retrieval of coded data in various ways (see Bazeley, 2007). Data triangulation (i.e., multiple data sources), theory triangulation (i.e., multiple theoretical schemes and conceptualizations from various research streams), and researcher triangulation (i.e., multiple researchers) helped enhance the trustworthiness of the results (see Flick, 2004). These results are elaborated next.

CASE RESULTS

THE FORMATION AND ORGANIZING PROCESS FOR A MULTI-INDUSTRY INNOVATION NETWORK

The initial background of the case and increasing markets for hygiene technology solutions

The general background of the case and project relates to the fact that today people spend more than 90% of their lives indoors, which exposes people to different types of indoor environment-related health problems. For example, nosocomial infections in hospitals are among the most significant infection problems in developed countries. In hospitals in the United States alone, health-care-associated infections account for an estimated 1.7 million infections and 99,000 associated deaths each year. The most important migration routes of nosocomial infections are contact, droplet, and airborne infection (Mäkinen et al. 2013, Klevens et al. 2007, Vincent 2003). Scientific researchers have shown that smart touchless faucets and hygienic surfaces reduce microbes that are detrimental to health (Mäkinen et al. 2013; Salgado et al 2013; Ahonen et al. 2013). In addition to particular products, some materials and compositions improve hygiene quality. Current antimicrobial products are mainly based on copper (Cu), its alloys (brass), or silver, which is used as an additive or coating. Moreover, different types of facilities, buildings, and different user groups have varying hygiene-related needs and challenges. Hygiene problems cause extra costs for the welfare and the health sector. Therefore, the proactive perspective, i.e., preventing hygiene problems through hygiene technology solutions, offers the necessary savings.

Based on this, several individual firms identified nascent but promising markets related to hygiene products and envisioned that diverse hygiene-related solutions and innovation could offer new business opportunities and growth potential for all of them. They identified an opportunity for collaboration and launched a common project, the HYGTECH project.

The aim of the HYGTECH project was 1) to analyze existing and prototype antimicrobial products (air, water, and surface related) in Living Labs and, 2) based on these research results, create and commercialize a HYGTECH concept that covers all the indoor environment elements: surface, air, and water. The HYGTECH network is based on a continuum of two projects: HYGTECH 1 (1.4.2012-31.7.2013) and HYGTECH 2 (1.8.2013-31.10.2014), both of which were funded by Tekes, the Finnish Funding Agency for Innovation.

The main goal of collaboration was to collaborate in order to generate a set of hygiene-related offerings. The roots of collaboration and the key target group for these solutions was planned to be public sector (e.g., constructing and maintaining hospitals, day care centers, etc.). However, in the beginning,

only a few actors created and developed hygiene-related offerings, and together, they did not provide holistic hygiene technology concepts that could have enabled constructing and maintaining buildings with increased hygiene quality; therefore, the network wanted more complementary actors to develop a holistic hygiene technology concept that comprised a complete set of offerings.

One ground-building aspect behind the emerging collaboration concerned global market opportunities. In domestic markets in Finland, which inherently is a tiny market, hygiene standards (e.g., water quality) are high. In emerging markets and other areas, however, hygiene standards are developing, and their relevance is increasing. Therefore, there is vast market potential in global markets.

Collaboration is launched: Copper-related innovation network HYGTECH 1 with "antimicrobial" focus

The collaboration started to emerge when the HYGTECH 1 project started in April 2012. The firms and the hygiene technology–related products are shown in Table 1. Satakunta University of Applied Sciences (Y) and the Nordic Water and Materials Institute WANDER (Z) coordinated collaboration and applied for funding for the project. At this stage, seven firms and one association (Tables 1 and 2) focused on water and surface solutions.

Some of the firms already had mutual long and deep relationships and a common history, since the operations of four of these organizations center on copper manufacturing. Thus, these four firms (B, C, D, G) comprise a "copper net" that had started to investigate the business potential of antimicrobial copper already at the beginning of the 2000s; this earlier collaboration set the preconditions for the collaboration. The common aim of this net is to promote copper as an antimicrobial element and find new partners to widen the copper-based product offering.

The firms wanted to elaborate innovation in networks and wanted to expand collaboration with complementary hygiene technology–related firms. They were looking for complementary, visionary subcontracting firms willing to switch from conventional raw materials (stainless steel, plastic, cast iron) to copper or brass in products that have been recognized as high-risk targets (door handles, trolley, railings, etc.) in scientific research in the health care sector. "Copper net," a lock and handle manufacturer (E), and a medical instrument manufacturer (P) conducted hygiene-related Living Lab tests in an assisted living facility in collaboration with a research partner in 2009 (see Laitinen et al 2010).

Although the results of this earlier collaboration and prototyping were promising (push from the manufacturing industry and pull from hospital infection doctors), development stopped at the prototype stage. The main problem was that 1) without an existing market and customers, small subcontracting firms would have to take a huge risk in changing their processes, and 2) without an offering, firms could not acquire customers beyond pilot projects (cf. Chiesa and Frattini, 2011)

Previous co-operation also existed between firms whose business was related to water. However, this group differed from the copper net in that earlier relationships and collaboration in the "water net" had been dyadic. All the firms had done business with the project coordinator (Z) since the mid-2000s.

Noteworthy is that at this stage of collaboration, the firms' hygiene technology–related products were at different stages of development. The faucet manufacturer (A) already had an established technology and a strong market position with touchless faucets, whereas the other firms were still more or less struggling with prototypes. Despite the challenges, positive outcomes started to emerge. For example, firm E had commercialized their coated door handles after their first pilot.

In addition, diverse stakeholders were involved in the HYGTECH network, particularly in research and development. The antimicrobial effect of the products had been tested in a technology center, day care center, assisted living facility, hospital ward, and school through the Living Labs. Thus, the innovation network also comprised diverse specialists and users and used their input in innovating.

Innovating in networks for hygiene technology expands: the multi-industry network HYGTECH 2 with "hygiene technology concept" focus

After more than a year of collaboration, the network got five new firm members and two new

research partners (Turku School of Economics and Tampere University of Technology) at the transition point when the first project ended and a new project phase, HYGTECH 2, started in August 2013.

At this point, new industries and technologies related to hygiene technology entered the collaboration. An important addition was getting an HVAC manufacturer to join, which shifted the focus to air. In addition, a concrete change in the life cycle concept was made by getting a representative from maintenance services (K) in the network. Thus, since the collaboration started to attract diverse firms whose business was related to hygiene, and many of these firms brought new resources in collaboration and widened the original vision, the focus of the collaboration started in a more stronger mode to turn toward a more holistic "hygiene technology" concept and business.

There were also other dynamics in the network relationships. One of the original network firms (F) had to withdraw from the network due to financial challenges in December 2013. This firm is a spin-off (founded in 2012), and the decision to join the project had been made by the parent company.

A remarkable aspect is that at this stage of collaboration, the innovative offerings and their "readiness" started to differ even more. Some mature firms with established business already had products and market knowledge whereas some actors were just developing and testing their products. The particular products' development paces were different (e.g., due to different industries), and this further complicated the development of a common hygiene technology concept.

Moreover, the ability to show the technical and customer benefits differed depending on the product. In "surface" products, it was quite easy to show the benefits of hygiene technology. Small improvements in products offered clear savings for customers, and scientific test results increased the credibility of the benefits and the proposed value. For example, there was much evidence on how facet products' hygiene technology–related features created savings. To give an opposite example, in the HVAC business showing the benefits of innovative hygiene technology products would be laborious and time-consuming.

Furthermore, there were also other, constant changes in the network. Some actors withdrew or neglected collaboration, since they thought the technologies of the relevant network actors conflicted with or were not compatible with their work or individual and common goals (e.g., the target markets) conflicted.

Innovating in networks triggers novel collaboration: Spin-off net with a narrower focus

The association member (D) has an important role in evolving the network particularly in disseminating knowledge of the hygiene technology project and scouting and matchmaking actors and coordinator organization Z. The association member promoted and participated in three pilot projects. HYGTECH project researchers visited one, the firm O's) occupational health care center pilot premises, in October 2013. This was a critical incident since one of the representatives of firm O became interested in the goals of the network and started to elaborate the idea further.

In this stage of innovating for hygiene technology solutions, firm O expressed interest in hygiene-related solutions. The firm operated in a business area in which the other HYGTECH network firms did not, quite the contrary, and several actors agreed that cooperating would lead to a win-win situation. Firm O has an established global business in providing turnkey office facilities in hospitals but wanted to extend its business to other facilities in hospitals, and the hygiene technology aspect would provide a competitive advantage. Firm O's turnkey solutions required integrating hygienic fabrics, metals, etc. Firm O was interested in exploring the business potential of antimicrobial surfaces further, and the copper net members had searched for a firm that would take the lead and operate as a leading partner that could provide more resources and channels for commercializing novel products and solutions. Firm O was already operating as a hub firm in its own business area and started actively calling together other firms whose products would complement the existing network.

The first spin-off net meeting was organized by firm O in January 2014. Almost 20 firms were invited, but due to time schedule challenges, representatives from only four new firms and four HYGTECH network firms attended. Three of the new firms had participated in the association's previous pilot projects, and one was operating as a subcontractor for firm P. Based on a common history, the

parties trusted each other and agreed on shared goals: exploring business potential and creating prototypes and showrooms together. The meeting memo was sent also to all absent firms that had expressed interest.

By the next meeting, which was held in March, firm O had created two new prototypes and firm P one in collaboration with subcontractor R. The firms had also decided to create three showrooms on the premises of firms G, O, and P. The other HYGTECH firms were also welcome to join and add their products and be a part of a collective offering presented in showrooms that facilitated commercialization of HYGTECH solutions.

KEY ACTORS COMPRISING AND FORMING THE CASE NETWORK

The actors involved in collaborating on HYGTECH are summarized in Table 2. The table shows the diverse actors with hygiene-related products, services, materials, and expertise and each actor's motivation and goal for collaboration.

Table 2 Key actors (firms) and their motivation and commitment to collaborate in the HYGTECH multi-sector network.

Firm	*Invention/new product/competence related to HYGTECH networking*	*Net relevant the firm*	*Why and how each firm is linked to the HYGTECH network: Motivation for collaborating and individual goals for HYGTECH collaboration*
A	touchless faucets, antimicrobial coated parts of faucets	water surface	*Product related to HYGTECH*: Firm began developing touchless facets in the late '80s with a hospital customer from a customer initiative and began serial production of touchless facets in the 1990s. *Key target groups:* Households are the firm's main target group for standard facets. Today, touchless faucets are used by default in public buildings in the firm's domestic market in Finland, and therefore, households are a new target segment. *Background and goals:* Competitive advantage based on having home expertise and prototyping. Faucet hygiene-related research project with project coordinator (Z) in 2008 aimed to generate wider research knowledge about faucet hygiene and getting a scientific article published to increase the credibility of the benefits. Also interested in getting basic research knowledge on antimicrobial coated faucet parts (coatings outside the house) and getting knowledge from real use of safety faucets that automatically shut off. *Commitment:* Strong commitment since hygiene technology markets are strategic for this firm.
B	copper water pipes, prototype copper railings and grips	water copper surface	*Product related to HYGTECH*: Firm has established business with copper water pipes. *Background and goal:* Interested in finding new application areas for copper tubes. Firm participated in a 2009 hygiene-related pilot project in an assisted living facility with railing prototypes manufactured by a subcontractor. The challenge for a volume manufacturer is that the process and the business model do not fit well with manufacturing smaller series. Aim to get research results from copper pipes in real use, getting basic research results concerning railing prototypes, increasing coverage, and getting research knowledge on customer value formation related to antimicrobial products. *Commitment:* Loose commitment
C	copper materials and occupational health care related know-how	copper	*Material related to HYGTECH*: Copper material that is naturally antimicrobial *Background and goal:* Scientific research results of the antimicrobial effects of copper alloys in surfaces awoke discussion in-house at the beginning of the 2000s. The firm established a project group in-house to find out the business potential of antimicrobial products. Due to strategy changes and organizational restructuring, the project was called off. The idea was reactivated several years later, and the firm participated in a hygiene-related pilot project in an assisted living facility in 2009. This large raw material manufacturer's interest is related to promoting copper use. The firm's role is/has been to bring in raw material and microbiology-related know-how; the latter is realized through the participation of the company doctor. *Commitment*: Loose commitment, sponsors the collaboration
D	global Cu+ brand, information and marketing of antimicrobial copper and its alloys	water surface, air copper	*Background and goal:* The Nordic Association is part of a global umbrella organization that created a global Cu+ brand and certification procedure for copper alloys at the beginning of the 2000s. The Finnish agency has granted awards for installing antimicrobial copper products, which resulted in two hospital pilot projects in 2012. Promoted and participated in pilot projects also in an assisted living facility in 2009 and occupational health care center in 2013. Aim is to promote the use of copper and its alloys. *Commitment:* Strong commitment since hygiene technology markets for antimicrobial copper are strategic for this association.
E	antimicrobial coated and brass door handles, copper prototype door handle	surface	*Product related to HYGTECH*: Antimicrobial-coated door handles, which is already established business. *Background and goal:* Coating technology partner and business idea found at a fair five years ago. No exclusive right to coating material use. Extensive laboratory testing with a research partner before product launch. The firm participated in a hygiene-related pilot project in an assisted living facility in 2009. A strategic decision made in 2013 that all painted products would be antimicrobially coated. Aim to get research results from real use of products, increasing coverage, and getting research knowledge of customer value formation. Interested in antimicrobial copper and brass, and getting basic research results concerning these prototypes. *Commitment:* Strong commitment since hygiene technology markets for antimicrobial copper products are strategic for this firm.
F	prototype online system for monitoring of water microbiological quality	water	*Product related to HYGTECH*: System for monitoring water quality *Background and goal:* Start-up firm's aim was to develop prototype technology with researchers in project laboratory. Satisfied with co-operation but felt that participated in too early stage of product development. The firm had to withdraw from the project and concentrate on getting funding. *Commitment:* Strong commitment due to the strategic relevance of markets for the start-up

G	copper sheets, strips, architectural products, prototype copper floor drain and door surfacing	surface copper	*Material/products related to HYGTECH*: Diverse products made from copper material *Background and goal:* Copper is a traditional construction material in Europe. Due to overcapacity in production globally, the firm started to refine copper for architectural products during the 1990s. The firm's competitive advantage is based on tailoring possibility and being able to offer product as sheets and strips. Interested in finding new application areas for copper sheets. The firm participated in a hygiene-related pilot project in an assisted living facility with floor drain prototypes manufactured by a subcontractor in 2009. The challenge for a volume manufacturer is that the process and the business model do not fit well with manufacturing smaller series. Aim is getting basic research results concerning floor drain prototypes and getting research knowledge of customer value formation related to antimicrobial products. *Commitment:* Loose commitment
H	(chemical) water disinfection system and online system for monitoring of water microbiological quality	water	*Product related to HYGTECH*: System for monitoring water quality; the firm sells tailored solutions: device, maintenance or comprehensive solution *Background and goal*: Part of the firm's disinfection technology is acquired from outside sources. An online monitoring system was developed in-house. The technology is targeted to handling big industrial water masses. Tested the technology with a research center. Previous co-operation with project coordinator (Z). Plans for starting own research project turned out to be challenging for a small firm and changed into participating in this project consortium. Interested in the possibilities for applying technology in new customer segments. *Commitment:* Loose commitment
I	prototype antimicrobial chilled beams, dirt resistant air terminals, prototype antimicrobial air terminals	air	*Product related to HYGTECH*: Air terminals with which it has a long and successful history with a private label. *Background and goal*: Strategic decision to invest in own brand creation in which customer value is based on dirt resistance testing conducted four years ago. Extensive laboratory testing with a research partner and coating technology partner before product launch. Exclusive right to coating regarding ventilation. Strategic decision made to invest in automation of dirt resistance coatings and manufacturing that as a standard product. Long history of R&D co-operation with project coordinator (Y). Aim to get research results from real use, increasing coverage and getting research knowledge of customer value formation. Interested in antimicrobial coatings, and getting basic research results concerning these prototypes. *Commitment:* Strong commitment due to strategic relevance for its business
J	(electromagnetic) water treatment device	water	*Product related to HYGTECH*: Water treatment device *Background and goal*: The technology for a water treatment device for domestic water was commercialized by a foreign firm during the first part of the 1990s. Firm has imported and sold this technology since the mid-1990s and participated in developing a device and filter for closed water systems at the end of the 1990s. Public image of water devices is poor because of the inconsistent product quality. Research co-operation started with project coordinator (Z) five years ago in order to improve the credibility of the product. Laboratory tests done also in co-operation with other research centers. *Commitment:* Loose commitment
K	maintenance, cleaning (hygiene) services	surface, air water	*Product related to HYGTECH*: Cleaning services *Background and goal*: Since the 1990s, the firm has operated in the food industry and other target groups where high demand for hygiene exists. Firm has a productized service for the food industry. Hygiene-related know-how is gathered at a competence center. Strategic decision made to specialize in this special know-how sector in the future. Project aim is to get knowledge of antimicrobial products and their cleaning demands in various user contexts, especially in the health care sector. *Commitment:* Strong commitment due to strategic relevance for its business
L	wearable sensor solutions know-how	surface	*Link to HYGTECH*: Cleaning services: know-how *Background and goal*: Firm produces custom wearable sensor solutions for customers. R&D operations are in Finland and manufacturing in China. Strategic decision made to invest in the health care sector, which has resulted in removing these operations to their own business unit. Long history of R&D co-operation with research partner (Å). General interest in hygiene issues related to the firm's manufacturing processes and health care–related Living Lab results. *Commitment*: Loose commitment, sponsors the collaboration
M	product marketing know-how	surface	*Link to HYGTECH*: Product marketing *Background and goal*: The food industry, which has stringent hygiene regulations, is an important customer segment of this firm. Earlier history of R&D co-operation with research partner (Å). General interest in hygiene issues related to the firm's manufacturing processes. *Commitment*: Loose commitment, sponsors the collaboration

Network and ecosystem dynamics

The hygiene network takes place in a multi-industry environment. In Finland, the construction industry is traditionally segmented into special design and operation areas: HVAC, electrical, architectural, interior, etc. The vision of a HYGTECH concept covering all indoor environment elements (air, water, surface) thus is challenging. Most of the interviewees brought out that the concept as a whole is interesting and has huge business potential for participants but also raised the question of managing such a challenging ensemble of different products and fields of know-how.

"There is demand I'm sure of it. But it might be difficult to manage. This is so huge entity for any single player to handle. There is enough challenge in this (one net). I don't know who it could be. Maybe it is a completely new business concept, like a new Nokia." (Firm G)

In the hygiene technology ecosystem, there are different levels of players (Fig. 2): the innovators (in the middle) and the other significant stakeholders (the outer circle of actors). Due to the vast number of relationships within the extensive multi-industry network, only the most significant connections are illustrated.

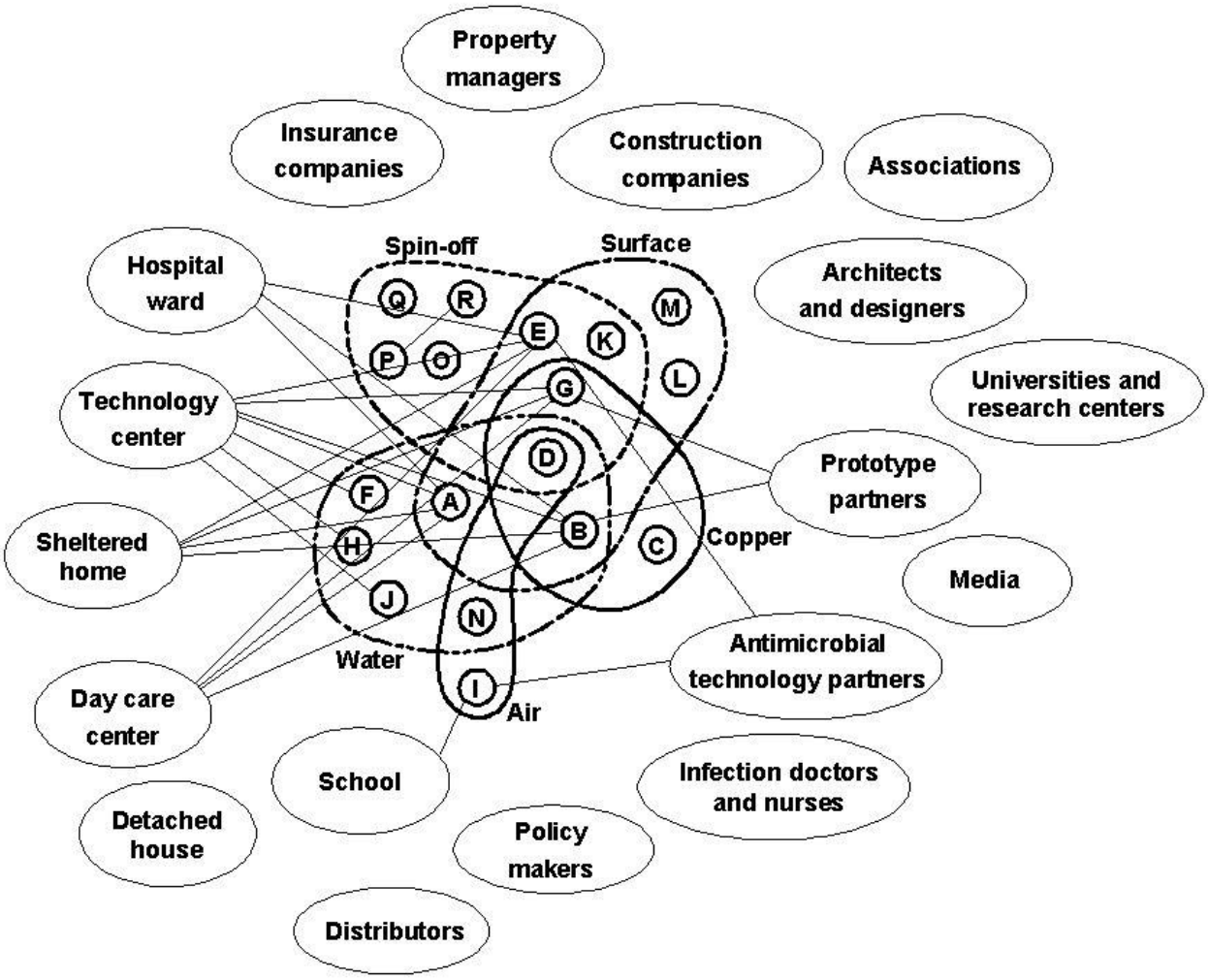

Fig. 2. Hygiene technology networks and ecosystem.

As shown in Fig. 2, the actual innovator network consists of 16 firms, one interest group firm, and one association. The multi-industry nature of the network is reflected through several nets found within

the network. The extensive network includes copper, surface, water, air and spin-off nets. The nets are formed around different business areas: water (six), air (three), and surface (eight). One strong net is formed around copper manufacturing. Members of this antimicrobial copper net (four) mostly belong to business area–based nets. The difference between a spin-off net and the other nets is that a spin-off does not belong under the HYGTECH funding and consortium agreement, and it was originally called together by a hub firm (a term not used by the researchers). Fig. 2 also depicts firms' participation in different Living Labs, brings out which firms' hygiene products are based on technology partnerships (E, I), and the firms' prototyping relationships (B, G, P, R) during the research period. Even in a single net, the firms and stakeholders may be very interrelated.

Stakeholders are an important, but evolving, actor group in a multi-sector innovation network. Most of the interviewees highlighted the importance of architects and designers in getting new products and visions acknowledged in construction plans early enough. In addition, big construction companies and product deliverers operating in a customer interface may act as gatekeepers to new products. When dealing with public construction, municipal policy-makers are an important stakeholder group. As highlighted earlier, innovating firms seldom operate alone or create all technology in-house. During the innovation process, firms co-operate with different prototype and technology partners. In order to get credibility for hygiene products, co-operation with universities and research centers has been a method for building a reliable scientific foundation and proof that antimicrobial products do what they are promised to do. In this ecosystem, infection doctors are potential professional users of antimicrobial products in their work environments and have microbiological know-how. Thus, this group comprises significant opinion leaders. Furthermore, associations can have an important role in informing their members in particular and the public in general. For example, the technical personnel in hospitals, an important reference group in relation to hygiene demands, are aggregated to the Federation of Hospital Engineering nationwide. Through the international parent organization, the Finnish association has extensive global networks. From the financial point of view, insurance companies are a stakeholder group that handles the insurance claims for epidemics if, for example, viruses spread among children at day care centers, which are challenging places concerning disease.

Another important stakeholder group of the case is the "test users" in the six Living Labs, which have been a central part of the collaboration. Research conducted in these facilities offers new knowledge about the technical issues of the products and their real use in a real context; for example, the cleanability and serviceability of the products are important issues to consider from the life cycle point of view. The representatives of the Living Labs also belong to the project steering group. Since H1 project research centered on water and surface hygiene, tests were conducted at a technology center, day care center, and detached house. In the detached house, researchers did not install new hygiene technology devices or products but analyzed the normal situation of the water quality and water system of an old house. The tests in this pilot subject were finished during the H1 project. At the technology center, there is also a water laboratory (closed system) where water pollution tests can be conducted. The products of the firms (A, B, E, G, F, H, J) were tested here (see Fig. 2). The day care center is another interesting context where users were observed and interviewed in addition to product testing (firms A, B, G, E). In the H2 project, three new Living Labs joined the project network: an assisted living facility, hospital ward, and school. The hospital ward is a challenging research place, and research permission to install the products of the firms (A, B, E) was the result of several negotiations. The air-related research centered on the school where the products of firm I were installed.

During the two-year research period, the network evolved, and network relationships and common and individual goals of the firms transformed since the firms went through different kinds of innovation activities during the innovation process. At the beginning of the networking, there were separate products of separate firms that were open-minded to the vague idea of improving indoor hygiene. The research focused on basic research and testing the hygiene features in different contexts. The concept was a distant vision. Noteworthy is that the firms and their products were and are still in different stages of development, which complicates further co-development and co-commercialization and therefore induces

problems and tensions.

Creating and fortifying the hygiene technology concept through collaboration has been more prolonged and arduous than firms expected. Emerging needs and yet evolving market complicated innovation activities as on the one hand encouraged to proceed but on the other hand did not offer much guidance for finding the optimal set of visioning, development and commercialization decisions. The following quotes explicate the firms' expectations and mood:

> *"This has clearly been a battle comprising imperceptible moves aiming to win the markets. At the beginning, we of course made marketing campaigns and so on, but in the building construction, concerning for example a hospital's extension, it can easily take two, three years to proceed from the architects table to real concrete purchasing to us. So it has taken its time, but now it is clearly one of our interesting products, kind of wholeness the plain (antimicrobial) coating. Added into our product." (Firm E)*

> *"Nowadays, you can say that in the home markets, in the restaurant toilets, garage toilets the customers' expectation is that there is a touchless product. We are now on the interface of proceeding to homes also." (Firm A)*

The visioning, research and development, and commercialization activities concerning individual products and the hygiene concept overlapped during the journey. The individual goals and common goals, resources, etc., have been discussed and worked from autumn 2013 (when all the firms were interviewed) until January 2014 (when the researchers organized a workshop to develop the concept further together based on the interview results). The vision of the concept and the steps toward it started to sharpen when the network members agreed on the following: 1) proceeding in developing the hygiene concept by making Delfoi research to get a wider vision of near-future trends from a group of indoor environment and construction-related professionals during spring 2014, 2) focusing first on new construction in the public sector and using knowledge about hospitals as a demanding customer, and 3) benchmarking the cleantech network operations model. From the construction process viewpoint, the HVAC business areas (water and air in this case) form a logical union, and the researchers' proposal to continue the visioning and development of the hygiene concept based on two segments (building services solutions and surfaces and fitments) was accepted.

Although the visioning of the concept was performed at the whole network level, the actual development actions centered on the smaller nets. The copper net firms had already participated in several pilot projects and were most interested in moving to the next level and getting products to the commercialization phase. Firm O started to orchestrate the development actions as the answer to their wishes. At the same time, when concept-related innovation activities were more or less at the vision level and the spin-off net was developing an offering to be commercialized, some firms were already refining their marketing and/or delivery plans of their own finished products or planning to moving into new customer segments with their hygiene offering.

1+1=3 – Emerging opportunities on different network levels

Even though the hygiene concept was, and still is, a somewhat vague goal to innovate and make business, most of the firms believed in this vision. At the network level, this multi-industry concept was something new that crossed traditional industry boundaries. It was at its best seen as creating new markets, enabling growth, and exporting business to developing countries or the Middle East where hygiene-related problems and business potential are bigger than in Nordic countries.

> *"It might even be a megatrend when environments are getting dirtier and becoming more urbanized, so of course there is demand for this kind of solution. And it doesn't relate only to hospitals but also to food industry, pharmaceutical industry, electronics etc. You can imagine that there is demand…….the challenge is that it isn't just a one shot case but there is continuum in the business, products are being renewed and maybe the world is changing to certain direction and maybe one year one is building or selling hospitals and next year moving to*

electronics. Food industry is changing so completely, the business can change, but important is to be able to keep an eye on megatrends. (Firm I)

As shown earlier, the hygiene concept was developed in smaller nets. The surface/spin-off net is a good example of how things can proceed quickly when the pieces fall into place after several rounds of trial-and-error piloting. This net, led by the hub firm, focuses on targets. Due to common history between key parties, the trust level was high enough to start exploring the business potential together.

Important technology and prototyping relationships between the firms existed. The Living Lab research has enabled individual firms to get knowledge about their products' real use and test prototype products that may open up new business possibilities. For a start-up, participating in the innovation network offered a chance to improve the firm's technology (F).

In sum, innovating generated multiple positive outcomes at the whole network level, net level, dyadic/portfolio level and firm level.

No pain no gain? - Challenges and problems at different network levels

Although the increasing tendency is to encourage multi-sectoral innovation networks (Rambersad et al. 2010), these networks tend to face crucial challenges in management that hinder innovation success, and this case highlights these problems.

At the HYGTECH network level, for example, there was vagueness about the ultimate goals for collaboration: what hygiene technology business and innovations could be and what kind of resources, actors, and activities are required for successful innovating. On the net level, there were several problems, for example, due to indirect competition. Therefore, tension between the actors became apparent and complicated negotiations and further planning. For example, within the water group, some firms felt they were competitors. Moreover, the water net's target market does not fit with the target markets of the whole network. Strong copper manufacturing and promoting representation might create a lock-out effect on other solutions based on silver coating, for example.

However, technological challenges complicated collaboration at the net level. For example, in relation to the surface/copper net, a crucial development challenge emerged: Copper is an expensive element that has aesthetic challenges because it becomes covered with patina. Different alloys have different coloring and therefore, creating aesthetically uniform offerings from this material is challenging.

In addition, different commitments created challenges. Some actors were highly committed and considered collaboration strategic, whereas some actors considered it an "inspiring task." (see Table 2, commitment).

Challenges also emerged at the firm level. For example, it turned out that firm F's goals and value creation were not in line with the concept, at least in the domestic market. Firm I (with offerings related to hygienic air) was a strong but lonely rider. The firm had fewer dyadic or net partnerships, but since collaboration is strategically important for the firm and its goals, and its offerings fit nicely in the ultimate goal of the innovation network, the firm has remained in the network.

DISCUSSION

DISCUSSING MAJOR RESULTS

In this research, we analyzed how one extensive innovation network emerged, went through visioning, research and development and commercialization activities in order to innovate a value-creating concept and what kind of challenges and opportunities this collaboration generated. These key results are now discussed in the following.

First, we analyzed how an innovation network comprising diverse actors from different industries with vague goals emerges and elaborates, i.e., how an extensive multi-industry innovation network evolves during the innovation process, and identified that the emergence and organization of such an innovation network occurs through several cyclic initiation, re-recruitment, and mobilization and re-organization processes. The process is complicated since during visioning, research and development, and

commercialization activities new goals and resource and actor requirements are identified. Thus, step by step, the firms realize what kind of actors and resources are crucial in the main innovating activities.

Particularly, since there are several diverse actors (firms and other organizations) with different types of business practices, offerings, and cultures, the starting point and first goals can be vague. Therefore, it takes time and requires open interaction on potential goals, visions, ideas, and commitment to collaboration, so that vague goals and visions for collaboration and outcomes can be elaborated and refined. As the evolution of the case network showed, this may take several collaboration initiation rounds and longitudinal iteration. After these time-consuming processes, the firms realized what they as a multi-industry network could innovate together and how, i.e., what common activities they conduct and who should be involved in dyadic collaboration and who should collaborate within a more extensive net.

The multi-industry innovation network comprises diverse actors with different strategic focuses, with different kinds of target markets in their minds, with different kinds of cultures and logics and, in particular, with different kinds of backgrounds and established relationships. This heterogeneity presents opportunities by providing complementary knowledge and offerings as well as challenges by setting limitations, gaps, and tension between desired innovation activities.

Some actors in this extensive innovation network form "the core of the innovating actors" whereas others (diverse stakeholders such as user organizations and experts) play supporting roles as facilitators and testers of vision, development, and commercialization decisions. As our analysis of network actors showed, some actors had good resources, such as particular capabilities in visioning, some in research and development, and some in commercialization, but at the end of the day, all these resources are required to create, develop, and disseminate the chosen visions to the market.

Through a detailed case analysis, we identified many business opportunities but also challenges throughout the innovation process and on different network levels in multi-sector networks. We also analyzed what new business opportunities and challenges emerge in a multi-sector network aiming to develop and commercialize new solutions and how they emerge in different relationships levels (network, dyadic relationships, and firm level). Within a multi-industry innovation network, radical new collaboration emerged. For example, a novel collaboration between firm O, a furniture manufacturer, and the copper net was created and developed. At the same time, within a multi-sector network, several network portfolios and nets started to collaborate more intensively, as some actors that had existing or earlier collaboration started to innovate more actively together. At the same time, trust problems, conflicting attitudes and commitments on the organizational level, and conflicting technologies on the practical level emerged. Our analysis emphasized that trust, shared common goals, "non-competitors" setting, and compatibility of technologies were required as preconditions for innovating in a multi-industry network.

CONCLUSIONS

THEORETICAL CONTRIBUTION

Since so much research has focused on innovation networks comprising a moderate number of actors and on one innovation activity/phase, for example, on research and development and commercialization periods, this study focused on innovating in a multi-sector innovation network. We analyzed in detail a multi-industry innovation network, its formation, and innovation activities, and identified emerging opportunities and challenges as positive and negative outcomes originating from such activities. Our results make several contributions which are discussed next.

First, due to our longitudinal research design and extensive network case analysis, we captured and conceptualized the composition and evolution of an innovating multi-sector network as well its transforming and changing innovation activities from early visioning to commercialization. Thus, we developed insights into the complexity of provoking and managing innovation collaboration and particularly strategic collaboration between and cross industries (e.g., Möller & Svahn, 2009, Aarikka-Stenroos & Sandberg, 2012, Håkansson & Waluszewski, 2002). Moreover, our results emphasize the

complexity of innovating activities in networks on several network levels. The longitudinal approach to innovating in a network also enabled us to capture the transformation and interdependence of innovation activities during the entire innovation process, thus deepening current knowledge of all innovating activities of the innovation process in a network (e.g., Heikkinen et al. 2009).

Second, we identified opportunities and challenges that originate in innovating networks. By classifying major challenges and opportunities, and binding them to network-level analysis, we contribute to the literature that has showed Janus faces of innovating in networks (e.g., Millson & Wilemon, 2008; Hoholm & Olsen, 2012; Olsen et al. 2014).

Third, by empirically analyzing an extensive network comprising diverse firms and other organizations, we developed new knowledge in the rapidly increasing literature on multi-sector innovation networks (e.g., Murphy et al., 2012; Hopkins et al., 2011; Lopez, et al., 2009; Chen et al. 2010; Bunn et al. 2002, Hardy, et al. 2006; Berkhout et al. 2007) and innovation collaboration that concerns radically dissimilar actors (e.g., Nissen et al. 2014), which are relevant in innovating the welfare business. The success of innovating in multi-sector networks seems to depend on how well managers address unanticipated and foreseeable trust and management problems and are reciprocally interactive (see O'Connor & Rice, 2013a), and bring something radically innovative to the market. Innovating in a multi-industry network includes much interaction with relevant stakeholders (users, related firms, policy makers) that complete the multi-industry network into an ecosystem. The role of these stakeholders as network members is an important aspect since firms tend to neglect the full potential of customers and other stakeholders to contribute to innovation throughout the process (Aarikka-Stenroos & Sandberg, 2012; Coviello & Joseph, 2012; Partanen et al., 2011).

MANAGERIAL IMPLICATIONS

Based on our findings, we offer several management proposals. First, managers are tempted to overestimate the advantages and potential of innovation networks, and the network actors' capability to vision, develop, and take innovations created through collaborations to the market; they should also focus on trust creation and realistic business planning between actors. Key partners and stakeholders should be identified and engaged in early interactions to develop market understanding, to increase credibility and feasibility, and to develop the ecosystem required for the innovation.

Second, to manage innovating particularly in a multi-sector innovation network, managers must understand how the challenges related to management are linked and impact, and how they can be overcome. Managers can use the conceptualized multi-industry innovation network picture to analyze their own cross-industry innovation networks and the challenges and opportunities throughout the innovation process, and thus be more aware of the critical challenges ahead.

LIMITATIONS AND ISSUES FOR FURTHER RESEARCH

Our findings stem from one extensive case network that crosses several industries. The varied set of actors in the network reveals common ground for opportunities and challenges across different network levels. However, studies on other industries might yield different answers. Nevertheless, our findings are likely to be applicable to diverse firms in innovating in networks, since even large firms are seldom able to vision, develop, and commercialize their innovations alone.

Based on this research, we see that visioning, R&D, and commercialization activities overlap and interact, and decisions made in one often impact other activities; this requires more longitudinal research designs that follow such interplay during the innovation process.

References

Aarikka-Stenroos, L., & Sandberg, B. (2012). From new-product development to commercialization through networks. *Journal of Business Research*, 65(2), 198–206.

Aarikka-Stenroos, L., Sandberg, B., & Lehtimäki, T. (2014). Networks for the commercialization of innovations: A review of how divergent network actors contribute. *Industrial Marketing Management*. In Press.

Ahonen, M., Heinonen, J., Inkinen, J., Kleemola, H., Kukka, M. and Mäkinen, R. (2013) Kiinteistöjen hygieniakonsepti Hygtech. Hankkeen loppuraportti. Satakunnan ammattikorkeakoulu, Sarja B, Raportit 5/2013.

Anderson JC, Håkansson H, Johanson J. (1994) Dyadic business relationships within a business network context. *Journal of Marketing*, 58(4)1–15.

Bazeley, P. (2007). *Qualitative Analysis with NVivo*. London, UK: Sage Publications.

Berkhout, A. J., & Van Der Duin, P. A. (2007). New ways of innovation: an application of the cyclic innovation model to the mobile telecom industry. International Journal of Technology Management, 40(4), 294-309.

Biemans WG. (1991).User and third-party involvement in developing medical equipment innovations. *Technovation*; 11(3):163–182.

Bunn, M. D., Savage, G. T., & Holloway, B. B. (2002). Stakeholder analysis for multi-sector innovations. Journal of Business & Industrial Marketing, 17(2/3), 181-203.

Chen, H. C., & Chen, S. K. (2010). An integrated value-creation model for innovation-intensive service industry. International Journal of Information Systems and Change Management, 4(4), 338-352.

Chiesa, V., & Frattini, F. (2011). Commercializing technological innovation: Learning from failures in high-tech markets. *Journal of Product Innovation Management*, 28(4), 437–454.

Dhanaraj C, Parkhe A. (2006) Orchestrating innovation networks. *Acad Manag Rev*. 31(3):659–669.

Flick, U. (2002). *An Introduction to Qualitative Research*. 2nd Edition. Sage, London.

Flick, U. (2004) Triangulation in qualitative research. In: *Companion to qualitative research*, eds. Uwe Flick – Ernst von Kardorff – Ines Steinke, 178–183. London: Sage publications.

Freytag, P., & Young, L. (2014). Introduction to Special Issue on innovations and networks: Innovation of, within, through and by networks. Industrial Marketing Management.

Garcia R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of Product Innovation Management*, 19(2), 110–132.

Grandori A, Soda G. (1995) Inter-firm networks: Antecedents, mechanisms and forms. *Organization Studies*;16(2):183–214.

Håkansson H, Snehota I. (1995) Developing Relationships in Business Networks. New York: Routledge.

Håkansson H, Waluszewski A. (2002) Path dependence: restricting or facilitating technical development? *Journal of Business Research*; 55(7):561–570.

Halinen A, Törnroos J-Å. (2005) Using case methods in the study of contemporary business networks. *Journal of Business Research*, 58(9):1285–1297.

Hardy, C., Lawrence, T. B., & Phillips, N. (2006). Swimming with sharks: creating strategic change through multi-sector collaboration. International Journal of Strategic Change Management, 1(1), 96-112.

Harrison, D., & Waluszewski, A. (2008). The development of a user network as a way to re-launch an unwanted product. *Research Policy*, 37, 1, 115-130.

Heikkinen M, Mainela T, Still J, Tähtinen J. (2007) Roles for managing in mobile service development nets. *Industrial Marketing Management*; 36(7):909–925.

Hoholm, T., & Araujo, L. (2011). Studying innovation processes in real-time: The promises and challenges of ethnography. Industrial Marketing Management, 40(6), 933-939.

Hoholm, T., & Olsen, P. I. (2012). The contrary forces of innovation: A conceptual model for studying networked innovation processes. Industrial Marketing Management, 41(2), 344-356.

Hopkins, M. M., Tidd, J., Nightingale, P., & Miller, R. (2011). Generative and degenerative interactions: positive and negative dynamics of open, user- centric innovation in technology and engineering consultancies. R&d Management, 41(1), 44-60.

Jarillo JC. (1988) On Strategic Networks. *Strategic Management Journal*;9(1):31–41.

Laitinen, K., Voutilainen, P. and Santala L. (2010) Clinical trial on using copper and brass surfaces in a hospital in West-Finland using microbiological assessment. Scandinavian Copper Development Association. http://www.scda.com/doc/uploaded/file/Result_report_Pori_veteran_home_clinical_trial.pdf

Lopez, U., Lopez, S., & Larraaga, I. (2009). Innovation in industrial cooperatives: special features and potential of the Mondragon model. International Journal of Technology Management & Sustainable Development, 8(1), 39-56.

Mäkinen, R., Miettinen, I., Pitkänen, T., Kusnetsov, J., Pursiainen, A., Kovanen, S., Riihinen,K.and Keinänen-Toivola, M. (2013) Manual faucets induce more biofilms than electronic faucets. Canadian Journal of Microbiology, 59(6), 407-412.

Millson M, Wilemon (2008) D. Designing strategic innovation networks to facilitate global NPD performance. *J Gen Manag*; 34(2):39–56.

Möller K, Rajala A. (2007) Rise of strategic nets – New modes of value creation. *Industrial Marketing Management*; 36(7):895–908.

Möller, A Rajala, S Svahn (2005) Strategic business nets—their type and management. *Journal of Business Research*, 58 (9), 1274-1284

Möller, K., & Svahn, S. (2009). How to influence the birth of new success fields – Network perspective. *Industrial Marketing Management*, 38(4), 450-458.

Murphy, M., Perrot, F., & Rivera-Santos, M. (2012). New perspectives on learning and innovation in cross-sector collaborations. Journal of Business Research, 65(12), 1700-1709

Nissen, H. A., Evald, M. R., & Clarke, A. H. (2014). Knowledge sharing in heterogeneous teams through collaboration and cooperation: Exemplified through Public–Private-Innovation partnerships. Industrial Marketing Management.

Olsen, P.I., Prenkert, F., Hoholm, T. and Harrison, D. (2014) "The dynamics of networked power in a concentrated business network", Journal of Business Research.

Partanen, J., Chetty, S. K., & Rajala, A. (2011). Innovation Types and Network relationships. *Entrepreneurship Theory and Practice*, May, 1–29.

Partanen, K Möller (2012) How to build a strategic network: A practitioner-oriented process model for the ICT sector; *Industrial Marketing Management* 41 (3), 481-494

Perks, H. & Moxey, S. (2011) Market-Facing innovation networks: How to lead firms partition tasks, share resources and develop capabilities. *Industrial Marketing Management.* 40, 1224-1237.

Prenkert, F. (2012). Commentary to "From new-product development to commercialization through networks". *Journal of Business Research*, 65(2), 207–209.

Rampersad, Giselle, Quester, Pascale, and Troshani, Indrid (2010) Managing innovation networks: Exploratory evidence from ICT, biothechnology and nanotechnology networks. *Industrial Marketing Management*, 39, 793-805.

Ritter T, Wilkinson I, Johnston W. (2004) Managing in complex business networks. *Industrial Marketing Management*; 33(3):175–183.

Ritter T. (2000) A Framework of analysing interconnectedness of relationships. *Industrial Marketing Management*; 29(4):317–326.

Salgado, Sepkowitz, John, Cantey, Attaway, Freeman, Sharpe, Michels, Schmidt (2013) Copper Surfaces Reduce the Rate of Healthcare-Acquired Infections in the Intensive Care Unit. Infection Control and Hospital Epidemiology , Vol. 34, No. 5, Special Topic Issue: The Role of the Environment in Infection Prevention, pp. 479-486.

Story, V., Hart, S., & O'Malley, L. (2009). Relational resources and competences for radical product innovation. *Journal of Marketing Management*, 25(5–6), 461–481.

Story, V., Hart, S., & O'Malley, L. (2011). Roles, role performance, and radical innovation competences. *Industrial Marketing Management*, 40(6), 952–966.

Troshani I, Doolin B. (2007) Innovation diffusion: a stakeholder and social network view. *Eur J of Innovat Manag*;10(2):176–200.

Wengraf T. (2001) Qualitative Research Interviewing. Biographic Narrative and Semi-Structured Methods. Thousand Oaks: Sage Publications.