MALLA MATTILA

Network Formation of Technological Innovation

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ACADEMIC DISSERTATION
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UNIVERSITY OF TAMPERE

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To Myry

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At my office, 28 January 2015.

Malla Mattila

Abstract

This study aims at describing and analyzing the network formation of technological innovation. Studying this research phenomenon as processes generally and as sociomaterial processes specifically calls for a holistic and process driven research approach. This approach is captured by adopting material constructionist research philosophy and consequently materially relativist style of thinking as well as the basic ideology of case study research. These research philosophical stances give an opportunity for me to become sensitized to materiality, process, conflicts, and interests when scrutinizing the network formation of technological innovation. The study is situated in the context of construction; I draw analytical insights from many sources and use these in describing and analyzing the network formation of technological innovation. These sources include the network studies in business context – business networks, social networks and entrepreneurial networks – as well as actor-network theory and the empirical case called the intelligent paper in the study period of approximately 13 years, thus from 1997 to 2009. The intelligent paper is a technological innovation and a network as I regard it in this study. It concerns cost-effective, high-volume and roll-to-roll production of printable optics and electronics which enables novel, intelligent functionalities onto printed matter. It is part of the emerging printed intelligence markets, which is located at the crossroads of several industries, namely paper and printing, optics, and electronics.

I identify two ways to describe and analyze the network formation of technological innovation, namely the concepts of network trajectory and translation. The first is the concept of network trajectory. It enables capturing simultaneously a network, that is, actors and their relationships and a path of movement of this network across space and time. From the previous network studies in business context, I identify three network trajectories: the goal-based, opportunity-based and integrated network trajectories. The contemplation of these trajectories leads to three shortcomings of this view: (1) heavy emphasis has been put on humans and their relationships as principal carriers of technological innovation activities, (2) non-humans and their relationships have only been treated as instruments in these activities, and (3) the human parties have rather deterministically and linearly been seen to influence and be influenced by the networks within which they are embedded while engaging in technological innovation activities.

These shortcomings are transcended in this study by following actor-network theory. I adopt the concept of translation and introduce certain relational and somewhat

metaphorical words not previously used in actor-network theoretical accounts or the network studies in business context (i.e., pack and filtering). The concept of translation shifts the focus onto sociomateriality involved in the network formation of technological innovation. It allows detecting the network formation of technological innovation as continually unfolding sociomaterial processes during which some actors – by becoming involved in network formation/technological innovation and chained together in a logical succession – succeed in pursuing a character while others remain objects of other actors' actions. At the same time, the underlying power relationships between them become revealed.

In the empirical part of the study, I discuss the case of the intelligent paper using heuristically Callon's (1986a) four-phase translation model. As a result, I narrate the network formation of technological innovation. This narration provides a multifaceted and empirically grounded understanding of the network formation of technological innovation. It displays several packs (heterogeneous network) that are competing with each other as well as multiple human and nonhuman actors, their actions, and their interconnected relationships in the network formation of technological innovation. It also reveals multiple phases during which these packs get continually reconfigured, transformed, and finally revitalised into one coherent pack as well as different strategies through which actors continually try to stabilise these configurations.

Interpreting the case of the intelligent paper through the concepts of network trajectory and translation, I build a revised understanding of the network formation of technological innovation. I broaden the networks as processes view generally and the strong process view to networks specifically by arguing that network formation of technological innovation concerns continually unfolding packs. These packs are heterogeneous networks; they are equipped with entanglements of humans, nonhumans and their interconnected relationships. The formation of these packs plays out as a process of translation and gets depicted as a sociomaterial network trajectory.

Contrary to Callon (1986a), in this study the process of translations comprises of four main phases: setting the agenda, forming the pack through performing various negotiations, potential betrayals, and filtering the spokesperson. These main phases involve multiple sub-phases during which the network of technological innovation is formed in a dialectical manner. Within these processes, concrete development paths are opened up and guided by the nonhuman actors engaged in the formation of the network and consequently the technological innovation. Also, the collaborative development work as well as the technology developers' personal career development opportunities that are used by the principal actors to seduce and enrol critical actors in the network of technological innovation are depicted.

In this study, these dialectical network formation processes get depicted as a sociomaterial network trajectory. This trajectory complements the other three network

trajectories identified from the network studies in business context in terms of the packs – heterogeneous networks – and the continual power plays occurring while forming the network of technological innovation (thus, how the packs get formed and enacted, including filtering). It also offers a broader explanatory frame to the possible courses of network formation of technological innovation.

The study has implications for practitioners who wish to better master networked innovation activities they are engaged with. These implications help them to better understand long-term, heterogeneous technological innovation processes and especially the important role of nonhumans in, and the effects of the collaborative work and the individuals' career development opportunities on, these processes.

KEYWORDS: Network, technological innovation, actor-network theory, trajectory, translation, sociomaterial, material constructionism

Tiivistelmä

Tässä tutkimuksessa kuvataan ja analysoidaan teknologisen innovaation verkoston muotoutumista yleisesti prosesseina ja erityisesti sosiomateriaalisina prosesseina. Tutkimusta ohjaa konstruktionistinen tutkimusfilosofia, materiaalinen relativismi ja tapaustutkimuksen perusideologia. Nämä tutkimusfilosofiset lähestymistavat antavat minulle mahdollisuuden herkistyä materiaalisuudelle, prosesseille, konflikteille ja intresseille kun tarkastelen teknologisen innovaation verkoston muotoutumista. Tutkimus asemoituu konstruktion kontekstiin. Teen analyyttisiä oivalluksia monista eri lähteistä ja hyödynnän niitä sekä kuvatessani että analysoidessani holistisesti ja prosessilähtöisesti teknologisen innovaation verkoston muotoutumista. Näitä lähteitä ovat verkostotutkimus liike-elämän kontekstissa – yritysverkostot, sosiaaliset verkostot ja yrittäjäverkostot, toimijaverkkoteoria sekä älykkääksi paperiksi kutsumani empiirinen tapaus, jota olen tutkinut vuodesta 1997 vuoteen 2009, siis noin 13 vuoden ajan. Älykäs paperi on sekä teknologinen innovaatio että verkosto. Siinä on kyse rullalta rullalle -menetelmän avulla kustannustehokkaasti tuotetusta painetusta optiikasta ja elektroniikasta, joka mahdollistaa uudenlaisten, älykkäiden toiminnallisuuksien tuomisen painotuotteisiin. Se on osa painetun älykkyyden kenttää, joka sijoittuu usean eri toimialan risteymään. Näitä aloja ovat paperi- ja painotuotteiden valmistus, optiikka ja elektroniikka.

Tunnistan kaksi lähestymistapaa teknologisen innovaation verkoston muotoutumisen kuvaamiseen ja analysoimiseen. Nämä tavat ovat verkostokaaren (network trajectory) ja käännöksen käsitteet. Verkostokaaren käsitteen avulla voidaan samanaikaisesti tarkastella sekä teknologisen innovaation verkoston toimijoita ja näiden välisiä suhteita että tällaisen verkoston liikehdintää yli paikan ja ajan. Aiemmasta verkostotutkimuksesta liike-elämän kontekstissa tunnistan kolme erilaista verkostokaarta, joita kutsun päämääräperustaiseksi, mahdollisuusperustaiseksi ja yhdistetyksi verkostokaareksi. Tarkastellessani lähemmin näitä verkostokaaria, valotan tämän lähestymistavan tutkimuksellisia aukkoja. Esitän, että verkostokaaret (1) painottavat ihmisiä ja näiden välisiä suhteita teknologisen innovaatioprosessin pääajureina, (2) redusoivat ei-inhimilliset toimijat ainoastaan välineiksi edistää teknologisen innovaation kehittämistä ja levittämistä sekä (3) tuottavat melko deterministisen ja lineaarisen kuvan teknologisen innovaation verkoston muotoutumisesta.

Näihin tutkimuksellisiin aukkoihin kiinnitetään tässä tutkimuksessa erityistä huomiota. Ratkaisua haetaan toimijaverkkoteoriasta, joka mahdollistaa teknologisen

innovaation verkoston muotoutumisen moniulotteisuuden, etenkin siihen liittyvän sosiomateriaalisuuden tarkastelun. Se antaa myös tilaa käyttää tiettyjä relationaalisia ja jossain määrin metaforisia sanoja (lauma ja suodattuminen), joita ei ole aiemmin hyödynnetty toimijaverkkoteoreettisissa tutkimuksissa tai verkostotutkimuksessa liike-elämän kontekstissa. Toimijaverkkoteoriassa keskeisen käännöksen käsitteen avulla voidaan kuvata ja analysoida teknologisen innovaation verkoston muotoutumista. Tällöin teknologisen innovaation verkoston muotoutuminen nähdään alati muuttuvina sosiomateriaalisina prosesseina, joissa inhimilliset ja ei-inhimilliset toimijat muokkaavat liittolaistensa intressit oman tulkintansa mukaisiksi ja näin vakiinnuttavat oman asemansa teknologisen innovaation verkostossa. Samalla paljastuvat myös toimijoiden väliset valtasuhteet.

Tutkimuksen empiirisessä osuudessa tuotan kertomuksen teknologisen innovaation verkoston muotoutumisesta. Kertomus pohjautuu älykkään paperin tapaukseen sekä Callonin (1986a) neljän vaiheen käännöksen mallin heuristiseen hyödyntämiseen. Tämä kertomus tarjoaa moniulotteisen ja empiirisen ymmärryksen teknologisen innovaation verkoston muotoutumisesta. Se esittää useita toisiaan vastaan kamppailevia laumoja eli heterogeenisiä verkostoja, inhimillisiä ja ei-inhimillisiä toimijoita, heidän toimiaan sekä heitä yhdistäviä kytköksiä teknologisen innovaation verkoston muotoutumisen aikana. Se tuo myös ilmi useita vaiheita, joiden aikana nämä laumat jatkuvasti muuttuvat, muuntuvat ja lopulta elpyvät osaksi yhtä heterogeenistä verkostoa. Samalla se avaa myös erilaisia strategioita, joiden avulla toimijat pyrkivät vakauttamaan näitä heterogeenisiä verkostoja.

Tulkitsemalla käännöksen ja verkostokaaren käsitteiden avulla älykkään paperin tapausta, uudistan ymmärrystä teknologisen innovaation verkoston muotoutumisesta. Laajennan näkemystä verkostoista prosesseina, eritoten vahvaa prosessinäkemystä verkostoihin väittämällä, että teknologisen innovaation verkoston muotoutumisessa on kyse alati muuttuvista laumoista eli heterogeenisistä verkostoista, jotka koostuvat ihmisten ja materiaalien sekä näiden välisten suhteiden vyyhdeistä. Tällaiset vyyhdit saadaan purettua auki tarkastelemalla teknologisen innovaation verkoston muotoutumista käännöksen prosessina, ja ne voidaan kuvata sosiomateriaalisena verkostokaarena.

Toisin kuin Callon (1986a), tässä tutkimuksessa käännöksen prosessi jäsennetään neljään päävaiheeseen: agendan asettamisen vaihe, lauman muodostamisen vaihe moninaisten neuvotteluiden kautta, mahdollisten petosten vaihe sekä puhemiehen suodattumisen vaihe. Nämä päävaiheet sisältävät useita alavaiheita, joiden aikana teknologisen innovaation verkosto muotoutuu dialektisesti. Näiden prosessien puitteissa tuodaan esille teknologioiden avaamia ja ohjaamia konkreettisia kehityspolkuja sekä avataan kollaboratiivista työntekoa ja teknologian kehittäjien omakohtaisia urakehitysmahdollisuuksia verkoston vakauttamisstrategioina.

Näitä dialektisia verkoston muotoutumisen prosesseja kuvataan tässä tutkimuksessa sosiomateriaalisena verkostokaarena. Tämä verkostokaari täydentää niitä kolmea verkostokaarta, jotka olen tunnistanut aiemmasta verkostotutkimuksesta liike-elämän kontekstissa. Se huomioi laumat eli heterogeeniset verkostot ja tällaisten laumojen muotoutumisen aikaiset jatkuvat valtataistelut (sisältäen myös ne prosessit, joiden kautta yksittäinen lauma alkaa suodattua muista). Se myös tarjoaa laajemman selityskehyksen teknologisen innovaation verkoston muotoutumisen mahdollisille kulkusuunnille.

Tutkimustuloksilla on myös merkitystä käytännön liike-elämälle, etenkin niille yrityksille, jotka haluavat paremmin hallita verkottuneita innovaatiotoimintojaan. Tutkimustani hyödyntäen yritykset voivat paremmin ymmärtää pitkän aikavälin heterogeenisiä innovaatioprosesseja ja etenkin ei-inhimillisten toimijoiden, kollaboratiivisen työnteon sekä yksilöiden urakehitysmahdollisuuksien merkittävyyttä näissä prosesseissa.

AVAINSANAT: Verkosto, teknologinen innovaatio, toimijaverkkoteoria, kehityskaari, käännös, sosiomateriaalinen, materiaalinen konstruktionismi

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1. INTRODUCTION

In this chapter, I introduce the most basic building blocks of this study. First, I present the subject of the study. Second, I define the key concepts of the study. Third, I outline the research context of the study, namely a technological innovation which I call the intelligent paper. Fourth, I present the research questions and how they are approached in this study. Finally, I describe the research process of this study as well as the structure of the report.

1.1 The subject of the study

Networks have been one of the key concepts in the social sciences since the second half of the twentieth century. The wide interest in them can be related to a general shift in research "away from individualist, essentialist and atomic explanations about the social world toward more relational, contextual and systemic understandings" (Borgatti & Foster, 2003, p. 991). The basic definition of a network is a set of actors and relationships which connect them (Fombrun, 1982). This definition was later extended to also consider the lack of relationships between the actors (Brass et al. 2004, p. 795), yet it still suggested stability. The network approach has taken into account people such as for instance individuals, groups, and organizations and their embedded relationships with each other (i.e., nodes and ties). However, research focus has largely remained on studying stable network structures rather than their dynamics. Network researchers have thus long been more interested in how human actors connect with others within and across network boundaries as well as the antecedents and consequences of such connections (for a review on network studies, see e.g., Borgatti & Foster, 2003; Jack, 2010; Pittaway et al., 2004; Provan et al., 2007). This has allowed them to discover the underlying principles which produce and reproduce network structures that shape human action. This has meant that there has been less interest in understanding how actors themselves constitute and change networks in which they are embedded.

This study transcends this stability of structures of relationships and consequently addresses this neglected issue of network dynamics; *the study aims at describing and analyzing the complex issue of network formation of technological innovation*. I will (1) focus on network studies in business context, namely social networks, business networks, and entrepreneurial networks, (2) adopt the actor-network theoretical perspective together

with the introduction of certain relational and somewhat metaphorical words (i.e., pack and filtering), and (3) study qualitatively and longitudinally the complex issue of network formation of technological innovation through an empirical case which I call the intelligent paper. These steps allow me to take seriously the calls for empirical and longitudinal studies that view networks in business context holistically and in a process driven manner (Aarikka-Stenroos et al., 2014, p. 13; Ahuja et al., 2012; Halinen & Törnroos, 2005; Jack 2010, p. 129; Knoben et al., 2006; Slotte-Kock & Coviello, 2010). This strategy also allows me to follow the suggestion to use qualitative methods and tools while studying networks in business context (Jack, 2010, p. 132). Thus, in this study, I cannot reduce the network either theoretically or empirically to its parts or collections of parts. Instead, I need to keep together all the pieces to depict and explain the 'story' of the network formation of technological innovation *as a whole* (Latour, 2005, p. 189).

The bulk of network studies in business context have largely focused on consequences of networks, thus, motivations and/or conditions for network formation (for a review, see e.g., Brass et al., 2004; Borgatti & Foster, 2003; Provan et al., 2007; see also Oliver, 1990). Causes of networks, thus, the process aspect in networks have gained much less attention. The studies adopting this neglected view have until now largely been either theoretical (e.g., Ahuja et al., 2012; Araujo & Easton, 2012; Halinen et al., 1999; Hedaa & Törnroos, 2008; Hite & Hesterly, 2001) or methodological (e.g., Halinen & Törnroos, 1995; 2005) in nature with a focus on change and evolution in networks (for a review on empirical studies on network processes in entrepreneurial settings, see Slotte-Kock & Coviello, 2010).

Consequently, these studies together with those locating technological innovation in networks (e.g., Huggins, 2010; Håkansson, 1987; Powell et al., 1996; Raesfeld et al., 2012) have put a heavy emphasis on the predefined human participants (individuals, firms, and organizations) of networks and their embedded relationships with each other. They have also rather deterministically as well as in a linear and evolutionary manner explained the network formation as a process unfolding over time but rather in a path-dependent manner. This process has been seen to emerge and develop either within dyadic relationships (e.g., Ahuja, 2000a; Ford, 1982; Gulati, 1995; Larson, 1991, 1992; Ring & Van de Ven, 1994), from dyadic relationships into a stable multidimensional and multi-layered network (e.g., Halinen et al., 1999; Hite, 2005; Larson & Starr, 1993; Schutjens & Stam, 2003), or alternatively at the network level from the start (e.g., Ahuja et al., 2012; Hite & Hesterly, 2001; Kilduff & Tsai, 2003; Lorenzoni & Ornati, 1988; Maurer & Ebers, 2006; Steier & Greenwood, 2000).

Furthermore, although the causes perspective identified from the network studies in business context emphasizes that networks are to be seen as processes, the process that this perspective depicts is however rather limited. The process is only equipped with

people and their embedded relationships through/in which technological innovation activities gets mastered rather deterministically and linearly over periods of time. Contrary to this view, recent conceptual business network studies explicitly pinpoint that we should move from viewing the process as involving changes in entities over periods of time toward seeing networks as continually unfolding social processes (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012). They thus urge researchers to adopt a strong process view to networks, which better enables grasping the complex issue of networks as processes.

In this study, I follow this call in general. In particular, I broaden this strong process view to networks by arguing that networks are to be considered as continually unfolding sociomaterial processes in their nature – an aspect touched upon by Araujo and Easton (2012) in their methodological paper on temporality in business networks. These continuously unfolding sociomaterial processes are called packs. These packs are heterogeneous networks which are made up of multidimensional and constantly evolving entanglements of human and nonhuman actors and their interconnected relationships (e.g., Latour, 1999, 2005; Law, 1999). Consequently, a network of technological innovation is not only equipped with people and their relationships, but also 'mindless' materials and their relationships with each other and with humans. This aspect is usually neglected in network studies in business context. Also, it is equal to the technological innovation and vice versa (Law & Callon, 1992; Nicolini, 2010; Schneider et al., 2012). A technological innovation is thus not only a distinct artefact existing in a stable state a priori to its diffusion or as a 'thing' to be first generated and then disseminated into markets or organizations. Rather, a technological innovation concerns packs – heterogeneous networks – in which multiple human and nonhuman actors together with their interconnected relationships are participating. In these packs, both innovation generation and dissemination occur simultaneously. Analogously following Latour's (2005, p. 7) understanding of organizations, I thus highlight in this study that technological innovations do not have to be placed into a wider social frame, because they themselves give a very practical meaning to what it means to be nested in wider sets of affairs (cf. Geels & Kemp, 2007; Geels & Schot, 2007; see also Geels, 2010).

This idea that objects and artifacts as well as materiality in broader terms should be included in theoretical accounts when studying organizational phenomena is not new. For instance, already half a century ago Tavistock researchers introduced the idea of 'socio-technical systems' in which organizing processes were seen to contain two distinct spheres – people and technology and the hyphen separating them – which impacted each other (Trist & Bamforth, 1951). Despite this, objects and materiality have long been in a marginal position. Quite recently sociomateriality has, however, re-emerged in the social sciences generally (e.g., Alac, 2009; Barad, 2003; Stacey & Suchman, 2012) and management and organization studies (e.g., Carlile et al., 2013; Jarzabkowski & Pinch,

2013; Orlikowski, 2007) as well as in marketing (e.g., Giesler, 2012; Martin & Schouten, 2014) specifically. This increasing interest in entanglements of the social and the material (and thus the removal of the hyphen) can be related to a counter movement to a variety of turns (linguistic, semiotic, interpretive and cultural), which have emphasized the social over the material. Quoting Barad (2003, p. 801): "Language matters. Discourse matters. Culture matters. There is an important sense in which the only thing that does not seem to matter anymore is matter."

In bringing this matter (materiality) back in, sociomateriality has taken many paths. These include for instance actor-networks (Callon, 1986a, 1986b; Callon & Latour, 1981; Latour, 1992, 2005), mangle of practice (Pickering, 1993), object-centered sociality (Knorr-Cetina, 1997), relational materiality (Law, 1991b, 2004) stemming from sociology and science and technology studies as well as constitutive entanglement (Orlikowski, 2007), 'performative approach' (Czarniawska, 2008; Sandberg & Tsoukas, 2011) and 'the new black' (Jarzabkowski & Pinch, 2013) from management and organizations studies. Although stemming from different theoretical origins, these views generally emphasize the need to understand research phenomena processually. In particular, they aim to deconstruct the dualism between 'man' and nature (as well as between micro and macro, and content and context), which has argued to be a result of historically situated human activity and not an ontological condition (Carlile et al., 2013, p. 3).

In this study, I have chosen to follow laboratory studies (Collins, 1983) better known as actor-network theory. This approach is one of the recently growing research streams that emphasize the constitutive affiliations of 'man' (humans) and nature (artifacts and objects) when studying social phenomena and how power relationships get enacted within these affiliations. It was first developed in the science and technology studies (STS) research tradition where the basic argument was that scientific knowledge and technologies should be treated as socially constructed (Pinch & Bijker, 1984, 1986, 1987). The work of Bruno Latour, Michel Callon, John Law and their students has given the approach distinct characteristics which separate it from its home base. One of these characteristics emphasizes that technologies are not to be treated as interpretive flexible (Pinch & Bijker, 1984) in the hands of those engaging in their development, but technologies themselves participate in the construction of the social through complex sociomaterial processes. They are thus able to act together with human actors. These complex processes are not to be explored by focusing on causation between social or economic interests and technological forms (Latour, 2005).[1] Instead, the actors should

[1] While the recent developments within actor-network theory are more relevant in this study, the discussion between actor-network researchers and those leaning on the social construction of technology (SCOT) and sociology of scientific knowledge (SSK) is set aside here. For those interested in these occasionally heated

be allowed to make connections themselves (Callon, 1986a, 1991; Latour, 1987, 2005). As a result, the focus in studying actors' relationships is on how and why these relationships hinder and/or enable actors to acquire their actorial shapes (Law & Callon, 1992).

Consequently, actor-network theory offers intriguing analytical concepts for this study. It enables broadening the view of a network contrary to the network studies in business context. It also enables to provide a dialectic and refined description and explanation (Latour, 2005, pp. 136–137) of the network formation of technological innovation which is full of noise and disturbances. More specifically, it helps in breaking down the dualisms between 'subject' and 'object', micro and macro, and content and context. It also allows introducing certain relational and somewhat metaphorical words (i.e., pack and filtering) within the network formation of technological innovation. In this study, hence, network formation of technological innovation concerns continually unfolding packs (heterogeneous networks) and consequently continually unfolding sociomaterial processes equipped with entanglements of humans (individuals, firms and organizations), nonhumans (e.g., machines, methods and apparatuses of many sorts) and their interconnected relationships. In this study, I argue that these packs are played out as a process of translation and are depicted in a sociomaterial network trajectory. These two key concepts of this study are defined in the next chapter.

1.2 Key concepts

While being engaged in the area of networks and technological innovation both theoretically and empirically, I have identified two different ways to conceptualise the network formation of technological innovation. The first way is the concept of a network trajectory. This concept is a composite of two rather amorphous terms, namely a network and a trajectory. To combine these terms, I consider the first term to refer to a set of actors and relationships which connect them (Fombrun, 1982), and the latter as "the path of a moving object across space and time" (Jenkins & Floyd, 2001, pp. 947-948; cf. Dosi, 1982, p. 152). Thus, *the concept of network trajectory refers to a path of movement of a network across space and time*. This definition is broad enough to take into account that the network formation of technological innovation is not necessary evolutionary (life cyclic) or teleological in nature but rather an unending and dialectical process full of contradictions. Also, it simultaneously captures a network – actors and their relationships – and these dialectic movements occurring within it over time and space

discussions, see for instance Callon & Latour (1992), Collins & Yearley (1992), Bloor (1999), and Latour (1999c).

(for a related remark, see Kilduff & Tsai, 2003, p. 88). In this study, I also add the key underlying logic of action, motives and contingencies while engaging in the activities of network formation of technological innovation (cf. Kilduff & Tsai, 2003; Purchase et al., 2014).

The second way of conceptualizing the network formation of technological innovation in this study (in addition to the network trajectory) is the concept of translation. *Translation refers to "all the negotiations, intrigues, calculations, acts of persuasion and violence, thanks to which an actor or force takes, or causes to be conferred on itself, authority to speak or act on behalf of another actor or force"* (Callon & Latour, 1981, p. 279). This concept is thus a specific analytical tool used in this study to capture the sociomateriality involved in the network formation of technological innovation; it allows me to detect a process during which some actors – by becoming involved in network formation/technological innovation and chained together in a logical succession – succeed through the above mentioned strategies in pursuing a character while others remain objects of other actors' actions (Callon 1986a, 1991; see also Czarniawska & Hernes, 2005, p. 9).

Consequently, the network formation of technological innovation from the viewpoint of translation is first and foremost about finding a place for everything and keeping everything in its place, thus combining two stages of being-in-place and being-out-of-place (Bloomfield & Vurdubakis, 1999). This combining through displacement is hence an inherent ingredient of the overall translation process. It refers to the actorial, spatial, temporal, and material shifting during which entanglements of humans and nonhumans are converted out/in of the scene they presently occupied (Akrich & Latour, 1992, p. 260; Callon, 1986b, p. 27; Latour, 1994, p. 39). Those actors who manage doing this shifting – enrolling other actors to follow their courses of actions and to silence the mutiny among them – are called the principal actor(s). They are the 'authors' who represent the network that has been formed and who speak over suppressed others. They also manage to stabilize the network forged in the first place that in turn determines both the repertoire and the size of the actors they enlist as well as the histories in which they take part (Callon, 1986a, 1986b; Latour, 2005).

Additionally, while describing and analyzing the network formation of technological innovation through this concept of translation, I introduce certain relational and somewhat metaphorical words. These words have not been previously used in actor-network theoretical accounts (or network studies in business context). These words are shortly introduced here. The first is pack (metaphor denoting to a group of animals such as wolves). It refers to continually unfolding heterogeneous networks equipped with entanglements of humans, nonhumans, and their interconnected relationships. The second is filtering, which refers to the slow divesting of competing packs. These words can be compared to allies (Callon, 1986a) or groups (Latour, 2005) that are depicted within the process of translation (i.e., packs) as well as the sociomaterial processes

occurring during (the final stage of) translation that finally enable a sole spokesperson – 'the author' – to slowly emerge, come out, to take care of the interests of others, to speak in their name, and to render them mobile, that is, to say what these entities are, what they want and experience (i.e., filtering) (see Callon, 1986a, 1986b; Callon & Latour, 1981, p. 279; Latour, 2005).

The reasons for using the novel vocabulary in this study derive from the processes of data generation, analysis and interpretation. Consequently, they have allowed me to become sensitized to already existing network formations within the network formation of technological innovation without a risk of confusion with the studied actors' own idioms. They have thus allowed a focus on 'things' (involving humans, nonhumans, and multitude of intermediaries) already created as well as processes already taking place but of course not forgetting that they had not always been there. Using these words, hence, I am able to emphasize organized collective actions, tensions emerging within a certain pack and between competing packs, and mechanisms of network (re)production, more specifically the continual power plays occurring while actors are engaging in the network formation of technological innovation.

1.3 Research context

For the empirical part of the study, I have chosen to 'follow the actors' (Callon, 1986a; Latour, 1987, 2005) in the case of a technological innovation which I call the intelligent paper during a study period of approximately 13 years, thus from ~1997 to 2009. This technological innovation and consequently a network as I regard it in this study is about the cost-effective, high-volume and roll-to-roll production of printable optics and electronics which enables novel, intelligent functionalities onto printed (flexible) matter. It is part of the printed intelligence area which is located at the crossroads of several industries, namely paper and printing, ICT/electronics, and optics. It thus combines multidisciplinary knowhow from several industries and focuses on bringing wider functionality to printed substrates, whether electronic, chemical, or biological in nature (VTT Technical Research Centre of Finland, 2012, p. 8).

The printed intelligence area has raised great interest both in the academia and among practitioners in recent years. This interest can be related to its ongoing pursuits aimed at changing the way we conduct business and live our lives; technologies developed within the area target to matters of 100 nanometres[2]. They can thus be included in a broad

[2] Following the 2011 Commission Recommendation on the definition of nanomaterials, they are defined here as "a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution,

manner to the field of nanotechnology. Annual conferences on the printed intelligence topic have shown over 20 % increases in attendance and numbers of exhibitors (VTT Technical Research Centre of Finland, 2013, 6). The market forecasts for printed electronics have estimated the field to generate more than 250 million dollars revenue by 2025 (VTT Technical Research Centre of Finland, 2009, p. 6).

Since the 1990s, remarkable public investments have been made in Finland related to this field. The manufacturing infrastructure for printed intelligence has been developed. Efforts have also been made to create a whole business sector around printed intelligence. Together, the activities have aimed at developing disruptive technological innovations which not only advance the high-volume manufacturing of everyday products within various existing industries, but also the creation of new markets for printed intelligence based products. VTT Centre for Printed Intelligence is today one of the world's leading centres in this emerging market.

In conclusion, the case of the intelligent paper provides first and foremost a relevant networked platform to empirically learn more about how and why a network of technological innovation forms as a real life 'system'. A 'system', which is social, technological, economic, and political in character. Besides providing this networked platform and thus an opportunity to study network formation of technological innovation as a real life 'socio-techno-economic-political system', the case of the intelligent paper as part of this emerging printed intelligence market also gives a timely platform to empirically learn more about the interconnectedness of networks and technological innovations from a processual, sociomaterial viewpoint. Additionally, actor-network theoretical view has been applied in studies of the paper and printing industry in Finland, more specifically within Finnish forest industry sector (Peltonen & Tikkanen, 2005) and among Finnish pulp and paper corporations (Aspara, 2007).

1.4 Research purpose and questions

The purpose of this study is to describe and analyze the network formation of technological innovation. To achieve this purpose, I ask:

How does a network of technological innovation form?

and thus

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one or more external dimensions is in the size range 1 nm-100 nm. In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution threshold of 50 % may be replaced by a threshold between 1 and 50 %. […]" (European Commission, Commission Recommendation 2011/696/EU, OJ L 275/39).

- *What kinds of actors can be defined and how are they related to each other in the network formation of technological innovation?*
- *How do the actors and their relationships shape the network trajectory?*
- *How does the concept of translation inform the trajectory?*

Studying the network formation of technological innovation as processes generally (Araujo & Easton, 2012; Bizzi & Langley, 2012; Halinen & Törnroos, 2005; Halinen et al., 2012; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock & Coviello, 2010;) and as sociomaterial processes specifically (e.g., Callon, 1986a; Latour, 2005; Law, 2004, 2006) calls for approaching the network formation of technological innovation in a holistic and process driven manner. This view will be captured by adopting material constructionist research philosophy (Demeritt, 1998) and consequently materially relativist style of thinking (Law, 1991b, 2004). These approaches will give an opportunity for me to become sensitized to materiality, process, conflict, and interests when scrutinizing the network formation of technological innovation both theoretically and empirically. They also position this study in the context of construction (Hammersley, 2011); I will draw analytical insights from many sources – business networks, social networks, entrepreneurial networks, actor-networks, and the empirical case of the intelligent paper – and use these in describing and analyzing the network formation of technological innovation.

Consequently, I will review the existing network literature in business context, namely social networks, business networks, and entrepreneurial networks. I will present two different ways of theorizing networks, namely the level of analysis (i.e., the actor or the whole network) and the focus of the study (i.e., whether they concern the causes or the consequences of the networks). Building on these two ways, I will categorize the studies through two theoretical angles depicting the network formation (i.e., reasons for network formation and network formation in different levels). Then, by conceptualising the network formation of technological innovation as the network trajectory, I will theoretically identify three distinct network trajectories. These will be called a goal-based, opportunity-based, and integrated network trajectory.

The contemplation of these three trajectories leads to three shortcomings of this view: (1) heavy emphasis has been put on humans and their relationships as principal carriers of technological innovation activities, (2) nonhumans and their relationships have only been treated as instruments in these activities, and (3) the human parties have rather deterministically and linearly been seen to influence and be influenced by the networks within which they are embedded while engaging in technological innovation activities. To transcend these shortcomings, I will introduce actor-network theory. This theoretical approach enables deconstructing (1) the dualism between humans and nonhumans; they both are to be seen as active participants in the network formation of

technological innovation, (2) micro and macro; the size of actors is not determined by their dimensional basis but by the influence they have on the activities and entities around them while engaging in the network formation of technological innovation and (3) content and context; a network equals with a technological innovation and vice versa. I will also conceptualize the network formation of technological innovation as a process of translation and analytically reflect upon studies that have utilised the four-phase translation model by Callon (1986a). In doing so, I will also introduce certain relational and somewhat metaphorical words not previously used in actor-network theoretical accounts (or the network studies in business context), namely pack and filtering.

The actor-network theoretical view to network formation of technological innovation calls for an understanding of the social as flat (Latour, 2005). This will be done in this study by adopting the basic ideology of case research (Ragin & Becker, 1992; Stake, 1995, 2005) complemented with certain distinctive principles from actor-network theory. These principles include agnosticism, that is, there are no a priori assumptions of actors and their relationships, generalized symmetry, that is, there is no a priori asymmetry upon actors, and free association, that is, there is no a priori distinction between 'man' and nature (Callon, 1986a; Latour, 2005). Quoting Mützel (2009, p. 876): "[Actor-network theory's] Analytical focus is first on the multifaceted interconnections of a local, egocentric network of an actor, before moving to the next connected local bundle of entanglements. Eventually these shifts and redefinitions between one micro-network of associations to the next over space and time add up to a larger narrative on transformations of ideas and practices." The orientation to methodology in this study will hence be holistic, meaning that the analysis will stay at the level of actor-networks rather than individuals participating in the network formation of technological innovation.

I have generated a total of 708 pages of research data about the case of technological innovation called the intelligent paper in the study period of approximately 13 years, thus from ~1997 to 2009. I have conducted interviews and gathered documents, such as for instance annual reports, research publications, presentations, patents, company webpages, and brochures.

I have narrated the network formation of technological innovation on the basis of this data together with the conceptualisation of the network formation of technological innovation as a process of translation and the heuristic utilisation of Callon's (1986a) four-phase translation model. Additionally, I have complemented the model with introducing certain relational and somewhat metaphorical words (i.e., pack and filtering). This narration provides a multifaceted and empirically grounded understanding of the network formation of technological innovation, which is full of noise and disturbances. It displays several competing packs and consequently several competing heterogeneous networks including multiple human and nonhuman actors, their actions, and their

interconnected relationships to each other while forming the network and consequently the technological innovation. It also reveals multiple phases during which these packs get continually reconfigured, transformed, and finally revitalised into one more coherent pack as well as different strategies through which actors continually try to stabilise these configurations.

With the help of this narration, I am able to communicate to the reader how (and why) a network of technological innovation forms and what kinds of implications it provides for the network studies in business context generally and for networks as processes view specifically. Interpreting the case of the intelligent paper as a process of translation and as a sociomaterial network trajectory, I build a revised understanding of the network formation of technological innovation. I broaden the current understanding of the networks as processes view (Ahuja et al., 2012; Halinen & Törnroos, 2005; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock & Coviello, 2010) generally and the strong process view to networks specifically (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012). I do this by pursuing the thought that the network of technological innovation concerns continually unfolding packs. These packs are heterogeneous networks; they are equipped with entanglements of humans, nonhumans and their interconnected relationships. The formation of these packs plays out as a process of translation and gets depicted as a sociomaterial network trajectory.

Contrary to Callon (1986a), in this study the translation process comprises of four main phases: setting the agenda, forming the pack through performing various negotiations, potential betrayals, and filtering the spokesperson. These main phases involve multiple sub-phases of 're' during which the network of technological innovation is formed in a dialectical manner. Within these processes, concrete development paths are opened up and guided by the nonhuman actors engaged in the formation of network and consequently the technological innovation. Also, the collaborative development work as well as the technology developers' personal career opportunities that are used by the principal actors to seduce and enrol critical actors in the network of technological innovation are depicted.

Furthermore, in this study these dialectical network formation processes get depicted as a sociomaterial network trajectory. This trajectory complements the other three network trajectories identified from the network studies in business context in terms of these packs – heterogeneous networks – and the continual power plays occurring while the actors are engaging in the network formation of technological innovation (thus, how the packs get formed and enacted, including filtering). It also offers a broader explanatory frame to potential and actual courses of network formation of technological innovation. This trajectory can be seen as providing a continually moving arena for progressing a certain pack and consequently a certain technological innovation as well as a continually moving arena for other packs and consequently other technological

innovations to potentially evolve – a viewpoint supported by quite recent actor-network studies (Nicolini, 2010; Schneider et al., 2012; for a related remark see also Nicolini et al., 2012, p. 622).

1.5 Study process

My research journey into network formation of technological innovation is depicted in Figure 1. It has not been a clear cut, straightforward and linear path. On the contrary, I have moved back and forth, from the empirical analysis to the literature and vice versa. Also, during the process I have re-formulated the research purpose and questions numerous times and applied different kinds of research methods. Finally, when writing this final report, I have corrected, rewritten, added, and deleted some parts. The things I have learnt during the process have certainly affected the whole research project and thus this final report of that process. Although I have felt distress from time to time, I still feel that the possibility of making continual changes during the research process is the greatest advantage of qualitative research – just as Eriksson & Kovalainen (2008, p. 31) have argued.

My initial interest in network dynamics can be traced back to my master thesis, in which I studied the market entry processes of large Finnish high technology companies to China from the business network perspective. When I started the PhD studies, I wanted to continue examining the processual aspects of networks. Selecting the final topic for the doctoral dissertation was, however, more or less an adventure into the world of networks research and 'beyond'. During this adventure, I was open to all kinds of topics related to networks, whether they were social, economic/industrial, historical, innovation, or heterogeneous. Some of these ceased to exist during the process (the historic perspective), whereas some became emphasised (social networks, business networks, entrepreneurial networks as the network studies in business context, and the actor-network theoretical view to networks).

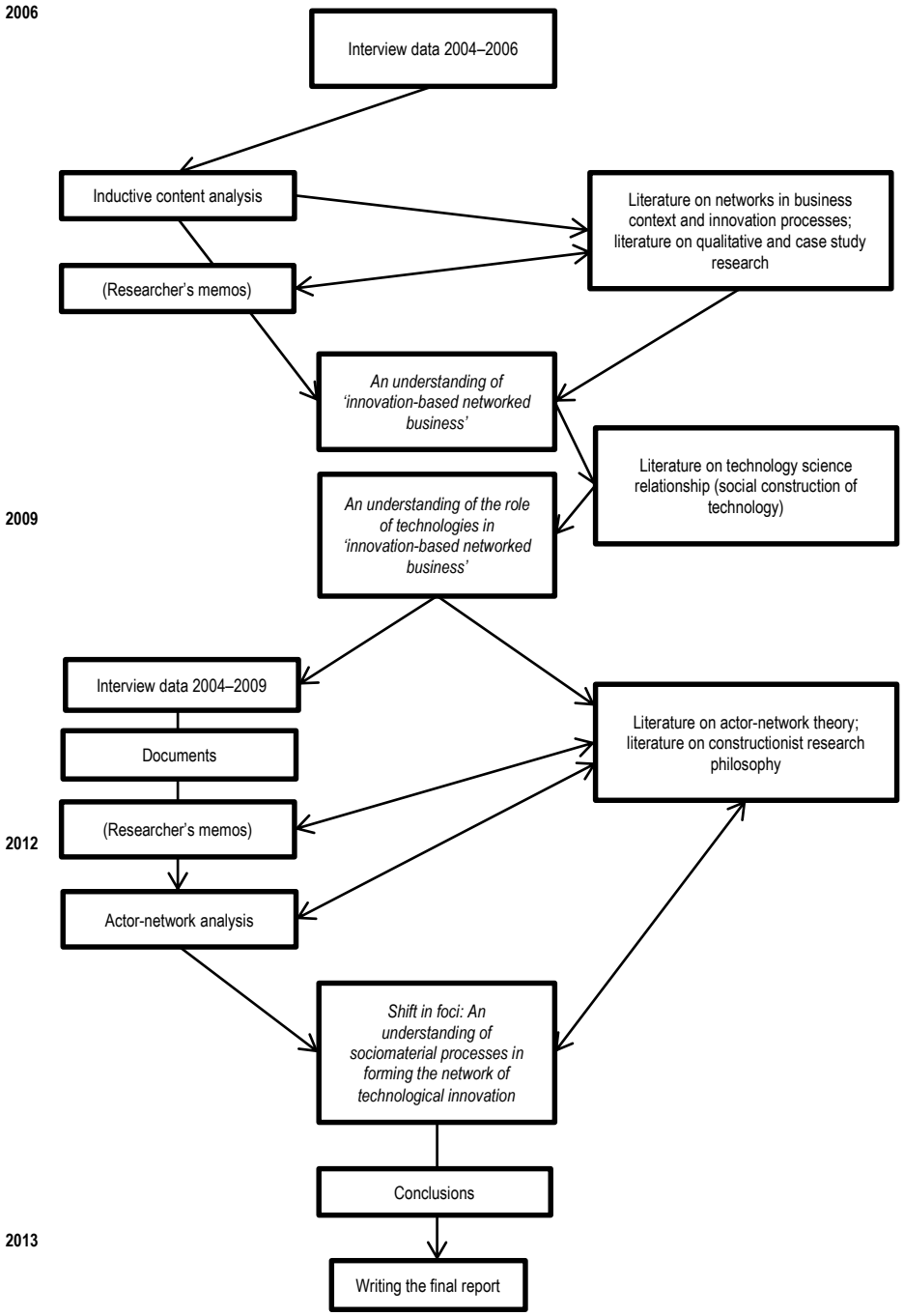

Figure 1. Research process of the study

I encountered actor-network theory as early as in 2006 as I was doing the compulsory PhD coursework. I doubted, however, whether actor-network theory would be ontologically, epistemologically, and methodologically too challenging to grasp for a beginning researcher like myself. I was also at the time impressed by studies conducted within the social networks field that emphasized how economic action is embedded in the social structure (e.g., Granovetter 1973, 1985) and how this embeddedness shapes organizational and economic outcomes (e.g., Burt, 1992; Uzzi, 1996, 1997). I pondered whether a process-oriented qualitative study would bring back something that the heavy emphasis on mathematic modelling with static visualisations had neglected. As a young management scholar, I was also interested in understanding the managerial side of networks, especially the mechanisms by which networks were orchestrated or managed (e.g., Dyer & Nobeoka, 2002; Dyer & Singh, 1998; Hardy et al., 2003; Håkansson & Ford, 2002; Möller & Halinen, 1999; Möller & Rajala, 2006, 2007; Möller & Svahn, 2006).

I reorganized these thoughts when I got access later in 2006 to interview data conducted in a technological innovation-oriented start-up firm that I call Alpha in this study. I consider gaining this access as the starting point for this study process. The process hence started from the empirical data. I utilized the method of inductive content analysis (Elo & Kyngäs, 2008; Franzosi, 2004) to reorganise interview data. I also wrote a few analytically oriented memos to better understand what the research phenomenon was and how I should approach it. Engaging thus with the research data produced the understanding that the research data depicted an innovation-based networked business as experienced by a few individuals in that firm (Lehtimäki et al., 2006; Mattila et al., 2007).

Despite these tentative empirical findings I achieved, I felt continual distrust over the aspect of 'innovation-based': what was actually the technological innovation that interviewees were talking about? and How did it affect the 'networked business' depicted? To find answers to these questions, I turned to studies focusing on technology-science relationships. More specifically, I read social constructivist studies of technology which argued that the making of technology innovations is a socially constructed process (Bijker, 1992; Pinch & Bijker, 1984, 1986).

Methodologically based on qualitative case histories and case studies of technological development, this approach acknowledged the interconnected and complex nature of the social and technical in technological innovation activities. It argued that a technological innovation process is affected by people, more specifically their interpretations about the particular technological innovations (interpretive flexibility), which then shapes the technical characteristics of innovations being developed over time (Garud and Karnøe, 2003; Pinch and Bijker, 1984; Bijker, 1987, 1992). These studies held relevant social groups (e.g., institutions, organizations, and groups of individuals), anti-groups and the interpretive flexibility of technologies as the locus of technological

innovation activities. They argued that technological innovations should not be seen as autonomous processes and driven by internal dynamics only, but as an active process in which technologies can be tracked down by identifying the meanings attributed to them by the relevant social groups (and anti-groups) as a network involved in their development (Bijker, 1992).

Although these studies advanced my understanding of technological innovations having a distinct role in 'innovation-based networked business', they made me yet reflect the role of technologies in the network. What would a network look like if I focused in more detail on the technologies described to me during interviews? Are there yet any other possibilities of approaching the technologies?

I then decided to find out how these questions could be theoretically and empirically addressed. This paved the way for me to take into consideration actor-network theory that I had previously abandoned. I started with early actor-network researchers (e.g., Callon, 1986a, 1986b, 1987; Callon & Latour, 1981; Callon & Law, 1982) and books about actor-network theory (e.g., Czarniawska & Hernes, 2005; Latour, 2005; Law, 2004; Law & Hassard, 1999). While doing this theoretical reading, I started to slowly realize that the inductive content analysis fell short in giving me answers to the questions I was asking. It neglected the sociomaterial processes in an 'innovation-based networked business' (although I had used different colours to sustain the temporal orientation) and more importantly, it reduced nonhuman actors to the role of instruments at best (Akrich, 1992).

Consequently, I made the decision to generate more research data and make another round of analysis where I would take into account also the aspects that the content analysis had missed. First, I gathered all the statements from the inductive content analysis that somehow related to nonhumans. Then, I journeyed into 'archives' to better trace these instrumentally treated actors. I also continued reading more recent actor-network theoretical studies, which utilised the four-phase translation model by Callon (1986a) and focused on (technological) innovation activities (Giesler, 2012; Harrisson & Laberge, 2002; Harty, 2010; Porsander, 2005; Schneider et al., 2012).

As I was re-engaging in processes of data generation, analysis and interpretation together with the theoretical reading on actor-networks, the research philosophy of the study as well as the study's purpose and questions changed. My interest shifted from the knowing mind (individuals in an 'innovation-based network business') to everyday sociomaterial processes (Hosking, 1999; Demeritt, 2002) taking place in forming the network and consequently the technological innovation. As a result, I no longer perceived the network formation of technological innovation as only related to (rational) human activity in which humans (rationally) add and subtract connections leading to a stable and predictable network of technological innovation (e.g., Ahuja, 2000a; Håkansson, 1987; Powell et al., 1996). My focus was on continually unfolding

sociomaterial processes as a certain arena in which multiple heterogeneous networks and consequently technological innovations get simultaneously generated, developed, abandoned, and disseminated (see also Nicolini, 2010; Schneider et al., 2012).

To conclude, my research journey has had many phases which have been closely intertwined with each other. In locating the case of the intelligent paper and understanding its value for learning opportunities to both academics and practitioners, I have gone from the data to theory and from the theory back to the data, generated more data, re-engaged in data analysis and interpretation, taken into account many events, occurrences, people, machines, and processes as well as stretched my intellectual limits to finally end up with this final thesis.

1.6 Structure of the report

The structure of this thesis is described in Figure 2. The thesis begins with the introduction chapter, including an introduction to the study's subject, defining the key concepts, presenting the research context, delineating the research questions and how they are approached as well as depicting the research process of the study and the structure of the thesis.

Chapter two reviews the literature related to the network formation of technological innovation. It begins by defining network formation and technological innovation, and continues by reviewing network studies in business context, namely social networks, business networks, and entrepreneurial networks. These studies are categorized through two theoretical angles depicting the network formation (i.e., reasons for network formation and network formation in different levels). Based on these studies, a theoretical model of network trajectories of technological innovation is presented in which the network formation of technological innovation is conceptualised as a network trajectory. These network trajectories are the goal-based, opportunity-based and integrated network trajectory. Next, actor-network theory is introduced together with the conceptualisation of the network formation of technological innovation as a process of translation (including the introduction of certain relational and somewhat metaphorical words, namely pack and filtering). The chapter ends with a synthesis.

Chapter three focuses on specifying the ontological, epistemological, and methodological choices of the empirical research of the study, and discussing the processes of data generation, analysis and interpretation.

Chapter four provides the analysis of the case of the intelligent paper in which the four-phase translation model by Callon (1986a) is applied in a heuristic manner.

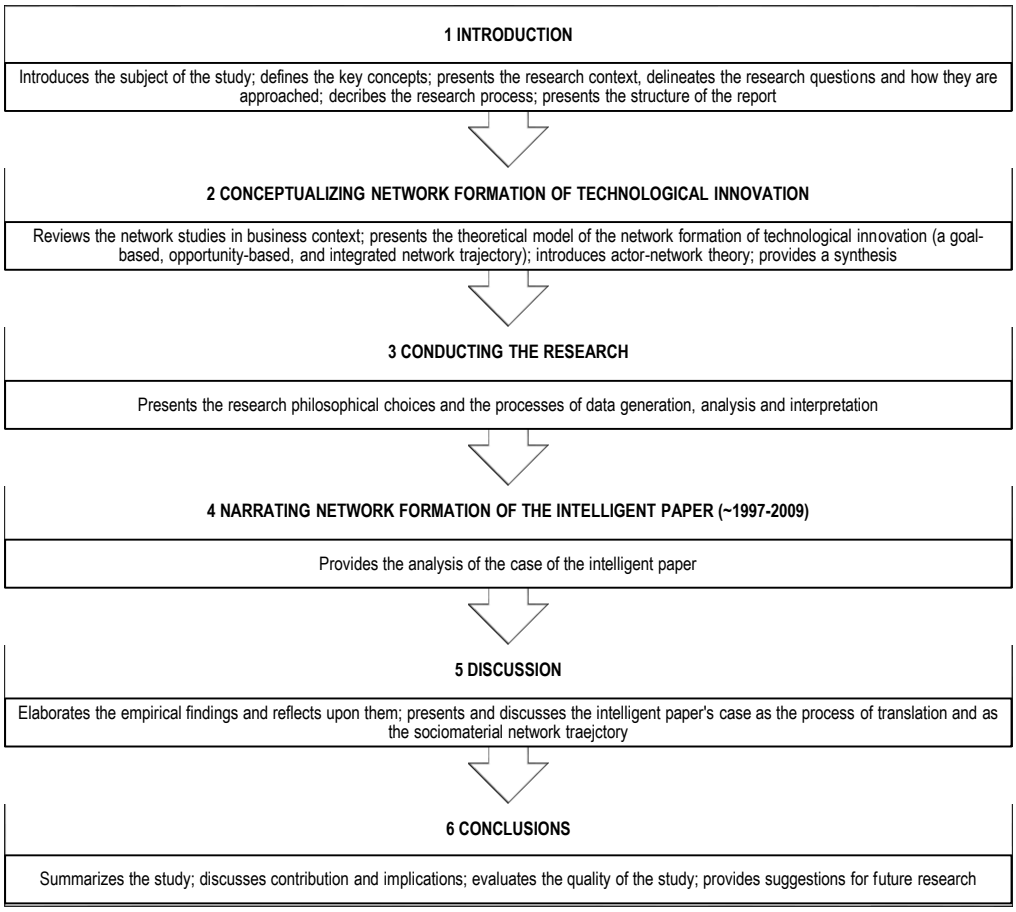

Figure 2. Structure of the report

Chapter five summarizes the empirical findings and reflects upon them. Thus, the interpretations and the interpretive implications of the intelligent paper's case as the process of translation and as the sociomaterial trajectory for the network studies in business context generally and to a networks as processes view specifically are presented and discussed.

Chapter six provides a summary of the study, its theoretical contributions and managerial implications as well as the assessment of its quality and future research directions.

2. CONCEPTUALIZING NETWORK FORMATION OF TECHNOLOGICAL INNOVATION

This chapter reviews the literature related to the network formation of technological innovation. First, I define the two key concepts of this study, network formation and technological innovation. Second, I discuss network studies in business context, more specifically within the literatures on social networks, business networks, and entrepreneurial networks. I present two different ways of theorizing networks, namely the level of analysis (the actor or the whole networks) and the focus of the study (the consequences or the causes of networks). Building on these two ways, the literature is next categorized into two different angles explaining network formation (reasons for network formation and network formation in different levels). Third, I present a theoretical model where network formation of technological innovation is conceptualised as a network trajectory. Fourth, the chapter introduces actor-network theory and conceptualizes the network formation of technological innovation as a process of translation (including the introduction of certain relational and somewhat metaphorical words, namely pack and filtering). In this process, heterogeneous elements find their place and are kept in place by those who have received authorship of speaking over suppressed others – at least momentarily. The chapter ends with a synthesis.

2.1 Defining the concepts of network formation and technological innovation

In order to understand the phenomenon of network formation of technological innovation, it is first important to offer some definitions on network and network formation as well as technology and innovation combined together. These terms (i.e., network formation and technological innovation) are outlined first through studies on networks in business context and studies on technological innovation. Then, the actor-network theoretical lens to both of these terms is provided, emphasising continuously unfolding, never-ending social-material processes rather than stable, predefined structures of entrepreneurs and/or business organizations for future profit.

2.1.1 Network formation

Networks have a long history. Rooted in theories of social structure and exchange, the network view in sociology started from the idea presented in the 1950s that the configuration of cross-cutting interpersonal bonds is somehow connected with the actions of these persons and with the social institutions (e.g., organisations) of their society (Barnes, 1954). In organizational research, more specifically in organizational behaviour research, the network concept can be traced back to the work of Roethlisberger and Dickson (1949), in which they described and emphasized the importance of informal networks in organizations. Since these seminal works, the network perspective has gained an extensive amount of interest among researchers in various disciplines such as sociology, psychology, anthropology, (strategic) management, and organizational studies. This boom is part of a general shift "away from individualist, essentialist, and atomistic explanations toward more relational, contextual, and systemic understandings" (Borgatti & Foster, 2003, p. 991).

Throughout the decades of academic interest in networks, many researchers have criticized the network concept for acquiring the character of an umbrella, a catch-all term under which a variety of theoretical and methodological positions in the social sciences have sought refuge (Araujo & Easton, 1996, p. 64; see also Nohria, 1992, p. 3). Those expressing anxiety about the increased metaphorical treatment of the network concept basically question whether it will lead to a terminological jungle in which everyone can plant his/her own tree. Such a jungle would easily result in misapplication of the concept and inconsistent research findings (Hoang & Antoncic, 2003, p. 172; Jack, 2010, p. 121; O'Donnell et al., 2001, p. 749). Those favouring the increased metaphorical treatment of the network concept embrace its inherently accepting and open character. The network concept enables theorizing without unwarranted constraint (Latour, 1996, p. 370); "More supple than the notion of system, more historical than the notion of structure, more empirical than the notion of complexity, the idea of network is the Adriane's thread of these interwoven stories… [which] remain more invisible than spiderwebs" (Latour, 1993, pp. 3–4)

For the purpose of this study, the term network is understood as an abstract notion referring to a set of actors and relationships which connect them (Fombrun, 1982). This network forms, that is, it emerges, develops/evolves, and even breaks down, when actors add and/or subtract other actors (and their connecting relationships) to/from a network – often to/from more than one (Latour, 2005, p. 28). These definitions are broad enough for a researcher to utilise her/his own imagination in determining the actors, the content of their connecting relationships, and how this network actually forms in a given context.

Previous network studies in business context have focused on individuals (e.g., entrepreneurs and business angles) and firms/companies as the main actors. These

studies have to a large extent shared the basic assumption that the social systems of individuals and/or groups have an impact on the 'upper level' of inter-organizational networks (e.g., Brass et al., 2004; Chetty & Agndal, 2008; Grandori & Soda, 1995; Hung, 2006). These interpersonal networks have been conceptualized not only as sets of cognitions inside the heads of individuals, but rather as structures of constraint and opportunity negotiated and reinforced between interacting individuals (Boorman & White, 1976, p. 1442; Kilduff and Tsai, 2003, p. 5). Special focus regarding these inter-organizational networks has been on the strength of relationships and what flows through them (Granovetter, 1973). Consequently, the studies have made an analytic distinction between strong (i.e., formal) and weak (i.e., informal and personal) network relationships. The grounding argument has been that weak tie relationships (indirect and informal ties) yield a better access to new information and opportunities whereas strong tie relationships (direct and formal ties) restrict information flows from outside sources (Granovetter, 1973; cf. Burt, 1992). Especially structural sociological studies have considered the extent to which actors are connected directly to each other and whether there are possibilities for brokerage, that is, to construct network relationships that connect the disconnected actors (Burt, 1992).

Also, it has been argued that different types of network relationships affect the flows of ties and hence the outcomes of inter-organizational networking activities. Through different kinds of network relationships the actors are thus assumed to be rationally and actively exploiting the network they find themselves in or create for themselves (e.g., Burt, 1992; Granovetter, 1973). A common way to approach these different network relationships has been to consider them as either formal or informal. The degree of formalisation is seen as being dependent on the purpose of the network (Chetty & Agndal, 2008) and whether the inter-organizational networking relationships are based on contractual or non-contractual arrangements (Grandori & Soda, 1995, pp. 199–201). Thus, a formal network is contractually formed to fulfil a specific purpose or a shared goal (for an example of this goal-directed inter-organizational, multilateral networking behaviour, see e.g., Human & Provan, 2000). This type usually refers to (strategic) alliances and joint ventures (e.g., Eisenhardt & Schoonhoven, 1996; Gulati, 1998) that occupy either direct or both direct and indirect network relationships (e.g., Ahuja, 2000a). Also the strategic networks of companies (Jarillo, 1995) can be included in these formal networks. The informal network in turn involves serendipitous network processes without contract-based guidance from any (central) network actor concerning the goals or the strategy (Chetty & Agndal, 2008; Kilduff & Tsai, 2003, p. 90); it thus forms naturally as the relationships between its members develop through interaction.

The above explained view to network formation provides a relational lens to understand that social systems are made of human actors and their relationships, and that this constellation emerges and expands (and/or breaks down) due to intentional

and/or unintentional actions of humans in the network where they are embedded. However, this view is blind to any other alternatives than humans as actors. Consequently, the view is not able to account for any other relationships between actors in the network than human relationships. To broaden this view, I have followed studies that emphasise sociomateriality, more specifically actor-network theory (e.g., Callon, 1986a, 1991; Latour, 2005; Law & Callon, 1992). Actors in this study are not considered as predefined and privileged groups of humans. Instead, they are being made; they are a hybrid and empirically based category of human and nonhuman entities that can act and influence other entities and that are continuously open to redefinition and transformation (e.g., Callon, 1987, 1991; see also Latour, 2005, pp. 28, 46). In this study, the term actor is used to refer to a person, a firm, a research project, a machine, a device, and a production method, for instance.

Actors are seen to be made out of various entities swarming towards them (Latour, 2005, p. 46). As a result, the focus in studying actors' relationships is on how (and why) they hinder and/or enable the actors to acquire their actorial shapes (Law & Callon, 1992). This focus differentiates my approach from previous studies focusing on the strength or formality of relationships. The sociomaterial process of acquiring actorial shapes which results in the authority to speak over or act on behalf of others is called translation (Callon, 1986a, 1991; Callon & Latour, 1981). It thus refers to "all the negotiations, intrigues, calculations, acts of persuasion and violence, thanks to which an actor or force takes, or causes to be conferred on itself, authority to speak or act behalf of another actor or force" (Callon & Latour, 1981, p. 279).

This concept of translation rejects seeing the network formation of technological innovation as a life cycle. A life cycle approach would assume that the network formation of technological innovation starts from the birth of certain actors and their connecting relationships and ends when this network ceases to exist for one or more reasons (for more on process theories, see Van de Ven & Poole, 1995). Rather, it emphasizes the understanding that network formation of technological innovation should be approached as a mess of overlapping heterogeneous networks involving humans, nonhuman and their interconnected relationships which are confronted by continuous and contradictory movements that are not necessarily evolutionary or teleological but certainly dialectical. These movements (and thus the underlying power plays of actors) are ongoing throughout the forming of the network and consequently the technological innovation. The network is only temporally stabilised by the actor ('the author') who manages to lock others into their places and keep them there (Callon, 1986a, 1991; see also Bloomfield & Vurdubakis, 1999). From this viewpoint, thus, the network formation of technological innovation should be regarded as an achievement of long sociomaterial struggles rather than stable (predictable) order of 'things' (for a similar remark, see Akrich, 1992; Schneider et al., 2012).

2.1.2 Technological innovation

Technological innovation is a composite concept. It contains two amorphous terms which have no coherent or consistent meaning in the literature. Instead, it seems that there are as many definitions as there are researchers working with these concepts. Both terms – technology and innovation – are present in almost all aspects of organizational life. These two terms have even sometimes been used as synonyms for each other (Nieto, 2004). If used interchangeably, however, some very important aspects are ignored, namely, how the term technology is intertwined with the physical matter of ongoing human action (e.g., Bijker 1992; Law & Callon 1992; Pinch & Bijker, 1984; Nicolini, 2010; Schneider et al., 2012) and the term innovation with newness (Johannessen et al., 2001; Wirtz & Janssen, 2010) – and not vice versa.

The combination of 'technology' and 'innovation' suggests that a technological innovation – or a "technology complex" (Fleck, 2004; Fleck & Howells, 2001; Howells, 2005) – encompasses a wide range of circumstances and historical epochs as well as involves human activities and artefacts that shape and reshape both the 'hardware' and the people involved in technological innovation development (Geels, 2004; Geels & Schot, 2007; Law & Callon, 1992; Pinch & Bijker, 1984; Nicolini, 2010). The aim of a technological innovation is ultimately to introduce new ideas to the market such as new technologies, products, services, procedures, policies, and organizational forms, and also profit from them (Dosi, 1982, Teece, 1986, 1996).

The literature on technological innovation usually considers it as the result of an assemble of ideas, information, technology, codified knowledge, and know-how that cannot be traced back to any single source or party but to a network of actors and their relationships (Garud & Rappa, 1994; Howells, 2005; Huggins, 2010; Håkansson, 1987; Rampersad et al., 2010; Teece, 1986, 1996). These actors comprising the network are not only those who discover new ideas such as engineers (Bijker, 1992), scientists, or people working in R&D departments (Argyres & Silverman, 2004) or those on the supply (Håkansson & Waluszewski, 2002; Petersen et al. 2005), customer and/or user side (e.g., Harty, 2010; von Hippel, 1988; Håkansson, 1987), but also those who possess complementary assets (Teece, 1986, 1996); privately or publicly funded technological innovation development activities (Ferrary & Granovetter, 2009; Martin & Scott, 2000), for instance. Further, this constellation should not only be limited to the actors who create it. A whole set of materials also circulates between actors, shaping and making technological innovations (e.g., Callon, 1991; Geels, 2004; Geels & Schot, 2007; Law and Callon, 1992; Nicolini, 2010).

As a consequence, networks that are involved and depicted within technological innovation processes have been called industrial districts (Becattini, 1991, 2002), innovative milieus (Crevoisier, 2004; Crevoisier & Maillat, 1991), new industrial spaces

(Scott, 1988), clusters (Porter, 1998), networks of innovators (DeBresson & Amesse, 1991), networks of innovation (Saxenian, 1996), innovation networks (e.g., Conway & Steward, 1998; Ferrary & Granovetter, 2009; Perrin, 1991); networked innovation (Swan & Scarbrough, 2005); techno-economic networks (e.g., Callon, 1991, 1992; Callon et al., 1992), and socio-technical systems (e.g., Geels, 2004; Geels & Kemp, 2007; Geels & Schot, 2007).

While the literature on inter-organizational networks in innovation generation increasingly locates technological innovation in networks (Powell et al., 1996; Raesfeld et al., 2012), the steps and activities through which technological innovations actually move to the marketplace are regarded in quite a linear manner. As a result, technological innovation is often presented more or less as a multiphase process driven by human activity which goes through different (linear) phases toward the products/services and their market introduction (e.g., Fleck, 2000; Khilji et al., 2006; Thompson, 1965; Tornatsky et al., 1983; Utterback, 1971, 1994). These processes are argued to be affected by historical events and choices made in the past and the trajectory they tend to follow (e.g., Dosi, 1982; Nieto, 2004; Teece, 1996). Here, technology is seen to evolve in cumulative and path-dependent ways, channelled by a limited set of possible technological alternatives perceived by the people involved in the process (Dosi 1982; Håkansson & Lundgren, 1995; Håkansson & Waluszewski, 2002; Linton & Walsh, 2008; Raesfeld et al., 2012; Shea, 2005; Teece, 1986, 1996).

This view has increasingly highlighted that technology emergence cannot be attributed to any one single actor but to multiple actors participating in the technological innovation process. Yet, it easily leads to technological determinism. The development of technological innovations is thus seen to follow some predetermined paths irrespective of human action. According to Dosi (1982), these paths are the normal problem solving activities that are framed by the wider technological paradigms in which they are embedded. These technological paradigms prevent the human participants from seeing other directions or other technological possibilities outside these paradigms.

To avoid the alleged technological determinism and the decoupling of artefacts from human action pervasive in previous research, Geels together with his colleagues (Geels & Kemp, 2007; Geels & Schot, 2007; see also Geels, 2010) have proposed that researchers should adopt a multi-level perspective. This means that the researcher should recognise the conjuncture of developments within the levels of technological niches (i.e., a protected micro level space in which radical innovations emerge), socio-technical regime (i.e., a meso-level accommodating broader community of social groups and their alignment of activities), and socio-technical landscape (i.e., a macro level which is beyond the direct influence of niche and regime actors). This can be done by approaching technological innovations as socio-technical systems that are – quoting Geels and Kemp (2007, p. 442) – "made up by a cluster of elements, involving technology, science,

regulation, user practices, markets, cultural meaning, infrastructure, production and supply networks". Furthermore, these socio-technical systems get stabilised not because of different path-dependencies or blindness and consequently inabilities of technology developers to see other technological alternatives, but because of the established roles, rules, and ways of thinking and doing while developing technologies as well as because of institutional arrangements, formal regulations, adapted lifestyles of people surrounding these technologies under development (Geels & Kemp, 2007; Geels & Schot, 2007).

Although the multi-level perspective underscores the existence of different variables and processes interacting with a regime in different ways, it can still be regarded as a macro-level model. Also, within this model, changes occur during (very) long periods of time. This is challenging for a researcher, especially when it comes to data generation and analysis. (For related remarks, see Geels & Schot, 2007, p. 414.) As such, this study deliberately takes a different standpoint. By analogously following Latour's (2005, p. 7) understanding of organizations, this study argues that technological innovations do not have to be placed into a 'wider social frame' such as into niches, regimes, and landscapes. This is because technological innovations are practically nested in 'wider' sets of affairs. (Ibid) Hereby, the distinction between content and context is broken. Technological innovation is therefore to be seen as a bricolage (Latour, 1999b), as a mixture of heterogeneous animate and inanimate elements which are concurrently used to create and disseminate new forms and order.

This viewpoint rejects the notion that technologies would embody some specific stable and social structures after they have been developed. Rather, technologies are constrained to continuous movement (Latour, 2005; Law, 2006) blurring also the boundaries between their generation and dissemination. Throughout their interlinked engagements, both technologies (nonhumans) and people (human actors) acquire actorial identities in relation to each other. They also form temporal structures that shape the technological innovation journey in question (Law & Callon, 1992; Nicolini, 2010; Schneider, 2012). Consequently, a technological innovation does not merely exist in a stable state a priori to diffusion and cannot only be considered as a distinct artefact placed in various spaces, such as markets or networks of people in organizations. Instead, a technological innovation gets constructed in the longer run through complex and reciprocal interactions introduced and disseminated by various human and nonhuman actors and intermediaries. As a result, a technological innovation from the actor-network viewpoint can be considered as a network in its own right; a network in which multiple (human and nonhuman) actors are participating.

2.2 Reviewing network studies in business context

This chapter reviews the literature of network formation in network studies in business context. Instead of providing an overview to different network approaches (for a review, see e.g., Araujo & Easton, 1996; Grandori & Soda, 1995), I will focus on specific network studies, namely social networks, business networks, and entrepreneurial networks. Firstly, I will present two different ways of theorizing networks (the level of analysis as well as the perspectives of consequences and causes). To explain network formation more profoundly, I will build on these two ways and categorize the literature into two different angles (i.e., reasons for network formation and network formation in different levels). Finally, by conceptualizing network formation of technological innovation as a network trajectory, a theoretical model with three network trajectories is presented.

2.2.1 Classification of social, business and entrepreneurial network studies

Theorizing about networks in business context comes usually from two different but complementary levels of analysis. These are the actor level (individual or business/organizational actors) and the network level (the whole networks) (Axelsson, 1995; Provan et al., 2007), which have also been called the micro-level versus the macro-level network focus (Galaskiewicz & Wasserman, 1994) and especially within the social network studies as egocentric and the whole network (Kilduff & Tsai, 2003).

Stemming from social network research, Borgatti and Foster (2003) offer an alternative way of theorizing by arguing that the fundamental differentiating dimension is whether the study is about the causes of network structures or the consequences. This line of reasoning also followed in entrepreneurship research (Hoang & Antoncic, 2003; Slotte-Kock & Coviello, 2010) and implicitly in business network research (Ebers, 1997a).

Generally speaking, the bulk of social network research has focused on consequences of networks, thus, motivations and/or conditions for network formation (for a review, see e.g., Brass et al., 2004; Borgatti & Foster, 2003; Provan et al., 2007; see also Oliver, 1990). To the extent that networks have been investigated in terms of change, the tendency has been to model simulated rather actual network dynamics (Carley, 1999). Borgatti and Foster (2003, p. 1000) argue that the emphasis on demonstrating the importance of networks in the outcomes of organizational life comes from the structuralist heritage of the field as well as the efforts to achieve legitimacy in the field of research. Until networks had legitimacy, thus, there was no use in publishing studies on how networks come to be or change over time.

Business network research, on the contrary, has from its beginning been interested in both patterns (structures) and processes through which business relationships get initiated, developed, maintained, and ended. The interest has thus been in the causes of networks including the pattern of interaction between business parties and processes emerging within interaction. For instance, over three decades ago Håkansson (1982) already proposed an interaction model in which the marketing and purchasing of industrial goods was seen as an interaction process between two parties (dyads). This was a process which included the exchange of resources, social exchange, adaptation and coordination processes. The entrepreneurial network research has to some extent followed the same line of reasoning as business network research. Study has focused on phenomena of networked entrepreneurship, more specifically on the content of entrepreneurial relationships, their governance (trust) as well as how networks impact on entrepreneurial activity and vice versa (for a review, see Hoang & Antoncic, 2003; Slotte-Kock & Coviello, 2010).

Additionally, some methodological studies within the business network research stream have recently been published with the focus on processes in and around networks (Araujo & Easton, 2012; Bizzi & Langley, 2012; Halinen et al., 2012; see also Halinen & Törnroos, 1995, 2005; Halinen et al., 1999; Hedaa & Törnroos, 2008; Hite & Hesterly, 2001; Slotte-Kock & Coviello, 2010). These studies can be seen as a response to the research gap still related to the causes perspective, thus, the lack of studies concerning network processes (Knoben et al., 2006; Parkhe et al., 2006; see also Borgatti & Foster, 2003, p. 1000; Jack, 2010, p. 129). These studies have developed the process concept from concerning changes in entities, that is, "the progression (i.e., the order and sequence) of events in an organizational entity's existence over time" (Van de Ven & Poole, 1995, p. 512) into seeing it as flux; "to think more in terms of verbs or actions, rather than nouns […] and to try to capture the dynamics of the everyday work of creating and maintaining and disrupting networks in interaction" (Bizzi & Langley, 2012, p. 231).

In particular, Hoang and Antoncic (2003) within the entrepreneurial research stream have categorized network studies as either focusing on how the entrepreneurial processes impact the development of inter-organizational networks (i.e., networks as a dependent variable) or how networks impact the entrepreneurial processes and outcomes (i.e., networks as an independent variable). Building on this conceptualisation and the process perspectives proposed by Van de Ven (1992) and Van de Ven and Poole (1995), Slotte-Kock and Coviello (2010) have reclassified network studies into two camps: (1) network studies which consider the entrepreneurial/business processes' impact on the network development, and consequently, reflecting either Van de Ven's (1992) second or third process meaning (i.e., the causes perspective), and (2) network studies in which the process is not directly observed but in which a process story or logic

is used to explain why networks exert a causal influence on entrepreneurial/business processes and outcomes (i.e., the consequences perspective).

Regarding the business networks research stream, Ebers (1997a) in turn has firstly followed the classification of micro and macro level focus by identifying three levels of analysis: the actor level, the level of pre-existing relationships among actors, and the institutional level. He has then implicitly followed the causes and consequences perspectives by identifying topics to which previous research has concentrated. At the actor level, he has identified different kinds of motivations of actors to build network relationships. At the relational and institutional levels (combined together), Ebers (ibid) has identified different kinds of contingencies that enable and/or disable inter-organizational cooperation.

Building on the two alternative ways of theorizing networks in business context, I have categorized network studies in business context as illustrated in Figure 3. This categorization follows more or less 'the implicit way' (Ebers (1997a). The decision for this stems basically from the observed difficulty of distinguishing whether the studies represent the perspective of causes or consequences. Hence, depending on the ultimate focus of arguments some network studies in business context related to network formation can be included under both perspectives and consequently, how they are placed in the classification is arbitrary (for a similar viewpoint, see Slotte-Kock & Coviello, 2010, p. 35). For instance, even though their studies concern network development and as such could be included under the causes perspective, Hite and Hesterly (2001), and Larson and Starr (1993) can also be included in the consequences perspective, because the focus of the first is on exploring networks that are "more conducive to the success of new firms" (Hite & Hesterly, 2001, p. 275) and the latter on organizational formation.

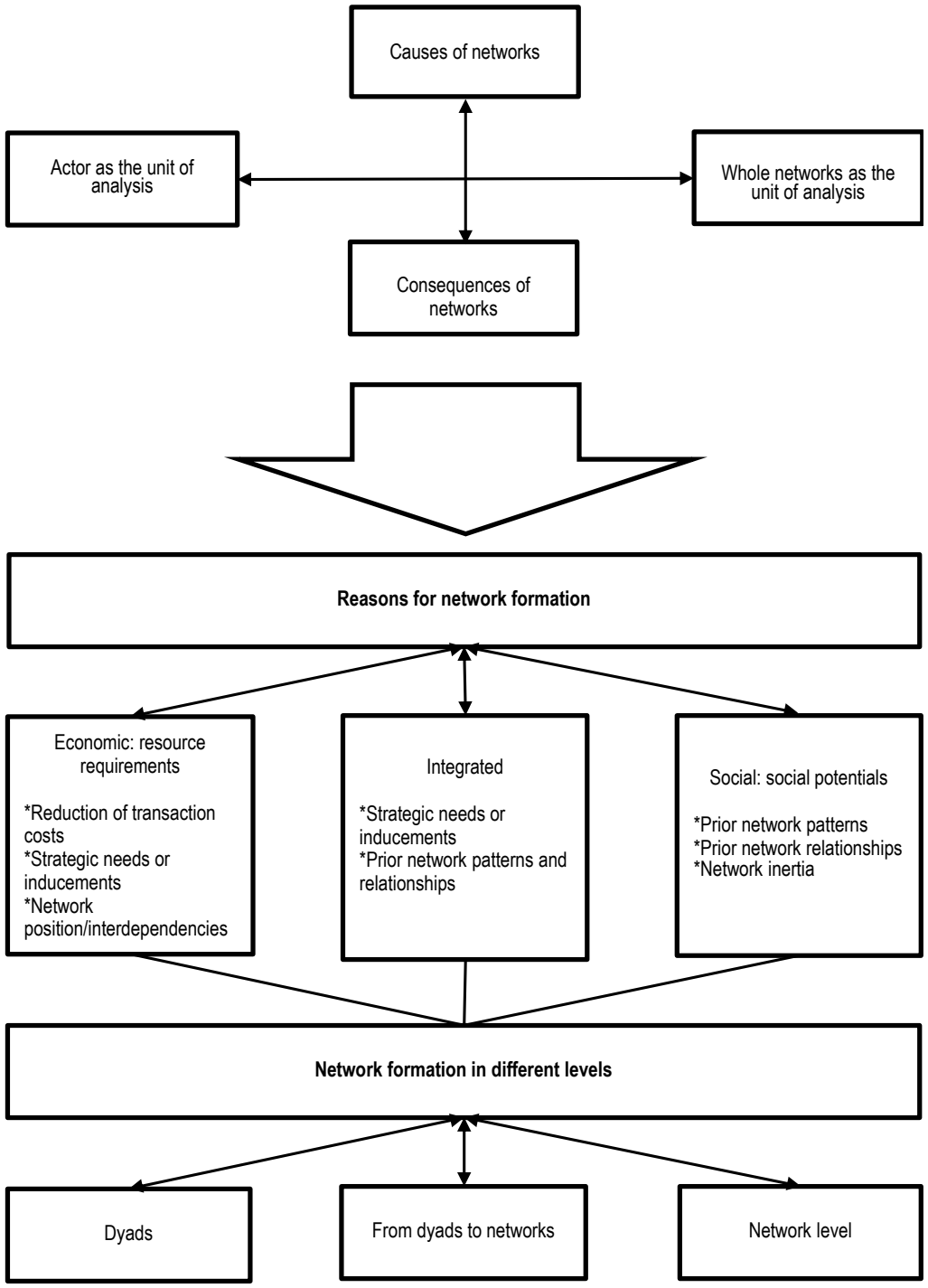

Figure 3. Theoretical angles to network formation

Consequently, the two-dimensional matrix in the upper part of Figure 3 illustrates the basis of the categorization, that is, the levels of analysis (horizontal axis) as well as the perspectives of causes and consequences (vertical axis). The lower part of the figure to which the white arrow points at illustrates the two theoretical angles (bolded) which are utilized in categorizing the network studies in business context, namely reasons for network formation and network formation in different levels. These angles and their constituting dimensions are linked by the two-headed arrows. The first theoretical angle (i.e., reasons for network formation) relates more or less to the consequences perspective. It thus focuses on key underlying enablers and disablers that induce or hinder the network formation (see Oliver, 1990, p. 241). The second theoretical angle (i.e., network formation in different levels) relates to the levels of analysis and processes through which different reasons get translated into particular network structures (see Ebers, 1997a, p. 13), that is, more or less to the causes perspective. The three black lines between these two theoretical angles illustrate their inter-linked connections.

The next two sub-chapters provide a review of the previous network studies in business context following Figure 3. First, I provide an overview to the reasons for network formation and their constituting dimensions. Then, I review the previous network studies by categorizing them into three different levels (i.e., dyads, from dyads to networks, and network level). Within these levels, I also provide an overview to processes taking place in the network formation. In doing so, I clarify dimensions to network formation more thoroughly than what has been done previously (Ebers, 1997a). Perhaps even more importantly, I enrich the dimensions by focusing on multiple sources of literature, namely research on social networks, business networks, and entrepreneurial networks in business context.

2.2.2 Reasons for network formation

In this sub-chapter, I provide an overview to network studies in business context classified as reasons for network formation. Reasons refer to key underlying enablers and disablers that induce or hinder the network formation (see Oliver, 1990, p. 241). In Table 1, I provide a summary of these perspectives, which in parallel with the levels explains the network formation.

Table 1. Reasons for network formation

Perspective	Enablers/disablers	Theoretical sources	Key driving forces to network formation	Exemplary works
Economic: resource requirements	Reduction of transaction costs	Economics	Efficiency (uncertainty)	Coase, 1937; Thorelli, 1986; Williamson, 1985
	Strategic needs or inducements	Resource dependency theory; resources-based view	Dependency over resources (asymmetry)	Ahuja, 2000a; Hite & Hesterly, 2001
	Network position	Structural and organizational sociology; resource dependence theory	Exploitation of resources (business performance; asymmetry)	Gulati, 1999; Owen-Smith & Powell, 2004; Walker et al., 1997; Zaheer & Bell, 2005
	Interdependencies	Resource dependency theory; resource-based view; structural and organizational sociology	Uncertainty (business performance; asymmetry)	Gulati & Gargiulo, 1999; Katila et al., 2008
Social: social potentials	Prior network patterns	Structural and organizational sociology	Social opportunities	Gulati, 1995; Kogut et al., 1992; Walker et al., 1997
	Prior network relationships	Theories of social and socio-economic exchange; structural and organizational sociology; resource-based view	Social opportunities (reciprocity)	Håkansson, 1982; Larson, 1991; Lorenzoni & Lipparini, 1999; Sherer, 2003
	Network inertia	Organizational ecology; structural and organizational sociology	Contents of relationships flowing through the structures	Gulati, 1995; Ebers, 1999; Kim et al. 2006; Levinthal & Fichman, 1988
Integrated	Strategic needs or inducements as well as prior network patterns and relationships	Resource dependency theory; resources-based view; structural and organizational sociology	Dependency over resources (asymmetry) and social opportunities	Ahuja, 2000b; Eisenhardt & Schoonhoven, 1996

Here, the network studies in business context are classified into three distinct perspectives together with their underlying enablers/disablers, theoretical sources, driving forces to network formation, and exemplary works as following: (1) Economic: resource requirements including the reduction costs to alleviate uncertainty and increase efficiency in business operations (deriving from the economics literature), the strategic needs or inducements to decrease/increase dependency over resources of many kinds (deriving from strategy/management research, more specifically from the resource-dependence theory and the resource-based view as well as network position to enable the exploitation of resources and thus enhance business performance (deriving from deriving from structural and organizational sociology, and strategy/management research, more specifically from the resource-dependence theory and the resource-based view), (2) Social: social potentials including prior network patterns and relationships to benefit from social opportunities (deriving from structural and organizational sociology) and increase reciprocity between the parties (deriving from theories of social and socio-economic exchange, structural and organizational sociology, and the resource-based view), and finally (3) The integrated perspective which takes simultaneously into account strategic needs or inducements as well as network patterns and relationships (thus derives from both strategy/management research, and structural and organizational sociology. Below, they are discussed in more detail.

2.2.2.1 Economic perspective to network formation: resource requirements

Traditionally, reducing transaction costs has been suggested as the explanatory factor for why firms form inter-organizational linkages. It has been argued that formation of inter-organizational networks is driven by achieving cost savings (Coase, 1937), for example through increased productivity or technical efficiency (Håkansson, 1987), by avoiding the heavy costs of governance (Thorelli, 1986; Williamson, 1985), and by gaining access to crucial know-how that cannot be made available internally or transferred by licensing (Teece, 1986).

This approach has significant limitations, because it treats transaction as a key explanatory factor and a discrete event in inter-firm network formation. Thereby the approach neglects other potential factors and emphasizes opportunism and efficiency over other theoretical logics (Noorderhaven, 1994). Later research from a variety of disciplines has recognised that transactions are embedded in a history of prior relationships and a broader network of relationships (e.g., Gulati, 1995; Håkansson, 1982; Larson, 1992; Zaheer & Soda, 2009). As a consequence, more emphasis has been placed on the strategic needs and the social opportunities of firms to form inter-firm relationships.

The resource dependence and the resource-based theorists have examined the formation of inter-organizational networks as a result of underlying resource (inter)dependence (Pfeffer & Salancik, 1978) and consequently of asymmetry existing between relationships. Several empirical studies focusing on alliances and their formation have empirically demonstrated that firms are induced to form network relationships with other firms to fulfil their strategic needs or inducements. These needs may involve for instance obtaining access to technical and/or commercial resources they lack (Ahuja, 2000a; Ahuja 2000b), improving their strategic position in the competitive markets by pooling complementary skills (Eisenhardt & Schoonhoven, 1996) and learning new skills (Powell et al., 1996). In entrepreneurial settings, network formation has also been linked both theoretically (Hite & Hesterly, 2001) and empirically (Baum et al., 2000) to the resource needs of the firm. The motivating factors to inter-firm networking include the access and potential access (Shaw, 2006) to ideas, information and advice and/or being able to reduce costs and share risks (for a review on alliance formation motives in SMEs, see Van Gils & Zwart, 2009).

Structural sociological studies emphasizing prior inter-organizational network patterns largely underscore the firm's location in a network. They thus share the basic assumption that the network position of firms (and consequently asymmetry between them) affects their capabilities for benefiting from inter-firm networking (e.g., Gulati, 1999; Powell et al., 1996; Owen-Smith & Powell, 2004; Uzzi & Spiro, 2005). Consequently, the more closed network, that is, the more centrally connected the firms

are and the stronger connections they have between each other, the easier it is for them not only to exploit business potential available to them through inter-firm networking but also to form new inter-firm linkages. Kim et al. (2006) link high status (as positional characteristic) to these centrally connected organizations. A high status enables an organization to reduce uncertainty in relation to other actors in choosing their future partner. On the contrary, low-status organizations lack access to critical resources, such as financial and human capitals and better potential network partners. (Kim et al. 2006, p. 713)

An alternative view which is more exceptional in the network studies in business context is to see network formation as a creation of an open network. Such a network is an opportunity channel that diffusely, imperfectly, and unintentionally directs transfers between the actors, facilitates spillovers of externalities that benefit both loosely and centrally positioned firms (Owen-Smith & Powell, 2004, pp. 5–6). In such cases, the weak connections among participants and therefore paying careful attention to partner selection offer returns to network members in inter-firm network formation (e.g., Ahuja 2000a; Gulati, 1995; Subramanian et al., 2013; Walker et al., 1997; Zaheer & Bell, 2005). In line with these studies, Kim et al. (2006) also argue that the benefits accrued from diverse network relationships (called a structural hole-rich position) enable an organization to avoid network inertia. This kind of an organization can bridge the ongoing relationships and increase in this way its networking capabilities.

A different way of conceptualising firms' positions within a wider network is to focus on the interdependencies that exist among them (for a related remark, see Oliver & Ebers, 1998). The general argument has been that firms will forge networking relationships to govern their access to those resources and capabilities which in the actors' view will reduce their dependence or otherwise improve their competitive position (and consequently increase asymmetry between them). Specifically, the resource dependency theorists have found that when firms are interdependent, they are likely to form inter-firm linkages to access each other's resources and to reduce resource uncertainty (Eisenhardt & Schoonhoven, 1996; Katila et al., 2008). The social network theorists, in turn, see that network relationships involve uncertainty about the quality of potential partners. Since the social embeddedness of potential partners reduces this uncertainty, it increases the likelihood of inter-firm relationships. In other words, firms prefer to form relationships with the firms that they are already connected to (Gulati, 1995; Gulati & Gargiulo, 1999) and those unknown firms that are linked to them via third parties (Gulati & Gargiulo, 1999).

2.2.2.2 Social perspective to network formation: social potentials

In addition to the resource requirements, also social opportunities of firms to form inter-organizational relationships with each other and reciprocal activities among them have gained increasing attention in the literature. The structural sociological perspective is prominent in these studies that do not follow the traditional assumption of impersonal and atomized economic activity. Instead, economic action like all action is considered to be socially situated. Hence, economic action cannot be explained by individual motives alone (Granovetter, 1985, 1992).

Social opportunities provided by prior network patterns and relationships have been linked with network formation both theoretically and empirically in the previous literature. The underlying assumption has been that the structure of the existing inter-organizational network influences the path of future relationship formation in terms of potentially available relationships. The majority of these studies has also either implicitly or explicitly emphasized how relationship formation is based on reciprocity and consequently the pursuit of mutual interests and/or goals – thus underscoring the mechanisms of cooperation, collaboration and coordination over domination, power, and control (for a related remark, see Oliver, 1990, p. 244). Empirical studies have demonstrated that prior network relationships among individuals advance the development of more formal business networking relationships (e.g., Eisenhardt & Schoonhoven, 1996; Larson, 1991; Larson & Starr, 1993; for a related remark see also Oliver & Ebers, 1998, p. 569). Pre-existing relationships thus create opportunities for inter-firm network formation by deepening awareness, trust, and commitment among the parties within the relationship (Håkansson & Ford, 2002; Larson, 1991, 1992; Larson & Starr, 1993). In alliance formation, prior experiences also matter (e.g., Eisenhardt & Schoonhoven, 1996; Gulati, 1995; Kogut et al., 1992; Zaheer & Soda, 2009). These social networks, hence, serve as a continual basis for economic and social exchanges among the parties.

Even though prior network patterns and network relationships can be seen as enablers for network formation, there is also a dark side to them. While they foster network formation, the pre-existing network relationships flowing through the established social structures may also act as mechanisms encouraging network inertia and persistence (Ahuja, 2012; Kim et al., 2006). The studies which have dealt with this 'burden of relationships' (Håkansson & Snehota, 1998) share the underlying assumption that firms in a network are not flexible enough to act according to their own wishes and aims, or to circumstances as they arise at little cost. Instead, they are surrounded by other firms' considerations and actions, which have to be considered when dealing with emerging challenges or situations of change.

Generally speaking, the division between those scrutinizing 'beneficial' content of relationships from those focusing on 'sticky' network patterns and relationships can be related to different ways to approach network effects. Thus, studies on social networks have largely focused on the first and consequently have adopted a perspective, which has separated effects from costs (Kim et al., 2006). Business network studies have in turn aimed to support the latter perspective, taking both effects and their costs into account, thus scrutinising network formation more or less as a historically evolving investment process, which both gives opportunities and imposes restrictions (Håkansson & Ford, 2002). The entrepreneurial network studies, in turn, fall somewhere in between these two extremes (see Downing, 2005).

In particular, Levinthal and Fichman (1988) have argued that persistence in relationships is greater when relationship-specific assets get developed or when prior network relationships have been long-lasting. Gulati (1995) continues with the same line of thought; he has demonstrated that prior alliances (based on trust and relationship-specific routines) increase the likelihood of firms to form alliances with the same partners in the future. Ahuja et al. (2012) and Kim et al. (2006) have later conceptually extended these views by proposing different mechanisms which influence network inertia at different levels[3]. Both these studies emphasize that similar dynamics can be seen as influencing processes of continuity and change. Network inertia thus includes pressures for both persistence and change. These pressures then drive or shape the content of relationships. Related to this, the same line of thought can also be found in the work of Håkansson and Waluszewski (2002), who have empirically demonstrated that path-dependencies should not be regarded as only hindrances for technological innovations' emergence. Instead, they can stimulate technical development, especially when resources built over time in (industrial) networks are confronted with new utilization possibilities (path dependencies can thus be regarded as possibilities). Quoting the authors: "In order to create any change, there has to be movement. Whenever there is a movement of a

[3] In their framework on the genesis and dynamics of organizational networks, Ahuja et al. (2012) have proposed that network inertia in the levels of ego-centric networks and whole networks is to be considered as one of the main factors in the network formation affected by actor similarity, their habits (rules and norms) and (shared) histories (collaborative expertise), and networking propensity. Further, Kim et al. (2006) have proposed that network inertia mechanisms include (1) organizational age and its past history of network change in the internal context affecting networks in two ways: either driving toward stability or complexity, (2) relationship-specific assets (e.g., institutionalized routines and human assets) developed over time and previous attachments (e.g., cooperative behaviours) in the network relationship-specific context influencing the duration of the network relationships as well as their scale (the involvement in a specific relationship) and scope (the breadth of involvement of participating firms), (3) brokerage (bridging structural holes) and central positioning (status) at the network position level affecting the likelihood of changing network partners, and finally (4) technical (competitive relationships among firms) and institutional (legitimacy-oriented relationships) environments shaping the overall competitive and organizational behaviours of firms.

resource in relation to other resources, there will be friction." (Håkansson & Waluszewski, 2002, p. 570).

2.2.2.3 Integrated perspective to network formation

The common strategy in empirical literature on inter-organizational networking has been to either underscore the multiplicity and inequality of resources over social embeddedness (e.g., Haeussler et al., 2012; Katila et al., 2008) or vice versa (Gulati et al., 2009; Simsek et al., 2003). To the best of my knowledge, only three studies have addressed both issues simultaneously or in other words, utilized both resource-dependence and social networks logics in their study. Next, these studies are shortly presented.

Firstly, Eisenhardt and Schoonhoven (1996) have focused on (single-boundary decisions of) semiconductor firms engaging in the formation of inter-firm networking relationships. Combining strategic and social factors to strategic alliance formation, the authors have empirically demonstrated that alliances between entrepreneurial firms are more likely to be formed when the firms are in vulnerable strategic positions, that is, in need of resources or when they are in strong social positions, that is, possessing valuable social resources to share. In her later study, Eisenhardt together with Santos (2009) have demonstrated that although alliance formation is driven by the need to achieve resources and/or competencies (to fulfil firms' strategic needs or inducements), they are also often motivated by a strategic interest of firms to achieve competitive dominance (to increase power and consequently asymmetry between actors).

The second study taking into account both issues is the study of Ahuja (2000b) in which he has not only combined the two views, but also brought forth other determinants than those arising from social opportunities (i.e., technical and commercial capital) that drive firms in collaborative relationships. Hence, he has tried to answer the question of how new actors lacking prior relationships can ever form inter-firm linkages.

Focusing on the horizontal and formal inter-firm relationships formation during a study period of thirteen years in the chemical industry, Ahuja (2000b) found that all studied forms of capital correlated with inter-firm network formation, thus, they were affected by both resource needs and social opportunities but their actual effect varied. Consequently, the increase in commercial capital increased the formation of joint ventures and technology arrangements by almost four times as much as an increase in social capital and twice as much as an increase in technical capital (Ahuja, 2000b, p. 333). Basing on the argument that the relationship between inter-firm linkage formation and social capital is non-linear, that is, the inter-firm network formation is not dependent on prior embeddedness in the industry, Ahuja (2000b) also found that radical inventions

had an effect on the capital-poor firms' inter-firm networking behaviour, especially in terms of joint venture formation.

The third is the study by Gulati and Higgins (2003). Focusing on the effects of interorganizational partnerships in the context of young biotechnology firms' initial public offering, the authors found that these firms benefitted from having partners with prestigious venture capital firms especially when the equity markets were relatively cold for new issues. In a situation where the equity markets were relatively hot for new issues, these firms benefitted from having partners with prestigious underwriters (investments banks). Regarding the value of strategic alliances to these firms especially in a situation where equity markets were relatively cold, the authors found no support. In their discussion, the authors concluded that network effects are contingent upon both the nature of a firm's relationships and the uncertainty associated with the marketplace (in this case the equity markets as being cold or hot).

Finally, there are a few network studies which have taken a more holistic (but still somewhat integrated) view to the patterns of relationships than the above. Powell et al. (1996) have demonstrated that biotechnology venture firms that formed many relationships early on gained valuable resources and reached more central network positions. The study of Ozcan and Eisenhardt (2009) also supported the interconnectedness of the existence of multiple relationships and firm performance. The authors found that entrepreneurs who did not begin with a series of single relationships with interdependent firms (but engaged in creating simultaneously multiple types of relationships) were able to create more high-performing alliance portfolios.

2.2.3 Network formation in different levels

In this sub-chapter, I provide an overview of network formation through the levels of analysis (Axelsson, 1995; Galaskiewicz & Wasserman, 1994; Provan et al., 2007), identified from previous network studies in business context and processes within these levels, that is, the steps and activities through which different reasons to network formation get translated into particular network structures (see Ebers, 1997a, p. 13). Table 2 summarizes this perspective, which in parallel with reasons explains network formation. Here, the network studies in business context are classified into three distinct categories (together with their driving forces to network formation and exemplary works) depending on their study level, that is, whether they concern dyads, an extended view to dyads, or the (whole) network. These categories are next discussed in more detail.

Table 2. The levels of network formation

Levels	Theoretical sources	Key driving forces to network formation	Exemplary works
Dyads level	Theories of social and socio-economic exchange; industrial marketing and purchasing; entrepreneurship research	Increase in reciprocity, mutual inter-dependence and efficiency; decrease in uncertainty and distance	Ahuja, 2000a; Håkansson, 1982; Larson, 1991, 1992; Ring & Van de Ven, 1994
From dyads to networks	Theories of social and socio-economic exchange; structural and organizational sociology; industrial marketing and purchasing; entrepreneurship research	Dependency over resources (asymmetry); exploitation of resources (asymmetry); social opportunities	Halinen et al., 1999; Hite, 2005; Larson & Starr, 1993; Schutjens & Stam, 2003
Network level	Theories of social and socio-economic exchange; structural and organizational sociology; industrial marketing and purchasing; entrepreneurship research; sociotechnical systems theory	Dependency over resources (asymmetry); exploitation of resources (asymmetry); social opportunities)	Gulati et al., 2012; Maurer & Ebers, 2006; McAdam et al., 2014; Steier & Greenwood, 2000

Most studies focusing on the processual aspects of networks rest on the argument that a network emerges and develops within dyadic relationships (e.g., Ahuja, 2000a; Ford, 1982; Gulati, 1995; Håkansson, 1982; Larson, 1991, 1992; Ring & Van de Ven, 1994). Despite their theoretical origins, these studies basically emphasise that a (dyadic) network develops from arms-length transactions to a deeper dyadic configuration. The network forms gradually and linearly from exchange relationships to partnerships. This takes place when the parties get to know each other better through sharing resources of many kinds and consequently through the increased reciprocity and mutual interdependence, and decreased uncertainty and distance.

For instance, basing on an ethnographic study of seven partnership alliances, Larson (1991) has distinguished two stages (i.e., the trial period and the period of partnership), during which firms at first through their initial arm's length market relationships start to experiment and build a deeper relationship configuration. This configuration evolves toward routine operations involving the integration of these two firms, investment processes, and a commitment to continuous improvement through reciprocated exchanges. In her later study on high-growth entrepreneurial firms, Larson (1992) has distinguished three distinct phases in which the dyads were developed. The first phase contains the preconditions for establishing a dyadic relationship based on personal reputations and prior relations as well as firm reputations. The second phase focuses on the conditions to build a relationship, namely through the development of trust and reciprocity norms between the parties. Finally, the third phase contains actions through which the relationships between these parties are operationally, strategically and socially solidified and controlled.

The second alternative view to network formation has proposed that the network forms from dyadic relationships into a stable multidimensional and multi-layered network (Halinen, et al., 1999; Hite, 2005; Larson & Starr, 1993; Schutjens & Stam, 2003). The key driving forces for this type of network formation are asymmetries

between firms and possessed resources (strategic needs or inducements and network positions prompt firms to form the collaborative relationships with external parties) as well as social opportunities stemming from prior network patterns and relationships established while operating in/through dyadic relationships.

For instance, Larson and Starr (1993) have distinguished three different stages of the entrepreneurial networking activity used to secure the critical resources needed to start a business. These stages direct the network to become increasingly dense and closed through time. The first stage focuses on the essential dyads, the second stage converts dyadic ties to socioeconomic exchanges and the third stage layers the exchanges. Basing on Larson and Starr's (1993) study complemented with the model by Butler and Hansen, (1991), Schutjens and Stam (2003) have provided empirical evidence of network formation among young firms implying that both closed and open network configurations can be found. An example of the first is a sales network where relationships are becoming increasingly dense and an example of the latter is a network where outsourcing, the supplier, and the cooperative relationships are becoming increasingly heterogeneous.

The third alternative to network formation argues that it takes place at the network level from the start (Gulati et al., 2012; Hite & Hesterly, 2001; Kilduff & Tsai, 2003; Lorenzoni & Ornati, 1988; Maurer & Ebers, 2006; Steier & Greenwood, 2000). The third alternative view follows the second alternative view as it also emphasizes asymmetries between firms and possessed resources as well as social opportunities during network formation.

For instance, Steier and Greenwood (2000) have empirically demonstrated how an initial financial network (of structurally separated clusters connected to the entrepreneur through a single link) evolves through prior personal network relationships and via third party relationships (i.e., acquaintances connected the firm to their acquaintances). This financial network first becomes a stable multidimensional network in which the network relationships represent a vehicle for marketing the company and for providing broader business advice and support rather than a vehicle for getting financing for new business creation. Then, the same network becomes a more complex multidimensional network involving both closed (strong) and open (weak) network relationships leading finally to the restructuring of the whole network in question (e.g., through internal reorganizing of tasks and duties, implementing more formal procedures and formulas, and by altering informal communication patterns).

Partly supporting this, Gulati et al. (2012) have found an inverted U-shaped evolutionary pattern, wherein they have detected an initially rising and then declining trend in the formation of the open network relationships. So, the early formation phase involves a social structure that offers entrepreneurial opportunities and possibilities for firms to form open network relationships with other firms. They are also offered the

chance to recombine diverse knowledge resources and other resources across different and loosely linked firms. As the firms get more interconnected and homogeneous, the evolving social structure becomes a source of constraint, hindering possibilities for accruing the benefits from these bridging relationships. Finally, this causes fragmentation to the small-worldness of the system.

2.2.4 Network trajectories of technological innovation

The previous sub-chapters provided an overview to network formation through the identified theoretical perspectives for/in network formation. This chapter combines these in order to build a theoretical model of network formation of technological innovation based on previous network studies in business context. The basic assumption behind the model is that network relationships forming the network may vary in their significance during long-term innovation activity. These network relationships may contain different 'things' in different points of time. As such, I argue that the network formation of technological innovation can be understood as a network trajectory during which the network of technological innovation gets construed.

This concept of network trajectory is a composite of two rather amorphous terms, namely a network and a trajectory. To combine these terms, I consider the first term to refer to a set of actors and relationships which connect them (Fombrun, 1982), and the latter as "the path of a moving object across space and time" (Jenkins & Floyd, 2001, pp. 947-948; cf. Dosi, 1982, p. 152). Thus, the concept of network trajectory refers to a path of movement of a network across space and time. This definition is broad enough to take into account that the network formation of technological innovation is not necessary evolutionary (life cyclic) or teleological in nature but rather an unending and dialect process full of contradictions. Also, it enables simultaneously capturing a network, that is, actors and their relationships and these dialectic movements occurring within it over time and space (for a related remark, see Kilduff & Tsai, 2003, p. 88).

The theoretical model of network formation of technological innovation has been inspired by Ahuja et al.'s (2012) quite recent theoretical framework on network dynamics in social structures. Hence, the network is seen to involve (human) actors that comprise the network, relationships that connect these actors, and patterns that result from these connections without regard to the level of analysis (Ahuja et al., 2012, p. 435). Contrary to Ahuja et al. (2012), change in network structures is scrutinised in the model only in terms of whether a network is seen becoming increasingly closed (i.e., a network becomes heavy with strong network relationships) or increasingly open (i.e., a network becomes heavy with weak network relationships). Thus, a network is developing/evolving toward closure or brokerage. Also, motivational factors to network

formation are scrutinised through (1) enablers/disablers for network formation, namely strategic needs or inducements, network position, prior network patterns and relationships, and network inertia, and (2) key driving forces to network formation, namely dependencies and exploitation of resources (asymmetries), social opportunities, and contents of relationships flowing through structures enabling or hindering the network formation in question (cf. Kilduff & Tsai, 2003; Purchase et al., 2014).

Taken together, these aspects help to construct a model of three different network formation trajectories of technological innovation as summarized in Table 3. These trajectories are called the goal-based, the opportunity-based and the integrated network trajectory. These trajectories are labelled according to the key underlying logics of action behind them, thus, whether they are driven by intentional and goal-directed actions (i.e., the goal-based network trajectory), serendipitous occurrences in ongoing network relationships (i.e., the opportunity-based network trajectory), or seen to draw elements from both of these two extremes (i.e., the integrated network trajectory) (cf. Kilduff & Tsai, 2003). As this model is theoretical, there are no single empirical (technological) innovation studies touching upon the dynamics of a network from this viewpoint. Some studies are, however, opened up in more detail in order to breathe life into the model and henceforth, to reflect upon their relation to these network trajectories.

Table 3. The network trajectories of technological innovation

Network trajectory	Key underlying logic of action	Enablers/disablers	Key driving forces	Direction for the network formation of technological innovation
Goal-based	Goal-directed (human) action	Strategic needs or inducements; network position; network inertia	Dependency over resources (asymmetry); exploitation of resources (asymmetry); (contents of relationships)	Multiple (both closure and brokerage exist)
Opportunity-based	Serendipitous (human) action	Prior network patterns and relationships; network inertia	Social opportunities; (contents of relationships)	One-way (toward closure)
Integrated	Goal-directed or serendipitous (human) action	Strategic needs or inducements, network position; network patterns and relationships; network inertia	Dependency over resources (asymmetry); exploitation of resources (asymmetry); social opportunities; (contents of relationships)	Multiple (both closure and brokerage exist)

The first network formation trajectory is called the goal-based network trajectory. In this trajectory, network formation is driven by goal-directed and intentional (human) behaviour that is aimed at enhancing the business/innovation performance of the organizations by exploiting resources available to them through closed (strong) and the open (weak) network relationships. The enablers/disablers for this type of network formation are based on strategic resource needs (e.g., Hite & Hesterly, 2001), persistence in network patterns and relationships (e.g., Gulati, 1995), and asymmetries between firms and possessed resources, namely dependencies existing among organizations and network positions the individual firms occupy (e.g., Eisenhardt & Schoonhoven, 1996;

Gulati & Higgins, 2003; Powell et al., 1996). As a result, a core-periphery type of a network structure (Borgatti & Everett, 1999) is suggested.

For instance, Jenssen and Nybakk (2013) have suggested that small, knowledge-intensive firms scarce in resources may be more prone than larger firms to develop dependencies on other firms. They need these dependencies to get access to a variety of external resources, more specifically knowledge and other informational resources. These dependencies can be built through both strong and weak relationships. The authors conclude by arguing that an innovation-promoting network should include two components: (1) a group of organizations that are tightly bound together (characterised thus as having strong relationships with each other and high redundancy/density) and (2) a large group of organizations that are loosely bound together (characterised thus as having relatively weak relationships and low redundancy/density).

The second network formation trajectory is called the opportunity-based network trajectory. Network formation is here driven by rather serendipitous behaviour based on increased reciprocity, commitment, and trust between parties engaging in network relationships in technological innovation. This type of a network formation is motivated by the availability of social opportunities to form inter-organizational network relationships as well as existing persistence in network relationships. As such, prior network patterns and relationships are assumed to provide either an elastic supply of linkage partners (e.g., Gulati, 1995; Kogut et al., 1992) or to constrain the network relationships formation (Ahuja, 2000b). In any case, the expected network configuration points toward a closed network, thus involving a cohesive and dense structure of strong network relationships during which a technological innovation gets developed.

Regarding the previous (technological) innovation literature, prior network patterns and relationships have been empirically demonstrated to affect technological innovation activities (e.g., Lipparini & Sobrero, 1997; Lorenzoni & Lipparini, 1999). This reciprocity applies in innovation generation regardless of the size of the firms engaging in innovation activities. For instance, in their studies on formal RD collaborations among biotechnology venture firms, Powell et al. (1996) showed how "the locus of technological innovation is found within the networks of inter-organizational relationships that sustain a fluid and evolving community[4]" (Ibid, p. 142), which fostered learning and growth among these firms. In line with this, Freel (2000) found in his study on barriers to product innovation within small manufacturing firms that the lack of trust and the identification of suitable partners acted as principal barriers to partnership formation. Also, in their study of Canadian firms, De Clercq et al. (2011) found that the

4 Later research has also considered that inter-firm networking activities are not only affected by prior community but they also reconstitute communities, sometimes rapidly (Uzzi & Spiro, 2005).

effect of cross-functional collaboration on product innovativeness is stronger if a higher level of trust exists.

The third network formation trajectory is called the integrated network trajectory. The constructing of this trajectory follows the integrated perspective or better saying the resource-dependence and social networks logics applied in the empirical works of Ahuja (2000b), Eisenhardt and Schoonhoven (1996), and Gulati and Higgins (2003). Consequently, this trajectory combines the above two trajectories and argues that key drivers for network formation of technological innovation can be related to asymmetries of firms and their possessed resources as well as social opportunities (and consequently contents flowing through structures) available to the organizations through their inter-organizational linkages. Prior patterns of network relationships, network position, and strategic needs of resources are hence seen to provide both the opportunities and the constraints for who can be contacted and/or reached through the network relationships and what can be drawn from the current and potentially available network relationships (Ebers, 1997b; Kim et al., 2006).

In (technological) innovation studies, the previous research has produced rather mixed results concerning whether the organizations are 'better off' in creating closed or open networks during technological innovation development. The network seems thus to form into multiple directions, especially depending on network inertia. Rowley et al. (2000) have for instance speculated that the effect of the open network is contingent on industry context. They suggest that a closed network is preferable if organizations are operating with a lower environmental uncertainty and in a competitive environment demanding a high degree of exploration. On the contrary, when organizations are operating in an uncertain environment which demands more exploration of new innovations and alternative strategic directions, an open network is more credible. Ahuja (2000a) found however that the collaborations he studied benefitted more from trust engendered by closed networks rather than information diversity garnered through open networks. Zaheer and Bell (2005) in turn found that innovative firm performance is positively linked with open rather than closed networks. The authors speculated that in 'turbulent' contexts in which the speed of innovation is high and rapid market responses are continually needed, open networks are more beneficial than closed ones. Further, in their study among biotechnology start-up firms, Walker et al., (1997) found that inter-firm network formation is better explained by the closed network view than the open network view. The social constraints such as prior network relationships driving firms close to each other predict the network formation thus better than the exploitation of social opportunities between the firms' networking relationships.

Instead of comparing these two opposite views like Walker et al. (1997), Owen-Smith and Powell (2004) have considered inter-firm networks (in biotechnology industry) as concurrently both closed (i.e., conduits) and open (i.e., channels). The researchers found

that collaborative relationships among the geographically co-located organizations mattered in explaining the innovative outputs of biotechnology firms. These relationships not only signalled local technological community involvement but they also enabled the firms involved in that community to benefit from geographically bounded information spillovers. In the case of geographically dispersed organizations, remoteness of firms and the dominance of firms committed to the proprietary uses of knowledge gave rise to more closed relationships. The authors concluded that the physical location and (institutional) characteristics of key members in a network are of a dual importance; both of them should be taken into account when studying networks in technological innovation because they have an effect on a firm's network position and consequently on how it can be utilized. (Ibid, pp. 15–17)

2.3 Introducing actor-network theory

In this chapter, I approach the network formation of technological innovation by outlining a theoretical perspective which emphasises sociomateriality and is open to multiple ways of doing research and theorizing without unwarranted constraints (Araujo & Easton, 1996, p. 65; Latour, 1996, p. 370). It is called actor-network theory.

Grounded in empirical case studies and ethnographies, actor-network theory has initially focused on understanding how scientific knowledge is generated and maintained (Latour & Woolgar, 1986; Latour, 1987). The origins of the approach are in technology and innovation oriented studies. However, perhaps due to its ultimate focus on power relations and the overall structuring of the social, the ideas presented between the early 1980s and 1990s are today increasingly being applied in the fields of education (Fenwick & Edwards, 2010), sociology (e.g., Latour, 2005; Law, 1986; 1991a; Pickering, 1993; Vaughan, 2006), politics (e.g., Flyverbom, 2010; Åkerman, 2009), organizational studies (e.g., Bloomfield & Vurdubakis, 1999; Czarniawska & Hernes, 2005; Czarniawska & Sevón, 2005; Lee & Hassard, 1999; McLean & Hassard, 2004; Newton, 2002; Whittle & Spicer, 2008), studies on markets (e.g., Descheneau, 2012; MacKenzie et al., 2007[5]) and consumer studies in marketing (Giesler, 2012; Martin & Schouten, 2014).

This chapter starts by providing an overview to its key concepts. The first is the concept of actor. It is related to questions like who should be considered as participants in technological innovation and how they together with their relationships constitute a spatial form called an actor-network which is constrained by continuous movement. Then, the network formation of technological innovation is conceptualized as a process

[5] Callon's (1998, 1999; see also Callon et al., 2007) works on the market functioning are rare exceptions to this list.

of translation during which actors (both humans and nonhumans) and their relationships not only find their place, but are also kept in place by those who have authorship of speaking over suppressed others – at least momentarily. I reflect upon and discuss the analytical insights to the network formation of technological innovation from the actor-network theoretical viewpoint.

2.3.1 Outlining the key concepts

This chapter outlines the key concepts of actor-network theory. Table 4 summarizes these key concepts, next discussed in more detail.

Table 4. The key concepts within the actor-network theory

Concept	Short description
Actor-network	An isomorphic heterogeneous network which acts and is acted upon (Latour, 2005); it is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of (Callon, 1987, p. 93).
Actor (called also actant)	A hybrid and empirically based category of human and nonhuman entities that can act and influence other entities and that are continuously open to redefinition and transformation (Callon, 1987, 1991; Latour, 2005).
Principal actor	An actor who is rewarded the authorship of representing the actor-network and of speaking in the names of the (supressed) others (Callon, 1986a, 1986b; Latour, 2005).
Intermediary	Anything passing between actors which define the relationship between them such as texts, technical artefacts, skills of human beings, and money (Callon, 1991, pp. 135–138).
Translation	All the negotiations, intrigues, calculations, acts of persuasion and violence, thanks to which an actor or force takes, or causes to be conferred on itself, authority to speak or act behalf of another actor or force." (Callon & Latour, 1981, p. 279)
Displacement	An ingredient of translation; an actorial, spatial, temporal, and material shifting during which heterogeneous entities are converted out/in of the scene they presently occupied (Akrich & Latour, 1992, p. 260; Callon, 1986b, p. 27; Latour, 1994, p. 39).
Black-boxing	To seal the contents of things so that they are seen as out of questioning and negotiations by other actors (Callon & Latour, 1981).

The unit of analysis in actor-network theory is an actor-network. It can be regarded as an isomorphic heterogeneous network which acts and is acted upon (Latour, 2005). This heterogeneous network comprises simultaneously the actors (humans and nonhuman) and the network in which they are 'embedded' – which accounts for the hyphen between the two words (Latour, 2005, p. 169). The actor-network is not, however, a static structure depicting the order of 'things', but rather a term which embodies tension. There is tension that lies between the actors and the network; hence, between network effects and spatiality not fixed or given (Law, 1999). The term actor-network thus emphasizes heterogeneity, relational materiality, and performativity. These features help broaden the understanding of the network formation of technological innovation. They aid in considering who participates in the making of technological innovations and how they are seen to be interwoven in technological innovation activities (thus actors and their relationships).

In the same way the concept of actor is used in network studies in business context, actor-network theory also conceptualizes those involved in technology innovation

development as actors[6] (for similarities between the reviewed network approaches and actor-network theory from the viewpoint of social networks, see Mützel, 2009). The difference lies however in the way actors are defined within these approaches. Within actor-network theory, actors do not exist 'out there' as privileged groups to be easily identified like they do in the network studies in business context. Instead, actors are made to fit in an agenda (Callon, 1986a, 1986b, 1991). They are to be considered as a hybrid and empirically based category of human and nonhuman entities that can act and influence other entities and that are continuously open to redefinition and transformation (Callon, 1987, 1991; Latour, 2005). The term 'actor' can therefore be used to refer to a person, a firm, a machine, or a production system, for instance.

The making of an actor also introduces the concept of intermediary. Intermediaries are "anything passing between actors which defines the relationship between them" (Callon, 1991, p. 134). Callon (1991, pp. 135–138) identifies four 'pure' main types of intermediaries: (1) texts such as reports, journals, books, patents, and notes; (2) technical artifacts; (3) skills of human beings; and (4) money. He also acknowledges that the world is – in practice – filled with hybrid intermediaries, that is, the combinations of several intermediaries which makes it even more difficult to make a distinction between humans and nonhumans (Ibid, p. 139; see also Callon & Latour, 1992). All these intermediaries may play the role of an actor if they associate or disassociate with other actors, that is, if they are provided with substance, action, intention, and subjectivity. As a result, the distinction between an actor and an intermediary is only empirical (Callon, 1991; Latour, 2005). At any given moment, actors can transform into intermediaries and vice versa.

To differentiate between actors and intermediaries, one can follow Callon's (1991, p. 142) argument: "Either you focus on the group itself, and go on further, in which case you have an actor. Or you pass through it into the networks that lie beyond, and you have a simple intermediary." Latour (2005) instead stresses the importance of action in determining whether something is an actor or not. For him, if an actor makes no difference, it is not an actor but only an intermediary (Latour, 2005, p. 130). Intermediaries are thus sealed actor-networks (Stalder, 2002)[7], because they only

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[6] Actor-network studies usually make a distinction between actants and actors depending on whether some element has acquired an actorial identity or not. Recent studies leaning on this stream of research have favoured the term 'actor' even though its character may yet be under negotiation (e.g., Martin & Schouten, 2014; Nicolini, 2010; Schneider et al., 2012). Due to the study's focus of scrutinizing elements that are already acted upon – and for the sake of simplicity – this study makes no distinction between these two entities.

7 The sealed actor-networks or black boxes resemble the concept of closure in the social construction of technology research tradition (Pinch & Bijker, 1987), that is, the mechanisms by which technologies are stabilized (basically either by solving or redefining the problem in question). The process of black boxing, thus "makes the joint production of actors and artifacts entirely opaque" (Latour, 1994, p. 36). Latour (1994) gives an apt example of a black box which is an overhead projector in a lecture room. As long as it

transport meanings or forces without actually transforming them into something else (Latour, 2005, p. 39; see also Latour, 1993, p. 77). As a result, all entities included in the network are participating in flows of actor-network formation (Latour, 2005).

Both concepts of actors and intermediaries as heterogeneous entities actively participating in actor-network formations emphasize performativity. Performativity is an inherent characteristic of actor-network theory. It means that the identities of actors are in constant movement just like the network they form. Quoting Callon (1987, p. 93), "An actor-network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of.". The identities of actors and the network they form are therefore maintained as long as other actors do not betray this heterogeneous network (Callon, 1986a, 1987; Latour, 2005). As a result, actantiality is not what an actor does but what provides actors with their actions; namely subjectivity, intentionality, and morality (Latour, 1999b, p. 18). A single actor may therefore take many different actantial shapes and conversely the same actor may play many different actantial roles (Latour, 1994, p. 33). To become an actor is thus as much a local achievement as obtaining a 'total' structure (Latour, 1999b, p. 18).

The process through which these actantialities are forged and (re)negotiated is approached within actor-network theory through the concept of translation. This concept comes originally from French philosopher Michel Serres (1982), who used it as a generalised operation (not merely a linguistic one) taking many different forms. For him, translation always involved transformation and potentially also displacement or substitution. Consequently, anything involved in translation had an uncertain character. Each act of translation changed the translation and that being translated.

The French sociologists of science and technology, namely Bruno Latour and Michel Callon first adopted this concept and transformed it to the use of actor-network theory. The rule was to detect traces left by actors who were involved in the making of science and technology without taking any sides (Latour, 2005). The aim was "to avoid using nothing more than a bit of common sense" (Akrich et al., 2002a, p. 191) by granting back the ability of actors "to make up their own theories of what the social is made of" (Latour, 2005, p. 11). There, the term translation started to refer to a process involving "all the negotiations, intrigues, calculations, acts of persuasion and violence, thanks to which an actor or force takes, or causes to be conferred on itself, authority to speak or act behalf of another actor or force."(Callon & Latour, 1981, p. 279).

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is doing the tasks assigned to it, it acts as a silent and mute intermediary. If, however, it breaks down, its existence becomes visible. When the repairman operates around it, many different parts can be noted, such as lens and pulps, each of them having a role and function of its own to play. Quoting him, "In an instant, our "projector" grew from being composed of zero parts to one to many." (Latour, 1994, p. 36).

This definition of translation is utilized in this study. It can thus be considered as a process, which does not directly determine how the interconnected links of actors are exactly made and what their characters are but through which the actantial identities of humans and nonhumans are however (re)created, (re)negotiated, and (re)stabilised (Latour, 2005 Law, 2006; see also Czarniawska & Hernes, 2005). To provide a deeper understanding of how this concept is approached in this study, the next chapter dissects the four-phase translation model of Callon (1986a). This model has diffused to many scientific arenas and is utilised in different contexts, such as for instance in (technological) innovation generation and dissemination (Harrisson & Laberge, 2002; Nicolini, 2010; Schneider et al., 2012), information systems (e.g., Macome, 2008), global politics (Flyverbom, 2010), markets and market creation (e.g., Callon, 1998, 1999; Descheneau, 2012; Giesler, 2012; Hardie & MacKenzie, 2007; Martin & Schouten, 2014; Peltonen & Tikkanen, 2005), multinational mining (Horowitz, 2011), organizing (Porsander, 2005), and scientific collaboration (Ponti, 2010). These studies have basically either tested the original model in different contexts, or tried to refine its parts. This study tries to avoid verifying the universality of Callon's (1986a) original account. Hence, the next chapter provides a discussion of the studies that provide more analytical insights to distinct phases of translation and consequently to the understanding of how the network formation of technological innovation can be scrutinised.

2.3.2 Translating the network formation of technological innovation

In this chapter, the network formation of technological innovation is conceptualized as a process of translation. By heuristically scrutinising the four-phase translation model by Callon (1986a) together with the previous related actor-network studies, I am able to reflect upon and discuss the analytical insights to the network formation of technological innovation from the actor-network theoretical viewpoint.

The original model four-phase translation model by Callon (1986a) outlines four distinct phases within the process of translation (i.e., Problematisation, Interessement, Enrolment, and Mobilization) during which heterogeneous elements making up the 'social world' are (re)defined, (re)negotiated and (re)delimited as illustrated in Figure 4.

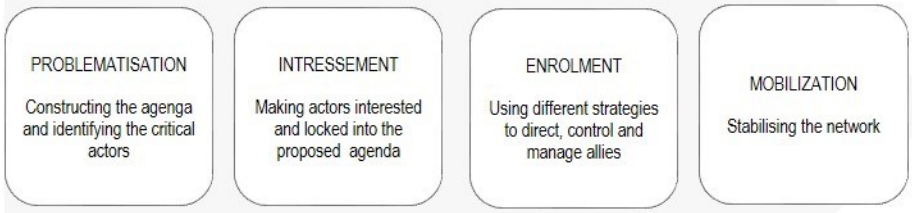

Figure 4. The general process of translation

(Sources: Callon, 1986a, 1986b, 1991)

Firstly, this study adopts the general argument of Callon's (1986a) seminal work, namely that distinct phases can be identified during the translation process. Through these phases, the actors are not simply shaped by the networks in which they are located, but they also influence the actors with whom they interact (Law & Callon, 1992, p. 25). This concurrent shaping and influencing actually breaks down an abstract distinction common in social analysis between actors and structure, or between content and context (Latour, 2005, p. 147; Law & Callon, 1992, p. 26). As a consequence, in this study the network is the same as the technological innovation. The technological innovation is not only a 'thing' progressed toward a commercial end, but also the network it forms. It is hence a network in its own right; a network in which multiple actors are participating.

Secondly, although I adopt the argument that distinct phases within translation can be identified, I have not approached these phases as taken-for-granted in this study. Rather, the model is heuristically utilised. This heuristic utilisation of the model means that the original model is not blindly and directly applied to a new setting, thus to the network formation of technological innovation. Rather, it provides, together with the related previous actor-network studies – a summary of these reviewed actor-network studies and their relevance to his study is presented in Table 5 – key analytical insights to the network formation of technological innovation. In doing so, this study is faithful to its epistemological position of relativism and reflexivity. Using the model unreflectively and positing translation as a universal phenomenon that 'exists out there' to be captured by the researcher would be a positivist strategy (Whittle & Spicer, 2008, p. 618) that I want to avoid. Consequently, by utilizing the model reflectively and

heuristically, I can sustain the research philosophical stances of constructionism and materially relativist style of thinking (Law, 1991b; 2004) as well as situate this study in the context of construction (Hammersley, 2011).

Table 5. Previous actor-network studies and their relevance to this study

Author (year)	Title	Aim	Methodology	Main results concerning the network formation
Akrich (1992)	The De-Scription of Technical Objects	To demonstrate how technical objects participate in the building of heterogeneous networks	Case study	Demonstrates how networks do not evolve by themselves; demonstrates material and directional irreversibility during the network formation; utilises semiotic vocabulary in depicting the actor-network
Callon (1986a)	Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay	To outline a new approach to the study of power	Case study	Identifies the four phases of translation; urges to 'follow the actors'
Callon & Law (1982)	On Interests and Their Transformation: Enrolment and Counter-Enrolment	To outline an alternative way to consider the 'problem of interests'	Conceptual paper	Identifies the attribution and attempted transformation of mutually interdependent interests as the main strategy to lock allies into their places
Giesler (2012)	How Doppelgänger Brand Images Influence the Market Creation Process: Longitudinal Insights from the Rise of Botox Cosmetic	To explore the creation of new market as brand-mediated legitimation process	Case study	Demonstrates how two competing agendas can be identified and consequently two contradictory narratives; supports the view that the network involves constant revitalisation
Law & Callon (1992)	The Life and Death of An Aircraft: A Network Analysis of Technical Change	To develop a vocabulary of analysis allowing the description and explanation of attempts to build a durable institution	Case study	Demonstrates how technological innovation gets construed by following the actors in (re)defining the relationships between the project and its neighbours; locates the agenda between the local and global network
Nicolini (2010)	Medical Innovation as a Process of Translation: A case from the Field of Telemedicine	To utilise actor-network theoretical tools and vocabulary in describing the circulation and stabilization of medical innovation in its early phase	Case study	Supports implicitly the framework of Law and Callon (1992); locates the same agenda in both networks; supports the view that the network involves constant revitalisation
Porsander (2005)	"My name is Lifebuoy". An Actor-Network Emerging from an Action-Net	To explore the construction of an actor-network emerging from an action net	Ethnography	Utilises relational vocabulary in depicting network formation
Schneider et al. (2012)	No-Tillage Farming: Co-Creation of Innovation through Network building	To explore alternatives to the generally adopted innovation-diffusion model to explain the development of no-tillage	Qualitative 'case study'	Identifies different agendas with the main related actors and the network formation activities (including different enrolment strategies) during the network formation; supports the view that the network involves constant revitalisation and requires constant maintenance work

Next, the four-phase model of Callon (1986a) is connected with the related previous actor-network studies. The focus of the next paragraphs is thus on the distinct phases of the model and how it has been used by previous research.

The original translation model of Callon (1986a) begins by describing the manoeuvres of principal actors that must be accepted and alliances that must be forged. The manoeuvres include the setting of the agenda that needs to be traversed by the actors who want to participate in a network as well as the identification of the critical actors seeking to change an existing situation and outlining their underlying interests. During the second and the third phases, then, the principal actors not only lock the allies into their places so as to form a power base for themselves, but also guarantee and monitor that the actors actually play the role distributed and assigned to them in the network. The translation process ends when a sole and ultimate spokesperson – the 'author' – gets finally filtered and designated. This relational and somewhat metaphorical word of

filtering has not been previously utilized in actor-network theoretical research (or the network studies in business context). Here, it refers to the slow divesting of competing packs. It can thus be compared to the sociomaterial processes occurring during (the final stages of) translation that finally enable a sole spokesperson – 'the author' – to slowly emerge, to come out, to take care of the interests of others, to speak in their name, and to render them mobile, that is, to say what these entities are, what they want and experience (see Callon, 1986a, 1986b; Callon & Latour, 1981, p. 279; Latour, 2005).

Scrutinising more closely these distinct phases of translation, previous actor-network research has quite unanimously assumed that the setting of the agenda is the de facto starting point for depicting the emerging actor-network. The studies however differ in their treatment of this agenda, namely whether one single or multiple agendas can be identified and – depending on their ontological and epistemological orientation – where they can actually be located. Those operating in theoretical borderlands seem to locate one agenda for both the local and the global network (Law & Callon, 1992) or implicitly argue that the same agenda can operate at both network levels (Nicolini, 2010). Those neglecting the existence of an implicitly present micro-macro setting (and the distinction between content and context) support the view that the agendas come in numbers; they emerge as new actors are introduced to the network compelling the actors to constantly renegotiate (Schneider et al., 2012). The agendas can also compete against each other, navigating toward simultaneous contradictory sociomaterial narratives (Giesler, 2012).

Regarding the strategies needed in the second and third phase to interest and lock allies into their places, previous research has identified only slightly different strategies through which the actors can be either displaced or inscribed in the current course of actions. In their early paper, Callon and Law (1982, p. 617) emphasise the attribution and attempted transformation of mutually interdependent interests as the main enrolment strategy. This strategy is articulated and explored in terms of (1) choices between the courses of action, (2) the actors' conception of their own interests, and (3) the imputed interests of the other actors. As later acknowledged, all actions such as pressuring, seducing, violence, or soliciting are possible as long as they enable the principal actors to cut or weaken the links between the interested actors and the others, and by this way hamper the efforts of those actors to define the entities and their identities in any other way (Callon 1986a, 1986b, 1991; Law & Callon, 1992; Porsander, 2005). In addition, Schneider et al. (2012) also demonstrate that although the emergence of new agendas does not necessarily introduce betrayal and the disintegration of the network formed in the first place, they definitely urge actors to adopt new strategies such as the introduction of new technologies that are then utilized to assimilate these agendas into an existing network.

With respect to the final phase of translation, the usage of the current strategies or the adoption of new ones does not, however, ensure that the process of translation

would go through to the filtering of the spokesperson that speaks over the others and renders the whole network mobile. On the contrary, translation may come in many forms and it may change as time passes. It may also involve betrayals during which the entities fall apart (Callon, 1986a, 1986b, 1991). As Law (2006, p. 61) notes: "no single network, no single strategy, could ever lock the participants needed to sustain strategy or network in place". As such, the nodes and ties in the network do not endure by themselves but they need constant maintenance work and the support of other nodes and ties. Networks can therefore be considered as achievements of long sociomaterial struggles rather than patterned network relationships or structures that are given in the order of things (for a similar remark, see also Akrich, 1992; Schneider et al., 2012).

The studies neglecting the existence of the micro-macro setting and the contrast between content and context especially highlight that network formation leads to a jungle of multiple actor-networks competing against and/or crossing over each other during technology generation and dissemination. As the process goes on, some of these heterogeneous networks cease to exist while some merge with other actor-networks, changing both the 'merger' and the 'mergees'. As a result and opposite to what Callon (1986a) proposes, the controversies occurring in the network formation do not necessary break down the initial network, but rather cause its constant revitalisation (Giesler, 2012; Nicolini, 2010; Schneider et al., 2012). The irreversibility holding the network together can relate both to the 'stickiness' inscribed in space and practice, and to a network in which accusations or charges can no longer be reversed (Akrich, 1992).

Finally, the actor-network scholars have usually applied ethnography or case studies (inspired by ethnographic methods). These methods have been suitable to study the circulation of the actors and the intermediaries through some events such as some technical vehicles or objects presented as a narrative during which competing networks get created and (re)negotiated (Nicolini, 2010; Schneider et al., 2012) or one certain network gets formed (Porsander, 2005). Intertwined with the story-making (Czarniawska, 2004) during which actors tie chains of events to one another in the pursuit of their agendas, the actor-network scholars have translated their research data into the 'language' of the actor-network theory. This 'language' has not only involved anthropomorphism, that is, the attribution of human characteristics to nonhuman actors (see e.g., Latour, 1992, pp. 234–236), but also the semiotic vocabulary for talking symmetrically about people and machines (Akrich, 1992; Akrich & Latour, 1992; Latour, 1992).

In this study, these two aspects have been taken into account similarly to Porsander (2005). In telling the story of turning the City of Stockholm into a 'cultural capital', she does not follow the semiotic vocabulary developed within the actor-network theory. Instead, she leans on a relational vocabulary while opening up the translation process of the 'cultural capital'. This means that the same vocabulary is used whether concerned

with humans or nonhumans. For instance, while introducing the potential actors and how they were enrolled to follow the agenda proposed, she writes "Stockholm ´98 was convinced…" (Porsander, 2005, p. 21), "Stockholm ´98 tried to find and engage [the actors]…" (Porsander, 2005, p. 24), and "Stockholm ´98 continued to assure the candidates…" (Porsander, 2005, p. 24).

Furthermore, while describing and analyzing the network formation of technological innovation, I have decided not to use the words proposed by Callon (1986a) – allies – or Latour (2005) – groups – to depict the actorial quests for character occurring during the process of translation. Whereas Callon (1986a) has laid no grounds for the utilization of the word 'ally', Latour (2005) uses the word 'group' because it, I quote, "is so empty that it sets neither the size nor the content. It could be applied to a planet as well as to an individual; to Microsoft as well as to my family; to plants as well as to baboons. This is exactly why I have chosen it."(Latour, 2005, p. 29) Instead, I have chosen to utilize another relational and somewhat metaphorical word, namely the pack.

The word 'pack' has no origin in actor-network theoretical research (or the network studies in business context). Rather, it has been utilized to refer to social groupings of certain animal species such as for instance wolfs or other canines. For me, however, this word enables becoming sensitized to already existing network formations within the network formation of technological innovation without the risk of confusion with the studied actors' own idioms; thus to focus on 'things' (involving humans, nonhumans, and multitude of intermediaries) already created (e.g., formal organizations, individuals, and technologies) as well as processes already taking place (e.g., collective actions and events occurring within certain technology development) but of course not forgetting that they had not always been there. This is not to say that packs are independent or anterior, but rather that they are constantly made and remade just like allies and groups during the process of translation.

Using this word of pack (and consequently also the word of filtering), hence, I am able to emphasize networks as heterogeneous collectives equipped with entanglements of humans, nonhumans and their interconnected relationships. Wolfs allow us humans to attach many actantialities to them, such as for instance an animal, a meat-eating beast, and a care-taker in terms of 'wolf-children'), organized collective actions (e.g. whereas wolfs hunt together, the emergence of technologies/network can be progressed through collaborative development work as happened in the case of the intelligent paper), tensions emerging within a certain pack and between competing packs (e.g., disagreements about pack memberships and hierarchies such as for instance who should be considered as the 'alpha male/female/pair' and on what grounds), and mechanisms of network (re)production in terms of continual power plays occurring while actors are engaging in the network formation of technological innovation to fulfil their agendas (for wolfs, packs are 'spaces' for survival).

2.4 Synthesis

In this chapter, I will provide a synthesis of the studies reviewed and discussed in the previous chapters.

The three network trajectories (i.e., the goal-based network trajectory, the opportunity-based network trajectory, and the integrated network trajectory) identified from the network studies in business context have emphasised the complexity of network formation. They have emphasised that no single individual or a company can be seen as the locus of technological innovation development. The network in which a person or a company is embedded is more important.

This view to the network formation of technological innovation is however rather narrow. It does not take into account the role of nonhumans in the network formation of technological innovation and the continuous and contradictory sociomaterial processes of forming the network and consequently the technological innovation. I have identified three shortcomings of this view as following: (1) heavy emphasis has been put on humans (individuals, organizations and firms) and their relationships as the principal carriers of technological innovation activities, (2), nonhumans and their relationships have only been treated as instruments in technological innovation, and (3), these human parties have rather deterministically and linearly been seen to influence and be influenced by the networks within which they are embedded while engaging in the technological innovation activities. Next, I will elaborate these three shortcomings in relation to actor-network theory.

The network trajectories identified from the network studies in business context have made a clear distinction between the material nature of technology and the coordinated human actions that construct it. The first is hence seen as an outcome of the latter. Together with their relationships and the patterns that result from these relationships, the humans (individuals, organizations and firms) in technological innovation have thus been considered as heavy with resources, knowledge, and understandings in many different forms. They have also been mastering the long-term technological innovation process – and as such are also hindrances of its advancement. In this process, the nonhumans (materials) have only been considered as instruments for the individuals and firms to conduct the technological innovation activities. This heaviness of these human parties has not been considered to result from the stickiness of actors and their networks inscribed in space and practice (Akrich, 1992), but from complex social interactions, adaptations, and investments made within and between the humans. Additionally, they have been rather deterministically and in a linear way seen to influence and be influenced by networks within which they have been embedded while engaging in technological innovation activities. The network thus forms as the human parties (rationally) add and subtract connections to and from the network.

As a result, more research is needed which takes more seriously into account the complexities involved in the network formation of technological innovation. Research should scrutinise the issues neglected in the network studies in business context as discussed above. Longitudinal accounts of the network formation of technological innovation are especially called for. These accounts are able to be sensitive to the processual aspect, contextual conditions, and power plays occurring in the forming of the network of technological innovation.

In this study, actor-network theory is introduced as a specific means to pay attention to heterogeneity in terms of sociomateriality and power plays of actors in the network formation of technological innovation. This view transcends the issues – the three shortcomings – which have been neglected in the network studies in business context, namely nonhumans and their relationships together with humans in the network formation of technological innovation as well as the rather deterministic and linear view to network formation. Thus, by conceptualizing the network formation of technological innovation as a process of translation, a dialectic and holistic view of isomorphic heterogeneous networks can be achieved which also reveals the underlying power relationships. These networks concern continually unfolding sociomaterial processes, which are equipped with humans, nonhumans and their interconnected relationships.

Consequently, this theoretical approach addresses the complexity of the research phenomenon in three inter-related ways: (1) by granting an actorial role to both humans and nonhumans (breaking down the distinction between human and natural phenomena), (2) by underscoring (dislocated) actions of these actors while engaging in network formation of technological innovation (breaking down the distinction between content and context), and (3) by blurring the boundaries between the actor level and the network level analysis as well as the boundaries between the perspectives of consequences and causes stemming from the network studies in business context. These issues are next discussed in more detail.

Actor-network theory assumes that materials are not 'mindless' but they together with the humans participate in the network formation of technological innovation. This breaks down the distinction between human and natural phenomena as well as between the content and the context. Related to this, the interest of actor-network researchers has not been on the efficacy of the structures produced but rather on how they can offer traces for discovering what sort of relationships may exist between the micro and the macro (Latour, 2005, p. 176). From the viewpoint of translation, researchers have been interested in how and why some actor becomes 'a macro-actor' while others do not. Further, isomorphic heterogeneous networks achieve their form as a consequence of the relations in which they are located (breaking the distinction between content and context) (Latour, 2005; Law, 1999). Network studies in business context that I have reviewed provide clues on what these relationships contain from the viewpoint of the

humans involved in the network formation of technological innovation. These clues are thus reasons (enablers and disablers) for network formation as well as network formation in different levels, more specifically processes (steps and activities) translating these reasons into specific network structures in the network formation. Although these clues emphasize human activity over nonhuman activity, they can be included in this study when analogously following what Latour (1996, pp. 269–370) states about including social relationships in actor-network accounts.

Previous network studies have tended to treat nonhumans instrumentally. Hence, how can I trace these nonhumans and their relationships while studying network formation of technological innovation? Actor-network theory offers one plausible answer by arguing that the 'social' does not designate a type of a link, but rather an association between entities recognizable as social when they are reshuffled together (Latour, 2005, p. 65). Detecting this reshuffling is however difficult, because "objects appear associable with one another and with social ties only momentarily" (Latour, 2005, p. 80, italics removed). Also, they "by the very nature of their connections with humans, quickly shift from being actors to being intermediaries" (Latour, 2005, p. 79).

This reshuffling understood in this study as translating the network formation of technological innovation occurs by detecting the actions through which the actors acquire their identities and consequently achieve their forms. Contrary to what many previous network studies depict, actions give meaning to an actor and consequently to the network from the actor-network viewpoint. Quoting Latour (2005, p. 46): "the very word actor directs our attention to a complete dislocation of the action, warning us that it is not a coherent, controlled, well-rounded, and clean-edged affair. By definition, action is *dislocated*. Action is borrowed, distributed, suggested, influenced, dominated, betrayed, translated. If an actor is said to be an actor-network, it is first to underline that it represents the major source of uncertainty about the origin of action – the turn of the word 'network' will come in due time."

In following these arguments, actor-network researchers have somewhat reduced human beings to the status of intermediaries and given nonhumans the honorary title of actors. Callon (1991, p. 156) argues, however, that all configurations are in principle possible. Related to the analytical affordance of the network studies in business context, I argue that human actors have an important functional role to play during the network formation of technological innovation (i.e., the weak view, see Castree, 2002, p. 135). I acknowledge that by granting this role to the human actors is an ontological, epistemological, as well as a methodological challenge as it may limit my understanding of the many different ways the voiceless and the 'mindless' affect the network formation of technological innovation. However, I believe that this is a critical decision that any researcher engaging in actor-network theory has to make.

The decision to scrutinise the network formation of technological innovation through its human participants in the first place resemble the social constructivist approach within science and technology studies which posits that technologies are by no means static and forever fixed but are interpreted and designed differently by the various social actors involved in their development (Bijker, 1992; Bijker & Law, 1992; Garud & Karnøe, 2003; Pinch & Bijker 1984, 1986, 1987). I wish to avoid treating the technological artifacts as 'open' for human action concerning for instance their usage, design and technical content developed. Therefore, I approach the nonhuman actors as if they themselves are willing to be treated as multiple (Latour, 2005, p. 116); thus letting them to make connections themselves together with humans (Callon, 1986a, 1991; Latour, 1987, 2005). I also use the same vocabulary whether concerned with humans or nonhumans (Porsander, 2005) added with certain relational and somewhat metaphorical words, namely pack and filtering (cf. Callon, 1986a; Latour, 2005).

Furthermore, Borgatti and Foster (2003, p. 1001) points out how the traditional levels of analysis in sociological and organizational studies have been the scope and complexity of entities being studied – organizations represent a higher level than persons – and how this dimension has distinguished studies into two different camps, namely micro and macro (e.g., Coleman, 1973) and those trying to bridge the micro-macro 'divide' (e.g., Goldspink & Kay, 2004; Molloy et al., 2011). The authors argue that this differs in (social) network research, because the levels of analysis (e.g., individuals, dyads, and the whole networks) do not necessarily correspond to the type of entities being studied and from which the data has been gathered. In fact, micro and macro can be very similar both theoretically and methodologically. (Ibid, p. 1001.)

In their effort to better locate their unit of analysis, social network researchers have either considered the same factors in different levels of analysis (Borgatti & Foster, 2003, p. 1001) or mixed variables of different levels in the same analysis (e.g., Uzzi, 1999). The entrepreneurial and business network researchers have largely followed the first way by assuming that the micro-level outcomes can be translated directly to the aggregate level (e.g., Håkansson, 1982; Larson & Starr, 1993; Steier & Greenwood, 2000). These two alternatives imply that network researchers in business context should be careful in applying theory about individuals and their inter-personal networks to networks at the level of organizations and institutions and vice versa (see Borgatti & Foster, 2003, p. 1001 for a similar viewpoint). On the contrary, individual actors can have different capabilities and relationships can have different meanings throughout their existence. Within social network research, Ahuja et al. (2012) touch upon this issue by emphasizing how important it is for a network researcher to be clear about the actors and relationships he/she includes in a study. The researcher should also be specific about the content that is expected or presumed to flow through the network and then build a

plausible case that the network being studied in fact generates such a flow and leads to the proposed outcome.

Actor-network theory offers a tempting solution to this methodological 'puzzle' through the unit of analysis (actor-network) and the notion of translation. The early actor-network researches have first theoretically (Callon & Latour, 1981), later empirically (Callon, 1986a, 1986b, 1987; Law & Callon, 1992) demonstrated that the difference between the micro and macro actors is not based on their dimensions (i.e., the actor level versus the whole network level analysis), but rather on the influence they have on the activities and entities around them. Before any translation takes place the actors and their networks are isomorphic. They have thus equal potential to influence the network and consequently to the technological innovation. Through the network formation considered as a process of translation an actor 'grows', i.e. becomes more influential. As a result, power is not something one can possess. Instead, it must be treated as a consequence rather than a cause of action exerted in relation to another actor attributed to both human and nonhuman actors (Latour, 1999b; Latour, 2005).

To conclude, the isomorphic heterogeneous network which is formed through dislocated actions of actors (and their networks) undertaken – or 'other-taken' if following Latour (2005, p. 45) – resulting the acquiring of character and consequently a powerbase to them in network formation of technological innovation from the actor-network perspective is never bigger than one another; it is simply longer or more intensely connected (Latour, 1996, 2005). This treatment of the network concept as an isomorphic heterogeneous network involving entanglements of humans, nonhumans and their interconnected relationships erases the distinction between inside and outside as well as between content and context. So, "in order to obtain the *effects* of distance, proximity, hierarchies, connectedness, outsiderness and surfaces, an enormous *supplementary* work has to be done" (Latour, 1996, p. 372). This supplementary work done in this study is discussed in detail in the next chapter together with the ontological, epistemological, and methodological choices.

3. CONDUCTING THE RESEARCH

This chapter specifies the ontological, epistemological and methodological choices made in conducting the empirical research as well as describes and discusses how the research data was generated, analyzed and interpreted.

3.1 Research philosophy

Good scientific research always involves a reflective account of the basic beliefs about human beings and the world (ontology), how knowledge can be produced and argued for (epistemology), and how we can gain that knowledge (methodology) (Alvesson & Sköldberg, 2000; Denzin & Lincoln, 2000). These three issues are next discussed. First, I shortly present my view of the philosophical positions of the studies reviewed in the previous chapter. Then, the ontological, epistemological, and methodological choices of this study are outlined. Table 6 summarizes the philosophical positions which are discussed in this chapter. The italics in the table illustrate the position adopted in this study.

Table 6. Research philosophical positions to networks and their formation

Research philosophy	**Scientific realism (positivism)**	**Constructivism**	***Material constructionism***
Ontology	One reality – one truth	A reality may exist	*Multiple realities, holistic view*
Epistemology	Realist (subject-object)	Inter-individuality, sense-making	*Relativist (no basic ground of knowledge),reflexivity*
Methodology	Natural science, case study	Case study (ethnography)	*Ethnography, narrative, discourse, case study*
Research process	Theory testing	Theory generating and testing	*Theory generating and testing*
Role of values in research	Value-free	Value-contingent	*Value-laden*
Theoretical perspective to network formation	The consequences perspective (focus on structure)	The causes perspective (focus on structure and process)	*The actor-network theoretical perspective (focus on sociomaterial processes and structure)*

(Sources: Araujo & Easton, 1996; Demeritt, 1998; Denzin & Lincoln, 2005; Hassard, 1993; Järvensivu & Törnroos, 2010; Keso et al., 2006; Law, 2004; Van der Haar & Hosking, 2004, pp. 1019–1020; Whittle & Spicer, 2008)

Most network studies in business context have been concerned with the consequences perspective in which the focus has been on the (structural) outcomes of inter-

organizational networks (for a review, see e.g., Borgatti & Foster, 2003; Jack, 2010; Provan et al., 2007). These studies have a realist research philosophical position. The truth exists 'out there' to be captured by a researcher who is clearly separated from the phenomenon he/she studies. Knowledge is produced though testing; by strictly (logically) following the scientific research methods of socio metric techniques and cross-sectional analyses.

Some network studies in business context have advanced an understanding of (longitudinal) network development from the causes perspective, mainly within the entrepreneurial and business network research (for a review, see Slotte-Kock & Coviello, 2010). Here, these studies are classified into the constructivist research philosophical position rather the constructionist philosophical position (cf. Järvensivu & Törnroos, 2010). The emphasis is on the inter-individual social processes in knowledge production processes rather than on relational realities and relational processes (Van der Haar & Hosking, 2004, p. 1020). Thus, constructing reality in the causes perspective studies is viewed more or less as an individual act of sense making. Hence, the Self (a person or a firm) and the Other (other people and other firms) are treated as independently existing entities (Järvensivu & Törnroos, 2010, p. 101; Van der Haar & Hosking, 2004, p. 1020), and the researcher's own (subjective) values have a rather limited role in research.

Consequently, the focus of the network studies within the causes perspective has been on (case) research designs which provide time-sensitive insight and fine-tuned data regarding network processes (Slotte-Kock & Coviello, 2010, p. 38). The unit of analysis in these studies has based on the individuals and then extended to cover the whole networks around them. Particular emphasis has been on acknowledging the rational and social aspects of knowledge and the sense-making of the lived realities of informants in richer manner than within the realist position (Järvensivu & Törnroos, 2010). The researcher's values are contingent; they have been recognized, worked with, and stated if seen as necessary (for an example, see Larson, 1992, p. 79). Also, the research processes have involved both theory generation and testing, and usually an abductive logic of reasoning (Järvensivu & Törnroos, 2010).

Actor-network theory has positioned in a research tradition where the emphasis has been on acknowledging that the making of science and technologies is socially constructed (Pinch & Bijker, 1984). Throughout the years, it has become adopted as part of the critical approach within organization studies (Alcadipani & Hassard, 2010; Whittle & Spicer, 2008), to be referred as an approach of construction-as-philosophical-critique (Demeritt, 2002), or to be positioned in the post-structuralist program (Kilduff & Tsai, 2003, p. 121; Law, 2006). Here, I classify it under material constructionism. This research philosophy can be included under the umbrella of social constructionism (Demeritt, 1998; Sismondo, 1993, 1996), which concerns the development of jointly constructed understandings about the world. These research philosophies have also been called

artefactual constructivism and social constructivism (Demeritt, 1998; Sismondo, 1993, 1996) or just constructivism (Denzin & Lincoln, 2005, p. 24). The 'nism' suffix is utilized in this study to underscore relational realities and relational processes (Van der Haar & Hosking, 2004, p. 1020), and consequently a relational ontology (multiple realities) and epistemological relativism (truth is undecidable if not meaningless) (Demeritt 1998; Law, 2004).

In short, the material constructionist research philosophical position to which I classify actor-network theory and consequently this study posits that objects of (scientific) knowledge are contingent outcomes of practice among multiple heterogeneous human and nonhuman actors (Demeritt, 1998, p. 176). It does not rely on realist epistemologies in which 'nature', 'culture', and 'scientific knowledge' are kept separate (Latour, 1993). On the contrary, reality is multiple, ambiguous, and debatable. As Law (2004, pp. 32–33) points out, realities are made and un-made at the same time; they do not pre-exist their construction. The world gets shared and common only after controversies have been resolved and statements about it have become fixed, definite, and unambiguous (ibid). Additionally, realities are not only created and maintained within social human interaction as argued within another branch of social constructionism (Berger & Luckmann, 1966; see also Burr, 1995), but also nonhumans take part in the making of realities. Without them, and statements they produce about the world, there are no realities (Law, 2004, p. 31). These characteristics are specifically related to the emphasis on material relativism (i.e., the reconstruction of the dualism between nature and 'man'). In actor-network theory as well, nature (artifacts and objects) and society ('man') are seen as the outcomes of heterogeneous sociomaterial processes rather than the starting point for explaining those processes (Demeritt, 2002; Law, 2004).

Next, I will discuss the research philosophical choices and consequently the material constructionist research philosophy of the study in more detail.

3.1.1 Ontological and epistemological choices

Ontologically, this study is based on (material) relativism. This view refutes any permanent, unvarying standards by which truth can be universally known (Guba & Lincoln, 2005, p. 204). The agreements about truth are thus subject to negotiations occurring between participants involved in technological innovation development, including also myself (Law, 1991b); things – including humans – are only definable in relation to other things (Castree, 2002, p. 118). Thus, there are no 'pre-individual' or virtual artifacts, but only actual artifacts, defined by their relationships with other actors (see Harman, 2009, pp. 160–161). As Law (2004, p. 29) nicely states it, I quote,

"Beforehand things are not clear and the realities in question are not yet made. Afterwards they are.".

Adopting this materially relativist style of thinking is not to say that there are no standards at all or that all things could be considered as equal. I acknowledge that I have personal preferences for some things over others, and I make choices accordingly. I am thus constrained and enabled by theories or practices about what should account as a satisfactory argument (Law, 1991b, p. 5). What is however important, is to continually try to recognise multiplicity and multivocality when attending to the craft work implied in practice (Law, 2004, p. 59). Quoting Law (1991b, p. 6), "Thus if someone tells us of a form of distribution that it 'must be so', we may or may not believe what we have been told. But we will certainly cling fast to the sense that what is seemingly so 'natural' *could be otherwise*. And we will be suspicious of that order, and ask, instead, why it is the way it is for those (including ourselves) who tell us that it is so." From this viewpoint, no clear picture of the nature of entities emerging from the empirical analysis should be made beforehand. Instead, they are emerging to me as a researcher while I am interacting with the research data. The consensual common-sense is therefore emphasized to some extent, not exactly in terms of, for instance, how different artifacts get construed and used differently by the people involved in their development (e.g., Pinch & Bijker, 1984, 1986, 1987), but rather in terms of how they themselves allow to be treated as multiple (Latour, 2005).

Regarding epistemology, actor-network theory embraces epistemological relativism (Law, 1991b). I include this to the adopted materially relativist style of thinking. It means to acknowledge that the standards for good knowledge vary between groups (Law, 1991b, p. 5) and consequently that questions of truth are ultimately undecidable (Demeritt, 1998, p. 178). Knowledge production is co-constructed; actors do not construct their understandings from being told what the world is (i.e., a reality is 'out there', existing independently of human thought). Instead, they base their understandings on interpretations of lived experiences (multiple realities). The task of the researcher is then to holistically capture these lived experiences (multiple realities) but not in the way of knowing better, thus, by using some meta-language in which the actors' language is embedded (Latour, 2005, p. 49). Instead, these realities get revealed by 'following the actors' (Callon, 1986a; Latour, 1987; 2005) – both humans and nonhumans – through time, spaces, and texts. Consequently, the epistemological emphasis is here on holistically capturing the realities of multiple actors (involving both humans and nonhumans) and being constantly reflexive (Alvesson & Sköldberg, 2000, p. 5). This is accomplished by acknowledging that the actors have lived realities (Latour, 2005) and by allowing them to define the worlds in their own terms (Latour, 1999) without forgetting my own presence in the knowledge production processes (Law, 1991b).

3.1.2 Methodological choices

The general way to do actor-network theoretical research is to conduct empirical case studies or ethnographies. The adoption of these research approaches has enabled researchers to organize their studies around a small number of issues, and to better understand what kind of a role science and technology play in constructing scientific truths (Latour, 1987) and structuring power relations (Callon, 1986a, 1987). In particular, the case research approach has allowed researchers to focus on issue-related data generation at specific sites such as a technology development project (Callon, 1987), laboratories (Latour 1987, 1999a,) or lately organizations (Carlile et al., 2013; Czarniawska, 2004). It has also often been connected with the interpretative, ethnographic, and field-research traditions (Dyer & Wilkins, 1991) and is suitable for new research areas or areas where existing theory seems inadequate (Eisenhardt, 1989, pp. 548–549).

Following these premises, this study adopts the basic ideology of case research (Ragin & Becker, 1992; Stake, 1995, 2005). This strategy enables sustaining the chosen material constructionist research philosophical position and consequently materially relativist style of thinking. It also drives me toward understanding the case within its own worlds and own languages. The emphasis is not, however, on separating the knowing subject from the object of knowing by applying procedures (i.e., research methods) which constrain the subjectivities (e.g., opinions) of the knowing subject (Smith & Hodkinson, 2005, pp. 916–917) which is the norm within the case research tradition. On the contrary, certain distinctive methodological principles are followed to connect material constructionism and consequently materially relativist style of thinking (actor-network theory), and case research together.

The first principle which is followed here is called agnosticism. It grants back to actors their ability of making up their own theories of what the social is made of (Latour, 2005, p. 11). Agnosticism urges the researcher to detect traces left by the actors involved in the technological innovation activities without taking any sides (Latour, 2005). In other words, I ought to abandon a priori assumptions of the nature of network formations, their causal conditions, or the accuracy of actors' accounts. Instead, I should consider all viewpoints as unprivileged and interpretations as uncensored. This is done by not fixing the identities of actors before they are thoroughly negotiated. (Callon, 1986a, p. 200)

The second principle is generalised symmetry, which requires that I should not impose a priori asymmetry upon actors. Instead, a single explanatory frame is employed when interpreting the actors, be they human or nonhuman. (Callon, 1986a, p. 200) This principle has been criticized for making it difficult to see which actors are to be selected and consequently which relationships are to be analyzed (Miettinen, 1999, p. 181). This

study follows Latour (2005, p. 76) who answers to the criticism as following: "ANT is not, I repeat is not, the establishment of some absurd 'symmetry between humans and nonhumans'. To be symmetric, for us, simply means not to impose a priori some spurious asymmetry among human intentional action and a material world of causal relations."

This argument by Latour also refers to the third methodological principle I follow in this study, which Callon (1986a, pp. 200–201) calls free association. This principle advocates abandoning the idea that natural and social phenomena are separated with a clear boundary (Ibid). Instead, one should 'follow the actors' (Callon, 1986a; Latour, 1987, 2005) "in order to identify the manner in which these define and associate the different elements by which they build and explain their world, whether it is be social or natural" (Callon, 1986a, p. 201). As Latour, (2005, p. 103) argues, "to explain is not a mysterious cognitive feat, but a very practical world-building enterprise that consists in connecting entities with other entities, that is, in tracing a network".

3.2 Data generation

This section details the process through which I generated the research data of this study (I have preserved this research material, thus providing a possibility to review them later if needed). The generative approach taken to data collection follows more or less both the actor-network and the interpretivist programs (Latour, 2005, p. 133; Silverman, 1993, p. 90). Table 7 summarizes this research data that I generated. It includes interviews and documents, in total 708 pages (for a closer examination of the research data, see Appendix A).

Table 7. The research data generated

Data source	Short description of the data	Pages
Interview data	Interviews with key persons involved in the intelligent paper's development activities between 2004–2009 (three separate points of time; in total 11 interviews)	222
Documents	Annual reviews and financial statements	119
	Research publications	96
	Presentations	89
	Brochures	9
	Magazines and news	20
	Other (e.g., profiles of the interviewees, patents, downloads from Wikipedia and company webpages)	153
Research data in total		**708**

The generation of interviews began by contacting the product development director of a start-up firm called Alpha[8], who helped the researchers to identify the key persons that played very important roles in developing certain intelligent paper technologies in the

[8] The name is a pseudonym.

borderline of the broad umbrella of nanotechnologies. Besides delivering valuable information, hence, the product development director acted as a gate keeper (Eriksson & Kovalainen, 2008, p. 53; Gummesson 1991, p. 28), facilitating contacts with other human actors. He provided both the physical and the mental access (Gummesson, 1991, p. 28) that was considered crucial for studying the network formation of technological innovation development, both initially and throughout the process. Consequently, although the operations of Alpha were discontinued during the research process, the researchers were yet able to continue interview data generation. The way interviewees were 'found' followed the Latourian spirit (and a snowball sampling technique); the first interviewee identified which (in this case human) actors were the ones that should be interviewed with regard to the study's research interest. The same persons appeared central also to other interviewed informants.

Interviews were conducted with one or two researchers present on three separate occasions, in the spring of 2004, from the late autumn of 2005 to the early spring of 2006, and in the spring of 2009. The duration of interviews was between forty-five minutes and two hours. Interviews of the four key persons were repeated to include a temporal dimension in the study. All interviews were conducted in Finnish, recorded, and transcribed verbatim. Only particles like 'um' and 'you know' were omitted. The interview data comprises of 222 transcribed pages.

The first interviews conducted in 2004 focused on interviewees' and the firm's backgrounds, the firm's current state and future prospects, as well as the challenges interviewees and the start-up firm had faced during the study period. These in-depth interviews were conducted as open-ended to elicit the actors' own interpretations of the situation (Mason, 2002; Seidman, 1991) and thus, to reach the (social) worlds the informants were picturing to the researchers (Miller & Glassner 1997, p. 99). This portrayal of interviews may pave the way for romanticism, but it does not, however, mean that either the objectivity or the subjectivity is negated (Ibid, p. 101). The initial reason for choosing this type of an interview strategy was the fact that the research phenomenon was still ongoing while interviews were conducted. In other words, the actions I considered relevant for understanding the network formation of technological innovation occurred simultaneously with interviews.

Subsequent interviews were semi-structured to investigate some themes more carefully, namely, the growth of the activities/firm, interviewees' experiences of acting in/through the network, the firm's future prospects, and development ideas. Descriptive illustrations reconstructed from the earlier interviews were also used in subsequent interviews in order to remind the informants where the discussion ended the previous time and more importantly, to effectively direct the discussion toward pre-defined themes not given to the informants in advance.

The generation of documentary data started in parallel with interviews with the primary purpose of contextualizing interview data. This data consisted of Annual reviews, different kinds of publications, presentations, brochures, magazines, news and other documents (e.g., LinkedIn profiles, patents, company webpages and Wikipedia downloads), in total 606 pages. It was contrasted with interview data so as to make the object of the analyses clear and more consistent (Speer, 2002). It was also conceptualized according to the methodological programs in research. It was thus considered as natural or naturally occurring rather than as contrived or researcher-provoked. In other words, although interviewees were concurrently living the incidents occurring within the network formation of technological innovation development, – and thus easing their memory of what had happened – the documents were in the first place meant to verify that interviewees were telling the truth to the researchers. This orientation further encouraged seeing and analyzing the materials as separate from each other, the first one (interviews) as the primary data source, and the latter (documents) as the secondary data source.

When I became familiar with actor-network theory my understanding of the nature of the research material that I had generated and consequently, the role of the researcher changed. The interest was no longer on saturation (Eisenhardt, 1989) and verification, but rather on detecting actors through time no matter where they could be found – in the transcribed interviews or other texts – and being sensitive to what they were saying to me. Whether a researcher views research data as natural or not depends largely on what he or she intends to do with them (Speer, 2002, p. 513). As the ultimate interest of the study was on detecting both humans and nonhumans in the network formation of technological innovation, there was no relevance to classifying research materials according to the state of their nature. Instead, "the more nonhumans share existence with humans, the more humane a collective is" (Latour, 1999a, 18, italics removed).

3.3 Data analysis and interpretation

Data analysis and interpretation in qualitative inquiry is often a highly intuitive and sensitive construction process. Throughout this process, ideas emerge while engaging with the data and they are further elaborated to make sense of evidence (e.g., Gummesson, 1991, Silverman, 1993). This process is highly heuristic; it is sometimes difficult to detect distinct phases during the process as they overlap. In the next paragraphs, I will go through the process by dividing it into two main phases, namely the phase of inductive content analysis and the phase of actor-network analysis.

In this study, inductive content analysis (Elo & Kyngäs, 2008; Krippendorf, 2004) preceded the actor-network analysis. Referential analysis (Krippendorf, 1980; p. 62) can

be considered as a synonym for inductive content analysis as it also focuses on the systematic portrayal of the research phenomenon. Also, its emphasis on social actors, their actions, and the social relationships in which they are involved resembles analyses of narrative text (Franzosi, 2004, pp. 553–555).

For this study, the choice of utilising the method of inductive content analysis can be explained through its convincing systematic orientation toward unstructured research data. Inductive content analysis can be effectively applied as a means to approach the fairly fragmented phenomenon of network formation. Also, despite the criticism (Akrich, 1992), the techniques of content analysis have already been applied in actor-network studies (Faraj et al., 2004; Neuvonen-Rauhala, 2009).

The inductive content analysis started by determining the unit of analysis (Elo & Kyngäs, 2008; Krippendorf, 2004). A statement comprising a word, sentence, or many words and/or sentences was selected as the unit of analysis. As the actual research question had not taken precise shape at the time, I applied the question of "What things can be related to the management of innovation-based networked business?" to guide the early analysis. A statement rather than a single letter or word was considered as better suited to answer the question. It was large enough to describe the management of innovation-oriented business but small enough to enable its categorization.

Induction (e.g., Maxwell, 1975, p. 110) guided the overall content analysis. This meant that I avoided starting from explicit assumptions about sets of relationships. Instead, the research material itself guided the analysis. My interest was on detecting how the informants experienced or interpreted what had happened during the study period. Also, only manifest content was analyzed. Latent content, such as silence and laughter, was ignored.

Regarding induction, my pre-understanding about networks may have affected the analysis and consequently, its output. Also, during the analysis some preliminary frameworks emerged, but I have revised them repeatedly. This is not considered as a pitfall but rather as a feature of knowledge production consistent with material constructionism and consequently materially relativist style of thinking adopted in this study. Hence, knowledge is co-created and co-constructed by the actors (humans and nonhumans) involved in the research process, including also the researcher (Law, 1991b). This makes the process always value-laden and biased because the researcher her/himself is nothing but a craftsperson that is part of the network that creates knowledge (Law, 2004) and ultimately guides practice. Consequently, qualitative inquiry is a twin process of writing up (notes and memos during the data generation, for instance) and writing down the narrative (research report) during which the researcher not only discovers the subject but also herself (Guba & Lincoln, 2005, p. 210). The separation of the researcher and the research phenomenon under investigation is

therefore not always feasible, just as the separation between theory and practice. Instead, they are interlinked. (Mir & Watson, 2001, pp. 942–943)

The next step of the analytical process was to organize the qualitative research data (Elo & Kyngäs, 2008; Krippendorf, 2004). This process comprised of open coding, the creation of categories and grouping them. Through this process, the raw research data was transformed so as to describe the research object of the study in a conceptual form. Open coding was conducted by first cutting and pasting statements related to the proposed question to a Microsoft word sheet (so called wash lists) in their original form. These statements were then marked with different colours to sustain the temporal scope in the analysis. Then, the statements were simplified and grouped under higher order headings which was named by using words that characterized their content. The purpose of the grouping was to reduce the number of categories by aggregating them based on their similarity or dissimilarity into broader higher order categories. Finally during the abstraction phase, the groups were further categorized and merged with similar categories. Each category was further named by using words that characterized their content as in the grouping phase. The abstraction process continued as long as it was perceived as reasonable and possible. Consequently, two iteration rounds were made, during which the categories were named inductively by using words that characterized their content and deductively by using already existing concepts.

Additionally, the temporal orientation in the content analysis was maintained by marking every interview with a different colour. As a result, by following those colours, I was able to distil the upper-level categories that had received more attention at certain points of time.

The second main phase of analysis and interpretation started after finishing the inductive content analysis. I had intuitive feelings that something had been left aside during the inductive content analysis. These feelings were not mitigated by writing down the overall case description of the technological innovation process (initially approximately 11 pages) or by going back to the research data to construct extra memos concerning a few key individuals' interviews (approximately five pages each), especially in terms of their motivations to join the technological innovation development and attitudes toward the networked innovation activities. At the same time, I started to read literature on technologies and networked innovation activities more thoroughly to find out what I was missing or thought I was missing. Consequently, I started to ponder whether a written memo of a few pages from the viewpoint of the technology being developed during the study period would help me to better understand the research phenomenon and to relieve the anxiety I felt about the inadequateness of the inductive content analysis. As a result, the question that I applied to the empirical data started to shift from the managerial aspects of networks in technological innovation toward the

question of "What things are to be related to the network formation of technological innovation?".

To follow my researcher intuition, I first gathered the statements from the inductive content analysis that seemed to be related to the technologies being developed during the study period. This exercise, however, fell short, since the focus of the analysis was originally on social action and thus, on individual people involved in the networked innovation activities. Despite the drawbacks, the analysis gave me clues I wanted to investigate in more detail, namely how did the human actors treat the technology? Who were brought up to the stage and at which point of time? Table 8 gives an example of these clues (in italics) which I started to follow.

Table 8. An example from the content analysis referring a technology

Original statement	Simplified statements	Sub-category
"… our starting point is that we take a look for such technologies that can be made today. And then, to see, well, what they could be used for…. it has led… *a redneck simple application* in a way…. in principle, it can be produced right away."	Simple application	Product differentiation
"…*bar codes* usually… they have this problem that… they are visible…"	Bar codes are visible	
"… [bar codes] spoil… the other *visual outlook* you want to give the product"	Bar codes distort the visual outlook of the product	
" "… it [the product] is about the same than that of this *bar code system* …"	The price of the product corresponds with that of the bar code system	
"… it [the product] is just made purely by *printing*…"	The product is produced purely by printing	
"[the product is] compared to *RFID*… much cheaper…"	The product is remarkably cheaper than RFID	

In this example, only a few quotations and some simplified statements demonstrate why the method of content analysis has received criticism within actor-network theory. By adopting an individual-centered approach, this method ignores the wide range of uses to which objects may be put and comes thus close to technological determinism (Akrich 1992, p. 208). Consequently, the example demonstrates how the content analysis diminishes potential ways in which the different technologies can be seen, for instance, the bar codes and printing methods as potential (full-blown) actors participating in the formation of the network. From the perspective of the content analysis only, they are reduced to the status of intermediaries in the activity of product differentiation.

The main instruction for tracking down agencies in the network formation from the actor-network viewpoint is basically to 'follow the actors' (Callon, 1986a; Latour, 1987, 2005) either directly or – perhaps even more importantly – "by the traces left behind by their activity of forming and dismantling groups" (Latour, 2005, p. 29). With this instruction in mind and in the first place through the human actors identified from the inductive content analysis I started to shadow (Czarniawska, 2004) those silence parties that were seen to relate to the network formation of technological innovation under study.

The emerging understanding that both human and nonhuman activity was important for describing and analyzing the network formation of technological innovation moved the foci initially followed in the analysis of this study. A rather positivist perspective had guided me in the inductive content analysis and the transcribed interviews were in the first place assessed as honest and truthful statements about the reality 'out there'. Now, however, I adopted an interpretive and reflexive perspective to bring forth the nonhuman actors that were lurking behind the human actors participating in activities of the network formation of technological innovation. The research material was, thus, no longer treated as a reflection of reality but as part of the reality being studied (Alasuutari 1995, p. 63), as a representation of the lived worlds of actors at certain points of time, containing also retrospective interpretation.

While following the actors through time, I also generated more documents to better track down how they related to the formation of the network of technological innovation. This research data generation is consistent with the advice given by Callon and Latour, (1981), namely that the humans and the nonhumans are to be investigated differently. While humans participating in the technological innovation development activities can be investigated through interviews, nonhumans can be examined through the intermediaries produced by these human participants. Such intermediaries can be for instance research reports, company presentations and patent releases. During this process, I realised that the technologies (and their networks) developed during the study period came in numbers, blurring the efforts for effectively and empirically determining the boundaries of the network in question. Consequently, a decision was made to follow only one technological innovation, that is, *the intelligent paper*.

Simultaneously with identifying and classifying actors who participated in the intelligent paper's network, I started identifying how they were related to the network formation occurring around the intelligent paper. This identification was done by adopting a certain method of communication which has utilized both in actor-network studies and case studies for presenting complex issues in an accessible and vivid format. This method was the narrative method of communication (Czarniawska, 1998, p. 13; Law, 2004). The analysis was thus entered by at first constructing two story-like descriptions which reflected the clock time (Ancona et al., 2001). The first description focused on the long-term technological innovation development in the name of the intelligent paper as a certain 'technology story' running between ~1997 and 2009 in terms of main actions taken, main outcomes produced and actors (both humans and nonhumans) identified. The second description comprising the same period of time focused on the social actors' networking activities, their interests to join the network, and the challenges faced within the technological innovation development process, thus a certain 'business story'. The main findings from these empirical investigations are illustrated in Appendix B.

After writing up these stories, I focused in more detail on the identified challenges occurring around the intelligent paper. I returned to the research data to better understand when these challenges actually emerged and how they were solved or tried to be solved. I thus tracked down the situations in which the actors started to disagree (or better, started to agree on their disagreement), and the points of time when the actors managed to solve these disagreements and work out a solid compromise to live together (Venturini, 2009, p. 261). These situations are called controversies within actor-network theory. Controversies are debated (the actors start to question the taken-for-granted things and ideas), reduction-resistant (disputes are difficult to reduce into a single resuming question), involving actors of all kinds (both humans and nonhumans), and displaying alliances that are forged (Venturini, 2009, pp. 261–262). As a result, I interpreted that these controversies were occurring around the intelligent paper. Implicitly following Venturini's (2009, p. 262) clarification of controversies in common-sense words, the intelligent paper was interpreted as being concurrently both an actor and a collective, a complex 'social' place (a socio-techno-economic-political 'system') where multiple actors participated, where alliances and opposition transformed seemingly haphazardly; in which nothing was simple as it seemed, and in which the actors were encountering constant conflicts and quarrels.

Next, to empirically re-categorize the actors acting in the intelligent paper's network and consequently its development activities, another instruction by Latour (2005, p. 32) was followed in the study, namely that for any combination of actors and their networks depicted the researcher has to have both the principal actors who speak for the group's existence and those who resist. In doing so, the actors were grouped by following Law and Callon (1992). The identified actors were classified into three different sets, namely the interested (enablers), the reluctant/hostile, and the silent/neutral. As the names imply, the interested actors are the ones that accept the agenda offered by the principal actors and act accordingly, whereas the reluctant/hostile actors resist advancing the agenda and the silent/neutral actors indicate no approval or opposition to the agenda. Besides these actors, also the punctualized actors (Law & Callon, 1992) were identified in the study. They are the ones that the principal agent is able to reduce into a single function, for instance to only provide funds for the technological innovation development. This act diminishes (neutralizes/mutes) these actors' voices against others. Also, these actors were no longer labelled according to their occupation or by utilising the names of the instances and companies. Instead, they were named according to their actorial roles in the network being under formation.

In the study, the punctualized actors occupied the silent/neutral actors, but were also identified among the interested and hostile actors. This consequently led to a decision to label certain actors as silent/neutral rather than punctualized. As a result, neutrality in this study does not mean that some certain actors (i.e., silent/neutral actors) would be

seen to occupy the position of "the hapless bearers of symbolic projection" (Latour, 2005, p. 10). If doing so, this would have affected the quality of the study. Rather, besides the other actors, the silent/neutral actors are also doing something – they serve a single function – in the network of the intelligent paper and don't just sit there (Latour, 2005, p. 128).

Conceptualising the network formation of technological innovation as a process of translation, I finally constructed one empirical portrayal of the network formation of the intelligent paper. This portrayal was presented as a narrative, during which the four-phase model of Callon (1986a) was applied in a heuristic manner. The heuristic utilisation of the model sustained the study's ontological and epistemological stances. The knowing subject and the object of knowing were also methodologically connected by carefully following the distinct methodological principles of agnosticism, generalised symmetry, and free association stemming from actor-network theory (Callon, 1986a, Latour, 2005) throughout the actor-network analysis.

Additionally, the adopted narrative method enabled the inclusion of temporality into this portrayal of the network formation of the intelligent paper; the narrative had a beginning, multiple middles and an end. It also enabled the production of a meaningful portrayal and the sustenance of a somewhat causal dimension in the analysis in which the network formation of the intelligent paper was located around isomorphic actors and their connections as well as around chains of events that had been organized into temporal sequences leading to momentary conclusions (for a critique, see Chapter 6.4.2).

Furthermore, in the narrative, I also utilized different kinds of figures of certain technologies, a few social network mappings which derived from my previous understanding of how a network could be graphically presented, and tables each depicting a certain phase of the network formation of the intelligent paper together with critical actors with small differences. Similar things are commonly seen in the (vivid case) descriptions within the network studies in business context. In this study, and although presented at certain time points (thus during different phases of the network formation), they illustrate for their part the continual movements of the critical actors in the network formation of the intelligent paper that the principal actors tried to settle. I acknowledge that there are other means to describe the network formation of technological innovation than what I have used in this study, such as for instance the ones used by Callon (1986a, pp. 206-207, 210) and the anthropomorphic metaphor (Pipan & Czarniawska, 2010; Porsander, 2005). The reason for neglecting the first was due to the vast amount of critical actors engaging in the network formation of the intelligent paper. Thus, whereas Callon (1986a) has only depicted three sets of actors (i.e., researchers, scallops, and fishermen), I had in my hands a multitude, blurring the efforts to map the network formation of the intelligent paper in an understandable manner. Second, although the anthropomorphic metaphor offers a common-sense way to understand

what the actors in the case of the intelligent paper created, and what kind of power relationships they had in relation to each other, it too offers the view of a network at a certain point of time only (thus blurring the overall process of the network formation) and even more importantly, it easily leads to an over-simplistic view of the network formation of technological innovation.

To conclude, both induction and deduction guided the overall analysis and interpretation in this study. At first, induction was utilised in the content analysis and in following the nonhuman and human actors in the research material. When classifying the actors as well as constructing and depicting the network of intelligent paper from the actor-network viewpoint, deduction was utilised by using analytical concepts that had already been developed and operationalized within actor-network studies.

Additionally, it should be noted here that other research methods focusing on processual issues exist, such as for instance event-based analysis. The reason for neglecting this type of a research method was due to my previous understanding of the method of content analysis and more specifically my early interest in grounded theory, especially in how it conceptualises the data navigating toward the theory laden arguments. This turn certainly affected the way in which the analyses processes are reported here, through which the abstractions and consequently the findings were derived. At a later stage, event-based analysis was neglected because although emphasising actors and their acts in the 'event-makings', it still makes a clear distinction between the social ('man') and the nature (artifacts and objects) in its determining process (Hedaa & Törnroos, 2008), and adopts a 'weak process view' to networks (Halinen et al., 2012).

4. NARRATING NETWORK FORMATION OF THE INTELLIGENT PAPER (~1997–2009)

In this chapter, I provide the analysis of the empirical data. I utilize the four-phase translation model of Callon (1986a) in a heuristic manner as well as the narrative method of communication. The analysis starts with a short overview of the case of the intelligent paper as a technological innovation and as a network in its own right. The case hence involves various human and non-human actors and their interconnected relationships. The analysis proceeds as a narrative where the network formation of technological innovation is located in a temporal and meaningful manner around the isomorphic human and non-human actors which both act and are acted upon (Latour, 2005), and around the connections that concern both the social relationships and the interconnectedness of human and non-human actors. Thus, the analysis emphasizes the actors (both humans and non-humans), their actions (in determining their status) and their interconnectedness in the network formation of the intelligent paper. All entities included in this network are doing something and not just sitting there (Latour, 2005, p. 128). As a result, I do not approach the network concept as a predefined set of actors and relationships which connect them (Fombrun, 1982) but as an isomorphic heterogeneous network. A network, which concerns continually unfolding entanglements of humans, nonhumans and their interconnected relationships – which are neither given nor fixed (Law, 1999).

Additionally, I have utilized quotations from the generated research material in the narrative to illustrate and/or clarify my logic of reasoning. These quotations in the narrative thus give a possibility for the reader to get acquainted with the generated research material and to assess the logicality of my observations and interpretations.

4.1 The case of intelligent paper as a technological innovation and as a network

To empirically grasp the landscape of network formation of technological innovation, I generated, analyzed, and interpreted a variety of research materials (in total 708 pages). These materials concerned a specific technological innovation development process called the intelligent paper in a time period of approximately thirteen years, from 1997

to 2009. The following quotation from one of the actors – the initiator, who was at some point in the process authored to speak over the suppressed others – opens up the birth of the intelligent paper in the mid-1990s:

> " … [In V[9]] we wanted to see what the future holds for paper. There are these fears that, is there any future for paper and what can be done so that there would be a bright future. Well then we brainstormed and… At that time, it was in the year 97, there was a lot of hype about these intelligent products in MIT … about the intelligence in products like coffee cups and so on. The project "Things that think" was ongoing. So we came up with this idea of intelligent paper. We then started to think about what one could do with this kind of intelligent paper. There could be things in packaging. We came up with ideas like these good-looking packages, packages that could measure their environment. It was much harder to come up with ideas in printing and what intelligent printing paper could be and what it could be used for. But for packaging it was easier to think about the possibilities that intelligent paper could be used for. Well then we wondered how one could make intelligent paper. We happened to come across what they were doing in electronics. You make something like a CD-rom where you print these little patterns on plastic. So I thought why couldn't you print these on paper as well in the same way you make these CD-roms… and similarly in electronics you could see these around the world, you could see on the web that they were doing research on these around the world, on using these plastic-like materials, conducting polymers applied and making electronic devices by printing. Like in electronics it's hard to make electronic devices with these silicon-based processes, so you look for easier roll-to-roll solutions. So it seemed fitting for our ideas about this intelligent paper. So okay, we could make intelligent paper by printing on the surface of these new kinds of materials." (Interview data/The initiator, 18.3.2004)

The technological innovation development that I discuss thus concerns a certain roll-to-roll printed intelligence development in Finland that "focuses on new functionalities of everyday high volume printable items" (Södergård et al., 2007, p. 1) and that "are enabling disruptive innovations and new business opportunities" (VTT Technical Research Centre of Finland, 2009, p. 4) "in the development of core-technologies closely coupled with active efforts to identify and build value-adding end applications and their paths to profitable and sustainable commercial exploitation" (VTT Technical Research Centre in Finland, 2008, p. 4). To simplify, they include the means by which novel, intelligent functionalities are brought onto printed (flexible) matter via roll-to-roll production. The roll-to-roll printed intelligence field thus combines know-how from several distinctive areas of industry, namely, ICT/electronics, optics, and paper and printing.

[9] V is a pseudonym.

This technology development can be broadly defined as a nanotechnology, since it ultimately targets to matters of 100 nanometres. The scale thus delineates the kinds of activities, artifacts, tools, knowledges, and structures that comprise this technological domain. Technological innovations that involve the application of scientific knowledge and inventions developed at the nanoscale for commercial ends have also been called nanotechnology-based innovations (Geho et al., 2004; Shea, 2005). The field of nanotechnology is often characterised as involving technologies that act both as the basis for technology solutions across a range of industrial branches and as the nexus for the convergence of other enabling technologies like communication technologies, for instance. As such, the developments made within this field have often been labelled as revolutionary or discontinuous. These innovations are thus enabled by the advances in and the convergence of the fields of physics, material science, and engineering, for instance. As such, they encompass the entire domain of building, integrating, and applying nanoscale structures into larger material components, systems, and architectures. (Geho et al., 2004; Shea, 2005) These development activities have dramatically increased during the past decade all over the world. Hence, how these scientific advances can be translated into commercially viable products in the marketplace has also become an important research issue (Fielder & Welpe, 2010; Gans & Stern, 2003; Kasch & Dowling, 2008).

The case of the intelligent paper can thus be understood as a technological innovation, that is, a process during which technologies are developed to commercial ends through human activity and in the context of a variety of circumstances and historical epochs that shape and reshape the technologies and the people involved in that process (e.g., Geels & Kemp, 2007; Law & Callon, 1992; Pinch & Bijker, 1984; Nicolini, 2010). However, the case of the intelligent paper can also be understood as a network in its own right. From an actor-network point of view, it represents a heterogeneous network in which multiple humans and nonhuman are participating. This study follows the actor-network view to network formation of technological innovation. It means that I give actantiality in this study to those that act or are acted upon (Latour, 2005). These actors can be human or nonhuman. The above quotation illustrates the intelligent paper as a technological innovation at its birth stage. Next, I utilize it as an illustration of the network of the intelligent paper at that time (italics are added to highlight this viewpoint):

> ” … [In *V*] *we* wanted to see what the future holds for *paper*. There are these fears that, is there any future for paper and what can be done so that there would be a bright future. Well then we brainstormed and… At that time, it was in the year of 97, there was a lot of hype about these *intelligent products* in *MIT* … about the intelligence in products like coffee cups and so on. The *project "Things that think"* was ongoing. So we came up with this idea of *intelligent paper*. We then started to

> think that what could you do with this kind of intelligent paper. There could be *things in packaging*. We came up with ideas like these *good-looking packages*, *packages that could measure their environment*. It was much harder to come up with ideas in *printing* and what could *intelligent printing paper* be and what could it be used for. But for packaging it was easier to think about the possibilities that intelligent paper could be used for. Well then we wondered how one could make intelligent paper. We happened to come across what they were doing in *electronics*. *You make something like a CD-rom*, where you *print these little patterns on plastic*. So I thought why couldn't you *print these on paper* as well in the same way you make these CD-roms… and similarly in electronics you could see these around the world, you could see *on the web* that they were *doing research* on these around the world, on using these plastic like materials, *conducting polymers* applied and *making electronic devices by printing*. Like in electronics it's hard to make electronic devices with these *silicon-based processes*, so you look for easier *roll-to-roll solutions*. So it seemed fitting for our ideas about this intelligent paper. So okay, we could make intelligent paper by printing on *the surface* of these *new kinds of materials*." (Interview data/The initiator, 18.3.2004, italics added to illustrate some of the actors in the network of the intelligent paper)

Thus, the network of the intelligent paper does not only involve people (e.g., the company V and the initiator) and their relationships to each other but also multiple 'mindless' materials such as for instance paper, printing, projects, packaging, 'little patterns' (micro/nano type lattice structures), 'something like CD-rom', plastics, printed electronics, conducting polymers, roll-to-roll processing, and the surface of the paper, as the above quotation illustrates. In particular, the network is no longer seen as forming solely between people engaging in the intelligent paper's development activities. Rather, the formation of the intelligent paper occurs as the actors (both humans and nonhumans) are acquiring their characters, more specifically when some of these actors manage to fit the others in their agendas and to silence the mutiny around and between the others. Adopting this viewpoint, henceforth, I perceive the network formation of the intelligent paper as an achievement of a long sociomaterial struggle occurring between actors in their quest for character rather than the patterned network relationships or the stable network structures that are given in the order of things (Akrich, 1992).

Finally, Figure 5 tentatively illustrates the case of the intelligent paper between ~1997 and 2009.

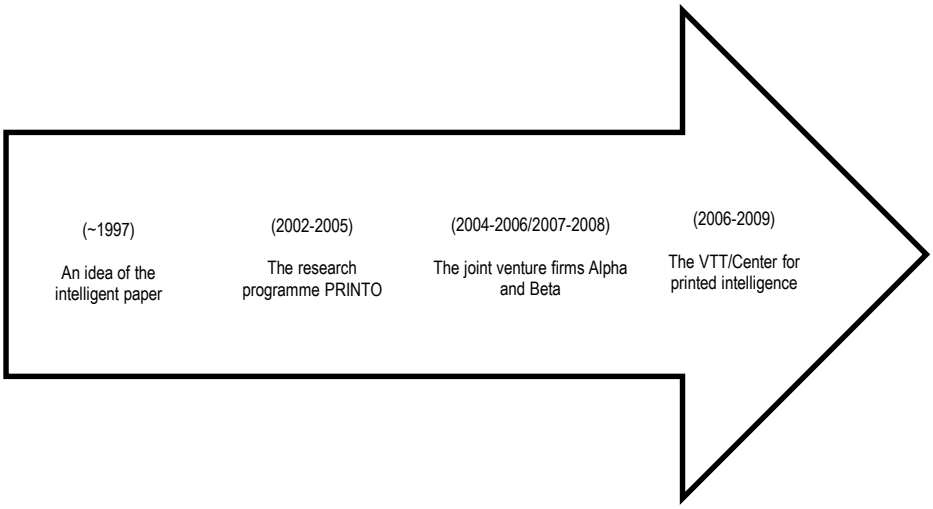

Figure 5. The case of the intelligent paper in a timeline

The starting point of the intelligent paper's network formation was the events taking place around the mid-1990s. At that time, an idea of the intelligent paper and how it could be fabricated was developed. This idea was then progressed and enacted through various sociomaterial practices strengthened the power base of some actors while diminishing that of others. Through these practices that led for instance to participation in the PRINTO research programme (in 2002) and to the establishment of two joint venture firms (Alpha in 2004 and Beta in 2007) as illustrated in Figure 5, one sole actor (i.e., the printed intelligence) was slowly filtered among the others. This actor with the help of VTT/Center for printed intelligence divested the network of the intelligent paper and consequently managed to suppress the others and speak in their names. This divesting did not however mean that the intelligent paper ceased to exist. Rather, it was revitalised by becoming integrated in a more coherent network, which found a common denominator (i.e., roll-to-roll processing). The new network managed to slowly transform its critical actors into a unitary whole.

4.2 Setting the agenda

The initial phase of the network formation of technological innovation from the actor-network viewpoint is called setting the agenda. It means that the principal actors are acting to define an agenda which needs to be traversed to the other actors wanting to participate in the emerging network. In doing so, the principal actors also reveal what they themselves are, want, and experience. (Callon, 1986a, 1986b, 1991; Porsander, 2005)

In this study, I identified three distinct sub-phases of this agenda setting phase: an initial agenda setting phase which occurred around the mid-1990s, and two distinct sub-phases during which this initial agenda was first redefined (approximately in 2004) and then refreshed (approximately in 2007). These sub-phases also included more than one agenda that complemented and/or contrasted the initial agenda. The next sub-chapters open up these three sub-phases in more detail.

4.2.1 Setting the initial agenda

I call the first sub-phase as setting the initial agenda. This phase took place around the mid-1990s. In this sub-phase, two different but somewhat complementary agendas were identified by the critical actors. The first agenda was related to the paper-maker's willingness to secure its future paper-making business. The second agenda emerged as a response to that willingness (see the quotation from interview data utilized in the previous chapter). The second agenda hence was the agenda of the intelligent paper set by the initiator. Table 9 summarizes this sub-phase in terms of the agendas and the critical actors identified. The classification of these critical actors follows that of Law and Callon (1992). The first group of actors accepts the agenda and acts accordingly (they are the interested actors), the second group resists it (they are the reluctant/hostile actors), and the third one takes no side, or better saying it serves only a certain function (they are the silent/neutral actors). Next, these are opened in more detail.

The starting point to the intelligent paper's development can be located in the mid-1990s when a paper-maker (one pulp and paper company) in Finland faced an increasing challenge of 'digitalisation'[10], namely the rise of ICT industry:

> "The consumption of paper will inevitably increase as living standards rise throughout the world and the world economy grows. Present forecasts say that not even electronic communications will be a threat to the forest industry. In North America and certain countries of western Europe growth will slow down considerably to 1.5 per cent a year, but in the NIC countries and Asia it will accelerate to five per cent a year. [..] A word of warning, however, has come from Professor Risto Seppälä, who is a Finnish expert in forest research: too much confidence in the developing countries of Asia and their consumption of paper on a wide scale might be misplaced. He says it is quite possible that the present heady growth will even itself out quickly, because the Asian societies may suddenly

[10] The brackets around digitalisation illustrate the fact that 'digitalisation' can also be considered as an actor-network that includes the parent company which accepts its existence and acts accordingly. As this study focuses on one technology and the development process around that technology, I will not go more profoundly into how the paper-maker was translated in the first place into digitalization's actor-network.

jump one stage in their information technology.“ (Documents/Magazines and news, BUSINESS Finland 1996, p. 57, bolds removed.)

Table 9. Setting the initial agenda

Agenda setting phase	Approximate year of occurrence	Principal actors	Agenda	Interested actors (enablers)	Reluctant/hostile actors (inhibitors)	Silent/Neutral actors
Setting the initial agenda	Mid 1990s	The paper-maker	To secure the future paper-making business	The inventor	‘Digitalisation’	The paper-maker’s business units Paper machines and tools produced by the paper-maker
	~1997	The Initiator	The intelligent paper	The paper-maker The technology developers (certain persons from the paper-maker, VTT and a few Finnish universities as well as a few private firms) Methods for making intelligent paper (incl. tools, methods and processes inside it Paper (and plastics) Paper-making The printing presses Pico (test apparatuses)	‘Digitalisation’	Offshore technology developers Investors (public research funding agencies)

To overcome this observed challenge, this actor proclaimed an agenda of finding scenarios that could help them anticipate changes in their branch of business (i.e., the agenda of securing the future paper-making business). In its actorial role, the paper-maker identified two other actors that would be critical in the future paper-making business. The first identified critical actor was the inventor (the paper maker’s RD department) that was considered as an enabler to secure the paper maker’s future business:

> “Through R&D, V masters the key processes and process controls and continuously develops new spearhead products.” (Documents/Annual reviews and financial statements, one Alpha’s shareholder/Annual review 1997, p. 1)

The second critical actor identified by the paper-maker was the information and communication technologies in terms of ‘digitalisation’. Digitalisation was considered a potential inhibitor for sustainable business development that the paper-maker wanted to respond to. Actors that were silent or neutral toward the proposed agenda were the paper maker’s other business units as well as paper machines and tools produced by the paper-maker.

To address the pressure coming from 'digitalisation', the paper-maker therefore turned to the inventor (the paper maker's RD department). Inside that actor one person, the initiator was assigned the task of creating plausible future business scenarios for the paper-maker. This task was at first part time and shortly later full time in nature. This person had a PhD in engineering and had worked in the R&D department of the parent company for several years. He had multiple contacts to different research institutes, research funding agencies, and experts in the area. He was personally interested in advancing his understanding on a certain branch of physics which deals with the behaviours and properties of light, especially in terms of its interactions with printed matter. (Interview data/The initiator, 18.3.2004; 7.11.2005; Documents/Other, Profiles of the 'interviewees', 2011) He had already been casually following together with the inventor the discussions surrounding the fabrication of nano-structures, for instance developments around thermoplastic nanoimprint lithography (T-NIL) (Interview data/The management of Alpha, 23.3.2004).

Regarding this method, in the middle of 1990s a few researchers from the U.S.A, namely from the University of Minnesota, had presented a novel idea about a pattern transfer process. These researchers wanted to create a cheap and easy way to fabricate nano features. Their grand idea was to imprint nanoscale structures smaller than 10 nanometres over large areas. Although not entirely reaching the structure size expected, they invented the T-NIL method in which a tool which has a nanoscale patterned surface is pressed on a substrate to copy the pattern on the tool to that substrate. In other words, by stamping a hard mould into soft material, more diminutive features can be fabricated. This development got the attention of many researchers all over the world that further developed many different variations and implementations of the original idea, including future business scenarios in the name of intelligent paper which were suggested to the paper-maker by the initiator (and at a later stage those included in printed intelligence). (Documents/Research Publications, Chou et al., 1996; Documents/Research Publications, Lenkkeri et al., 2003; Documents/Research publications, VTT/Research and development activities in printed intelligence 2009, p. 20; Documents/Magazines and news, Technology Review, 2003; Documents/Other, Nanoimprint lithography, 2012)

Consequently, the initiator started to consider whether T-NIL type of developments could be applied to paper-making so as to fabricate intelligent paper that in turn would act as a plausible future business scenario for the paper-maker and consequently be a response to 'digitalisation':

> "… it all probably started around 1997. In V, we pondered what the future holds for paper, for instance how we could radically change the properties of paper. At that time, we examined the possibilities that electronics and optics can offer. They are familiar areas to me, I have studied them… I have a background…and in V

> A[11] I have long worked in developing these automations. But back then, it was kind of perceived that in optics they spoke about diffractive optics and how optical structures are produced on flat surface. So they are not lenses but threads, precise threads upon this surface. You can do similar things with them as you can do with lenses. And then in the electronics side, it was perceived that there are novel materials which can be handled as liquids. […] It was quite a radical thing because plastic is an insulating material which is conductive and thus this development was born in which it was pondered that memories and microcircuits could be made from plastics. It offers an advantage over silicon, because it is liquid based, it can be handled as liquid in printing.. it can be printed and by that way the production volume can be increased onto a whole different level. These developments were back then in 1997 examined and it was noticed that while M[12] was involved with the production of paper machines, this idea fitted well with this. As M is producing paper machines, we can examine how printed electronics and optics could be applied to paper's surface..." (Interview data/The initiator, 7.11.2005)

To advance this idea, the initiator started to identify critical actors and their identities that would not only buy the idea of the fabrication of intelligent paper, but also help transform the idea into concrete business solutions. The initiator thus set another agenda which it saw would fulfil the needs of the paper-maker. This agenda was the intelligent paper as a means to lengthen paper's life cycle, more specifically, the idea of fabricating optics and electronics onto paper (see the quotations above).

The initiator identified the critical actors both inside and outside of the paper-maker. The critical actors identified were the paper-maker, the technology developers (a few units inside the paper-maker, VTT Technical Research Centre of Finland, as well as a few Finnish universities and private firms), and the methods for fabricating intelligent paper (including different kinds of tools, methods, and processes inside the fabrication methods). Also, paper (and later plastics as the above quotation also illustrates) and paper-making (certain processes within the paper-making process) were identified as critical together with printing presses and test apparatuses which I call henceforth Pico. All these actors were considered as enablers for advancing the proposed agenda. Whereas the paper-maker would provide resources for the core technology development (i.e., act as a specific resources provider), the developers together with the fabrication methods and paper would transform these resources into such sellable solutions that the

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[11] Name is a pseudonym.

[12] M is a pseudonym. This company was created in the summer of 1999 though the merger of the earlier mentioned V and another Finnish multinational company (Literary material/Annual reviews and financial statements, One of Alpha's shareholder/Annual review 1999).

paper-maker could utilise in its future paper-making businesses (i.e., act as specific resources exploiters).

Silent but yet critical actors were the offshore technology developers in relevant scientific fields (especially those developing T-NIL method) and investors (public research funding instances such as Tekes[13]). The initiator thus anticipated that these instances would accept the agenda of the intelligent paper with no extra effort. Also, they would more or less serve a certain function, namely to act as resources providers. Reluctant or hostile actors were at that time only 'digitalisation' which had been identified by the paper-maker in the first place.

4.2.2 Redefining the initial agenda

The activities aimed at securing the intelligent paper's existence led to the establishment of the joint venture firm Alpha in 2004. These activities also started to transform the initial agenda (set by the initiator) and the critical actors. Table 10 sums ups this sub-phase during which the initial agenda and the critical actors were re-identified by the management of the joint venture firm Alpha. The management seized the moment to speak over the others.

Table 10. Redefining the initial agenda

Agenda setting phase	Approximate year of occurrence	Principal actors	Agenda	Interested actors (enablers)	Reluctant/hostile actors (inhibitors)	Silent/Neutral actors
Redefining the initial agenda	~2004	Alpha (the management of Alpha)	Alpha as the mediator between the technological innovations' development and the paper-making business	The initiator The experts in the hard core The customer-partners The investor-partners Friends and partners The intelligent paper (incl. product D) The printing presses (the heatset offset presses and the gravure presses)	Actors inhibiting the agenda of the intelligent paper (e.g., some technology developers, paper-making, paper and hot embossing)	The investor-owners Investors (public research funding agencies)

While the initiator had identified the critical actors both inside and outside of the paper-maker in the first sub-phase phase of the agenda setting in the mid-1990s, he had also

[13] The Finnish Funding Agency for Technology and Innovation

revealed his true nature. This nature was to be a mediating actor between the technological innovations' development and the paper-making business. The following quotation illustrates his actorial role:

> "… one thing related to my role is to try and keep up what people are doing and where as well as with whom they are working with and how everything goes. [It is important to] …make enough phone calls to these people so that one knows how to respond if someone brings up a problem that hey, the other guy is dealing with similar things… in this kind of a network, it is good for someone to have some kind of a big picture of where things are going." (Interview data/The initiator, 18.3.2004)

This actorial role the initiator had acquired enabled the early network building but fell short when a few parties started to question the actorial roles assigned to them, namely the paper-maker as a resources provider and VTT (and a few other universities) as the technology developers to the network of the intelligent paper.

When the joint venture firm Alpha was established in 2004, a few persons that comprised Alpha's management seized the role of the principal actor. The principal actor started to redefine the initial agenda. They considered Alpha and not the initiator as the one who should act as a mediator between the technological innovations' development and the paper-making business as illustrated by the following quotation:

> "…[the issue of] what we are doing here belongs to the firm and not to some product development engineer working for us…" (Interview data/The management of Alpha, 16.1.2006)

The initiator was thus to be seen only as one expert among others and a carrier of one specific technological development among other potential developments around intelligent paper in the future. Alpha, in turn, was to be seen as a high-technology provider, a mediator bringing new technological innovations to the marketplace related to intelligent paper-making and printing as illustrated by following quotation:

> "… we operate as a system integrator both in the commercial and the technological; then we also operate as a technology firm. It is so big a thing that we are taking forward here that is enough for us to focus on our hard core competence and additionally the management of this whole ensemble." (Interview data/The management of Alpha, 16.1.2006)

To follow this redefined agenda, the management started to re-identify the critical interested actors that they wanted to include to the network in order to promote the agenda. The initiator and the actors enrolled to the network around the intelligent paper that had been formed so far were nevertheless considered as critical parts of the network

(e.g., paper-making, paper and plastics, different printing presses, and methods for making intelligent paper). Intelligent paper itself, re-identified as the technological basis of Alpha, was also considered critical. However, it was no longer considered as the main agenda to be promoted, but rather the basis from which various technological innovations were going to be launched in the future. The following quotation is interpreted to illustrate this re-identification of the intelligent paper:

> "… we own the core technology around which we build the business model … and then we build them further; the further we go from the core, the more we begin to utilize partners to accomplish the task at hand. But nevertheless, we try to master the hard core ourselves, the way we implement it and above all take the development further." (Interview data/The management of Alpha, 16.1.2006)

The technology developers, re-identified as experts, were also critical actors as they were the ones who would continually bring forth the innovative technological solutions that Alpha could sell and/or licence to other parties. These other parties were now more thoroughly clarified as potential customers.

The hostile actors were at that time considered to be those critical actors who casted doubt over the promotion of the intelligent paper. These actors were especially the actor of the method for fabricating the intelligent paper and some technology developers (mainly VTT and actors surrounding it) who had continuously eroded the promotion of the intelligent paper and its network formation.

The critical silent actors were those that were considered as accepting their roles without the need to make any extra effort to enrol them. These 'punctualized' actors were the investors (including the future owners of Alpha and the public research funding provided by Tekes and VTT via the PRINTO programme run between 2002 and 2005) who had already been enrolled in the network and the actors surrounding these investors. These actors were still considered to serve a single function, namely to provide financial resources to Alpha.

Whereas the intelligent paper, the initiator, the experts, and the investors were quite easily re-identified as actors in the intelligent paper's network, the identification of potential customers required further negotiations. Some human members of Alpha envisaged global brand owners' value-chains as Alpha's main customers. The others prompted to consider the brand owners themselves as Alpha's main customers. The following quotation illustrates these negotiations from the viewpoint of one Alpha's expert (the bridge builder):

> "… this has been somewhat a topic for conflict in these developments. Some say that brand owners are our customers. Others say that no, we have to go along the chain and that brand owners are the end goal. But you don't want to make them angry. I do not see any conflict between these two. It is a matter of the brand

> owner's needs and especially the needs of communication between a brand owner and a consumer. And the issue is how to reach that. We go along two paths; directly to brand owners and indirectly by investing our own inputs in the developments combined with that of our partners." (Interview data/The bridge builder, 10.3.2004)

These human members of Alpha also discussed whether the technological solutions developed within Alpha should be utilised in product authentication or be seen in a broader manner, as the means for global brands to invigorate interaction between the brands and their users. The initiator envisaged that Alpha's future technological solutions could be utilised to both purposes:

> "In a way, our products have two characteristics. On one hand, they protect the brand, its value. We produce an effect which is difficult to copy and which guarantees that within a certain package, there is authentic stuff inside. […] On the other hand, we can utilize this effect for attraction. With the help of the effect, we make more attractive packages which draw attention." (Interview data/The initiator, 7.11.2005)

As a result of these negotiations, Alpha's management finally decided to target global (consumer) brand owners as its main customers whose interests were in product authentication and/or the extension of physical brand experience. They were not only considered as enablers for capturing large volumes and profitability (see the first quotation below), but also enablers for technology mobilization (see the second quotation below):

> "… our volumes are the problem. The volumes should be so big that there are no such instances in Finland which would produce such high-volumes. That is our problem. We speak about hundreds of millions of pieces of some product and in Finland, nothing is being produced in hundreds of millions actually, nothing at all." (Interview data/The management of Alpha, 16.1.2006)

> "Although one might think that it is challenging to have some big global brand as a customer, but there is at least the issue that if they are interested, they also have money to invest in it, so as to advance things." (Interview data/The initiator, 7.11.2005)

Finally, all actors mentioned above were further differentiated into either hard core or friends and partners. The hard core were the (human) actors which "owned core technology" (see the quotation of the management of Alpha above). These were basically considered to be those (human) actors, "our own experts" (see the quotation below), which got a monthly pay from Alpha. Friends and partners comprised of the actors who could occasionally bring input to Alpha and its network. They could be evoked if needed,

such as technology developers, subcontractors and suppliers of certain devices, for instance. The identification of these instances was purposefully left quite open. The management of Alpha considered that the friends and partners could operate in any (re-)identified actorial roles as long as they enabled the technological innovation development and its dissemination in the longer run. The following quotation illustrates these friends and partners:

> "… we have developed a term of Friends & Partners. Basically, they are partners that help us realize our developments. […] We call these partners because the idea is that we do these developments for brand owners in order to fulfil their needs. And the idea is that over time, these brand owners would support projects and involve their advertising agencies and printing houses and package suppliers and we would do these projects together in a way as forced by the brand owners, but anyhow together. The goal is to create an ethos of working on behalf of a shared interest. We have noticed, however, that we have to have our own candidates to offer in these negotiations. It may occur that a brand owner dislikes the idea of compelling some printing house to participate in the project and invest in it. So, it would be better for us to have some Friends & Partners that we can suggest if the brand owner does not have a candidate of its own or for some reason does not want to involve that party in the project at that stage. So, we have now discussed of having these partners in flexible packaging. In paperboards, we have printing house H. Why not advertising agencies and these types of experts as well. And then we can complement projects with our own experts." (Interview data/The bridge builder, 10.3.2004)

Consequently, the management of Alpha no longer considered the investors as only providing monetary resources (investor-owners or investors such as for instance Tekes), but also as owners providing inputs both in the development activities sphere and in cash flow generation. The same concerned the customers; they were not only seen as providing a basis for business survival but also as parties participating in the technological innovation development, thus as customer-partners. Similarly with the experts (at the later stage), they were not only considered as giving inputs into the technological innovation development, but they could also be considered as expert-investors/partners, if also providing monetary resources to Alpha.

4.2.3 Refreshing the redefined agenda

Alpha's operations were discontinued in early 2007. This did not result however in the breaking down of the network of the intelligent paper formed so far. Instead, a few actors were still deeply interested in continuing to act in the network of the intelligent

paper. These actors were the initiator and one of Alpha's experts that I call the code promoter:

> "We have developed a solution, based on printed electronics, which can authenticate and track goods and documents .Unique codes, which are optically not distinguishable, are printed on documents and goods according to rules established by proprietary algorithms. Codes may be invisible or hidden under the artwork. The codes, which may contain 96 bits of digital information, are read and decrypted with specifically designed Radio Frequency electronics. We focus on a simple, practical and reliable solution which can be printed with standard equipment on documents and goods. Our codes can be authenticated on the field with simple readers, the information contained in these can also be sent to a database for tracing or registration purposes. The N[14] solution is cost effective and safe for the protection of large series of documents or of mass products." (Documents/Brochures, Printed Electronics for Authentication and Tracking: Our contribution to a safer world, 2011. Bolds removed.)

The other actors interested were the two initial investor-owners called the paper-maker and one of Alpha's customer-partner C[15]:

> "In Alpha's development, there was a desire to focus on D technology area. This area is close to the core business of M as well. For this reason, a buying commission was carried out in which N sold its Alpha shares to M. H continues as a minority shareholder in Alpha, because D technology also relates to their business development plans." (Documents/Annual reviews and financial statements, Alpha/financial statement 1.1.2007–31.12.2007)

> "C has continued to work with these things; it has utilized ordinary holograms in some marketing campaigns. (Interview data/The initiator and the bridge builder, 29.5.2009)

These actors started separately from each other to refresh the redefined agenda and consequently to re-identify critical actors according to their agendas. Table 11 provides a summary of this third sub-phase of setting the agenda that are next discussed in more detail.

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[14] Name is a pseudonym.

[15] The existence of this actor is only acknowledged here. This is due to nonhuman elements attached to it, namely the "*ordinary* holograms" as illustrated in the above quotation. By definition (given to them by the initiator), these thus cannot per se be attached to the intelligent paper. I have thus followed the initiator here in how he has made the distinction between what is to be included into the intelligent paper and what is to be left out. Also, the other actors which I have followed in this study have not elsewhere set this potential actor onto a stage.

Table 11. Refreshing the redefined agenda

Agenda setting phase	Approximate year of occurrence	Principal actors	Agenda	Interested actors (enablers)	Reluctant/hostile actors (inhibitors)	Silent/Neutral actors
Refreshing the redefined agenda	~2007	Beta (the initiator and the code promoter)	The Intelligent paper extended	The investor-owners and investor-partners The customer-partners The network of the InkByte (e.g., the electronic code, a code reader, software to read the electronic data, demos, inks as well as a few technology developers and a few experts) The network of the intelligent paper (e.g., paper, paper-making, hot-embossing, different kinds of inks, Pico as well as a few technology developers and a few experts)	(The actors inhibiting the agenda of the intelligent paper)	-
	~2007	The paper-maker	To secure the future paper-making business	The intellectual property rights of Alpha VTT One Finnish technology consulting company	- (Actors inhibiting the agenda of the intelligent paper)	-

The activities that the initiator and the code promoter engaged in finally led to refreshing the redefined agenda through establishing a firm called Beta[16] in 2007. At the background was a chain of events where short after the launch of Alpha in August 2004 the code promoter from one of Alpha's investor-partners had joined Alpha's network. He had a long working history in the field of communications and information technology and a deep personal interest in developing his career (Interview data/The code promoter, 23.1.2006; Documents/Other, Profiles of the 'interviewees', 2011). His main duties included developing and disseminating the InkByte[17] technology as illustrated in the following quotation:

> ".. my job is to take care of the InkByte product family and in practice it means to productize and commercialize it. […] the group that has been working here has been relatively big in terms of the amount of people […] in making these prototypes last year, we involved, let me see, about four to five firms in these developments. We have involved them in making the product and then we have

[16] The name is a pseudonym.

[17] The name is a pseudonym.

> also had several patent offices, consultancy firms and such instances along. So it has been quite a legion that has participated in the development… one advantage of a little firm like us from my point of view is that I can get involved in many things, so that the domain of operations is not too narrow. On the other hand it means that everything is continually going on." (Interview data/The code promoter, 23.1.2006)

The idea for this technology development had emerged already during the PRINTO programme that was run between 2002 and 2005 in close collaboration with the VTT researchers. The idea was that electronic data could be roll-to-roll embossed on paper for authentication purposes. InkByte can thus be considered as an extension of the first product version D launched to the market in early 2006 in the name of the intelligent paper. While this product was considered as a passive and simple printed technical solution, InkByte was meant to be more active and intelligent. Following quotation illustrates its core property:

> "… as regards InkByte, the point is to have electronic data fabricated onto printed matter. Our advantage of course to a large extent is in being able to hide the code so that it does not disturb any other information that there may be for instance in the label of a bottle or on the surface of a mobile phone package or on a page of a magazine." (Interview data/The code promoter, 23.1.2006)

From the late 2004 onwards, the code promoter started to identify the critical actors in order to advance the extended idea of the intelligent paper which was to roll-to-roll emboss electronic data on paper. These critical actors were (besides the initiator and the code promoter) the technology developers (i.e., a few researchers from VTT Electronics) and several devices, tools and technologies that the code promoter planned to either induce or force to be enrolled in the network around InkByte. Together with these critical actors InkByte was slowly concretised and consequently, the network around it was gradually formed.

During the PRINTO programme the first generation of InkByte was tested with success (i.e., some measurement signals were received in a laboratory. Some technology developers developed a code reader with suitable software used to read the data embossed on a print with certain conductive inks. One of Alpha's experts who was specialised in flexography developed conductive inks' printing techniques together with a few other technology developers coming from VTT's side together with the initiator. While the first patent related to this technology development was applied for in 2005 (Documents/Other, patents related to the technology development, 2011), the second generation prototype was jointly tested with one Alpha's main customer-partners in Singapore. The code promoter together with the technology developers and a few experts from Alpha had created a demo package replicating one of the investor-partner's

products. This demo package was then utilised in the tests in Singapore. To the surface of that product, they had imprinted game-type information, which was then read by the demo phones. They had also developed a demo computer program, which modelled what the test group was doing with the handled demos. (Interview data/The initiator, 7.11.2005; Interview data/The code promoter, 23.1.2006; Documents/Presentations, Kopola, 2005a, 2005b; Documents/Magazines and news, VTT news 2.2.2005)

Although the first product version D launched in early 2006 was complex in its true nature, it was experienced by Alpha's experts as an easy solution for customers to use because no extra investments in manufacturing equipment were needed. In the case of InkByte, the code promoter together with the initiator had to evoke the whole network around it (starting from suitable conductive inks, electronic codes, their embossing on different prints, code reader devices, and computer programs around core technology as well as the potential customers) before it could be launched to the market. When Alpha faced a second financing round by the end of 2005, almost all parts of InkByte's network existed in some form as illustrated below:

> "[The initiator] has started to think about these ideas at the turn of the century, so now at the moment, we have advanced that technology into a stage where we have a certain prototype level of electronics and software that can be in principle delivered to initial users and that can be tested and productized with a substantially small effort, so as to launch it to the markets. And, at the same time, it is a whole system; it is not just a single device but a system so everything is starting to look assembled. Some things are still missing but it can already be utilized to do something in reality. From that perspective, then, it already exists." (Interview data/The code promoter, 23.1.2006)

Investors and customers which were the parts of the network that were not considered as important during Alpha's existence emerged as critical enablers for InkByte after the closing down of Alpha. Just like in the case of Alpha, these critical human actors were planned to occupy multiple actorial roles simultaneously, namely providing finance and joining the ongoing technology development, thus acting as owner-investors, investor-partners and customer-partners (Interview data/The initiator and the bridge builder, 29.5.2009). The yet critical but reluctant actors were considered to be those actors that were already inhibiting the agenda of the intelligent paper. No silent actors were identified. All the actors that the initiator and the code promoter (as the authors of Beta) identified were thus considered only as either enablers or inhibitors for InkByte and its network.

While the initiator together with the code promoter continued acting in the network of the intelligent paper after the closing down of Alpha's operations, so did the paper-maker (now two initial investor-owners of the joint venture firm Alpha) (see the second

quotation at the beginning of this chapter). The reason for continuing stemmed from the paper-maker's deep interest in the area as it intertwined with its own core competences. It was also experienced as an important agenda to secure the paper-maker's future operations in the paper-making business.

Hence, the paper-maker started to re-identify the critical actors that would either accept or hinder its agenda. Similarly to the initiator and the code promoter (as the authors of Beta), it re-identified only those actors that would either enable or hinder the advancing of "D technology area" (see the second quotation at the beginning of this chapter). The critical re-identified enablers were the intellectual property rights within "D technology area" that Alpha had acquired through its human participants (obviously with the help of several nonhuman actors) throughout the years of engaging in the intelligent paper's network. VTT and one Finnish technology consultancy company specialised in R&D and business strategy and the advanced materials were also considered as critical enablers. Together with these actors, the paper-maker planned to advance its agenda further. The inhibitors of the promotion of this agenda were the actors that had already for years inhibited the agenda of the intelligent paper, such as for instance the methods for fabricating the intelligent paper.

4.3 Forming the pack through performing various negotiations

Identifying an agenda and critical actors accordingly is not enough to form a network in technological innovation from the actor-network viewpoint. Instead, through various negotiations the principal actor advances its agenda so that it imposes and stabilises the identity of the critical actors and consequently diminishes their interest in other alternatives (Callon, 1986a, 1986b, 1991; Porsander, 2005). Callon (1986a) has identified these actions to take place in two distinct phases in the original four-phase model of translation, namely the phases of interessement (the pack formation phase during which the actors are made interested and locked into the proposed agenda) and enrolment (the phase of performing various negotiations to direct, control, and manage packs).

In contrast to this model (Callon, 1986a), I have bound these two phases together in this study and call it as 'Forming the pack through performing various negotiations'. In doing so, I also utilize the relational and somewhat metaphorical word of pack rather the word 'ally' (Callon, 1986a) or 'group' (Latour, 2005). The decision for the first was alleviated by the observed difficulty to separate these two phases of 'Interessement' and 'Enrolment' from each other as well as my interest in empirically demonstrating the continual contradictory movements occurring while forming the network of the intelligent paper rather than pointing out the actual moments when the actors were finally locked. (For a more detailed discussion on this subject, see Chapter 5.2.) The

decision for the latter stemmed from the generated data as well as from the data analysis and interpretation processes, in which I engaged myself with already existing network formations occurring around the intelligent paper.

Consequently, while the principal actors engaged in advancing their agendas and therefore tried to lock the critical actors into their places in the network of the intelligent paper, a number of negotiations and re-negotiations were performed. There was a need to transform questions circulating around the idea of the intelligent paper – that is, can optics and electronics fabricated onto paper?; do the critical actors identified want to participate in intelligent paper's network? – into more stable statements. These statements included that the optics and electronics *can* be imprinted onto paper; the actors *want* to accept their role given and thus join the network being under formation. I have identified these negotiations within five distinct sub-phases (i.e., forming the initial pack, reforming the pack, forming the pack according to the redefined agenda, and forming the pack according to the refreshed redefined agenda) that took place both before and after encountering potential betrayals, affected by the agenda setting sub-phases. These negotiations aimed to ensure that the identified and re-identified critical actors were playing along the roles assigned to them. They included seduction, transaction, the creation of new actors, collaborative work, coercion or silent consent, or simultaneously all the manoeuvres. The next sub-chapters present these five sub-phases in more detail.

4.3.1 Forming the initial pack

The initial pack formation phase occurred between the mid-1990s and 2001, after the paper-maker started to consider its future role in the paper-making business and after the initiator seized the possibility to provide a solution to the paper-maker for the challenge that it encountered. Table 12 summarizes this first sub-phase.

Table 12. Forming the initial pack

Phase of forming the pack and performing various negotiations	Approximate year of occurrence	Principal actors	Agenda	Interested actors (enablers)	Reluctant/hostile actors (inhibitors)	Silent/Neutral actors
Forming the initial pack	~1997– ~2001	Initiator	The intelligent paper	The paper-maker The technology developers (certain persons from the paper-maker, VTT and a few Finnish universities as well as a few private firms) The bridge builder Potential customers (a Finnish food industry company) Methods for making intelligent paper (the method of hot embossing) Paper-making (calenders and flexography The printing presses (Heatset offset presses) Pico (test apparatuses)	('Digitalisation') (T-NIL method) Offshore technology developers Paper and plastic (e.g., paper's surface and plastic foils) The paper-maker's gravure presses	Public research funding agencies

Approximately at the time of receiving the full-time task from the paper-maker to focus on the intelligent paper development activities in 2000, the initiator had already reviewed current developments in the field made within the T-NIL method. He was convinced that paper would accept the utilisation of the T-NIL method and consequently, both these two actors would be easily integrated into the emerging actor-network. Prompted by published studies at the time, in late 1990s he contacted offshore technology developers, those silent in the phase of setting the agenda. He also travelled to a few places where these technology developers were eagerly studying nanoimprint lithography processes such as MIT (where the person claimed as a father of T-NIL had moved) and the University of Tokyo (in 1998). The following quotation illustrates these early actions taken that were targeted to advance the agenda of the intelligent paper and consequently lock the identified critical into their places:

> Interviewee: "… the starting point for us here has been that the competence is scattered. We cannot get the competence we need; there is no way for us to gather it together."
>
> Researcher: "Well, how has this then come into being in such a way that the competence is scattered?"

> Interviewee: ”It has come into being in such a way that once there is a goal, we want to do this thing now. Then we have tried to find the experts. Now some have been found in Italy, some in Joensuu, some in Oulu, some in Helsinki.”
>
> Researcher: ”How were these experts initially found?”
>
> Interviewee: ”I am familiar with some Finnish research institutes from my previous work. I am familiar with VTT’s competences. I am familiar with Joensuu’s competences. And then, when I have new problems, I may approach these instances again. I have also found some others by making a little search effort. We have done these, at first little projects and then bigger ones. At the beginning of this project, I thought that this is that type of a development project that I cannot necessarily find competences I need from Finland. I thought I needed to search, to create connections in different directions. I went to Japan a little. I went to the U.S. a little. I noticed that they were not so keen on collaborating. […] Then, we had that Italian company. We noticed that they have such knowledge and competence that might be related to what we had in mind. They had already created local connections to different parties in Italy. Then I realized that I had been trying to find competences in the U.S. and Japan like a madman but when I observed what Finland has to offer, I noticed that VTT has people, it has knowledge in this area. Through these events it kind of started to form then. ” (Interview data/The initiator, 18.3.3004)

As the above quotation illustrates, these offshore actors showed little interest in traversing the proposed agenda and can thus be considered as reluctant actors. Rather than (only) linking the reluctance to the size of these diminutive fabricated features (i.e., matters exceeding 110 nanometers are worth studying similarly to those that fall below), it was related to cultural differences in working habits and the distance between Finland and these countries rather than the size of these diminutive fabricated features as illustrated below:

> “Well, it may be a patriotic thing. Maybe the Japanese want to work with each other just like the Americans. We are here in Finland and now we should, since we are in a starting phase, maybe we could try to find partners from Europe.” (Interview data/The initiator, 18.3.2004)

This drawback encouraged the initiator to contact other technology developers (see the quotation above) that possessed knowledge, tools and devices for modifying the agenda through intertwining it with a method of hot embossing, more specifically with a method of hot embossing micro/nano type structures onto *paper*. The following quotation illustrates shortly the areas where hot embossing has been previously utilized:

> “Hot embossing is the technique to fabricate high precision and high quality *plastic microstructure*. […] Hot embossing is actually used only for *a few optical applications*

> where high precision and high quality are important.[…] Already years ago microstructures are made this way. However, for industrial production, hot embossing often is considered as being not very attractive. It is believed to be too slow and to be associated with too much manual work." (Documents/Research Publications, Heckele et al., 1998. Italics added.)

The initiator anticipated that both this fabrication method and the paper would be easily integrated in the network of intelligent paper as long as the technology developers accepted their actorial roles. Figure 6 illustrates this fabrication method called flat-on-flat hot embossing.

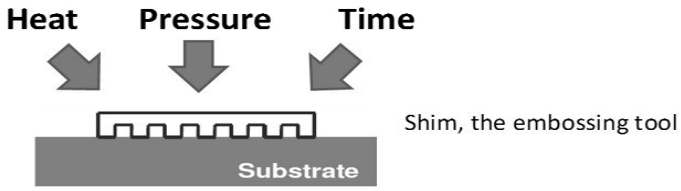

Figure 6. The basic method of hot embossing

(Source: Documents/Presentations, Korhonen/Elmo Results Promotion, 8.11.2005)

The fabrication basically proceeds as follows: firstly, the embossing tool called a shim is pressed hard against a substrate in a high temperature. Then it is kept in place for a while so that the pattern on the shim is copied onto the substrate. Finally, the shim is separated from the substrate. If the method is applied to plastic materials (for manufacturing polymer microstructures), the temperature must first be above the softening point of the plastic and then cooled down below the softening point. (Documents/Research Publications, Heckele et al., 1998; see also Documents/Magazines and news, Technology review 2003, pp. 42–43; Documents/Other, Nanoimprint lithography, 2012) For fibre-based materials, heat is also needed to transfer the pattern on the shim to the chosen material[18] (Documents/research publications, VTT/Research and development activities 2009, p. 20).

This method was anticipated to be able to create patterns on a wide range of materials with rather simple mechanical and thermal requirements. It was also considered suitable on porous materials like paper. (Documents/Research Publications, Heckele et al., 1998; Documents/Presentations, Kololuoma, 2005; Documents/Other, Nanoimprint

[18] In 2009, the initiator reported that the embossing cylinder must be heated to over 100°C to fabricate the nano patterns onto paper or plastic (Documents/Research publications, VTT/Research and development activities 2009, p. 20).

lithography, 2012; see also Documents/Research publications, Annual reviews and financial statements, Infotech Oulu, 1998, p. 46; Documents/Research Publications, Varjus, 2012, p. 17; Documents/Magazines and news, Technology review 2003, pp. 42–43) Thus, while the T-NIL method was targeted to fabricate top-quality nanoscale electronic structures, this hot embossing method that was planned to be used in fabricating the intelligent paper operated with surfaces of a lower quality, that is, structures exceeding 110 nanometres in breadth as illustrated below:

> "We are already quite far from the way optics people calculate the kinds of thread patterns that should be fabricated onto a surface. Patterns are approximately below micro meter, a couple hundred nanos in breadth and 150 nanos deep lines. If its depth decreases to 100 nanos, we lose efficiency so we need to control it very well in order to achieve that 150 nanos. If it is 130, it can still be correct; if it is 110, it is a failure". (Interview data/The initiator, 7.11.2005)

To enrol paper, 'paper-making' and the chosen method of hot embossing to the network being under formation, the initiator therefore turned to a few technology developers located in Finland. Inside the paper-maker, the initiator contacted a few business units he already knew from previous development tasks. The following quotation illustrates how some humans from one of these units gradually showed willingness to accept the actorial role of a technology developer and thus, to be enrolled to the network of intelligent paper (this instance was at a later stage also considered as the most potential place for future intelligent paper's production line):

> "… I joined at the time when I was working as a CEO in Italy, in V R[19] […] at that time people were talking about displays, about printed displays… We print, we produce transparent displays at the moment. And back then, [the initiator] and [the inventor] noticed that in M, there is a company which manufactures printing machines. They came to Casale to see it and we had.. We have also a certain pilot production machine ["Pico"] and with the help of that machine they then [experimented with the intelligent paper]. And also, it had one process which was included. And then there was another process or a similar process in which [the initiator] and P R[20] and P K[21] and I, we searched for future products. And because I was operating in the printing side and converting side, in the manufacturing of converting machines which is like the next phase where M traditionally operates. I was taking part in these teams. And then, they started making experiments in Italy so that was how it started. I felt, I experienced that because we are a machine supplier, our margins are so lousy. But if we could sell whole systems and not only

[19] Name is a pseudonym.

[20] Name is a pseudonym.

[21] Name is a pseudonym.

> machines, we could raise the margins onto a whole other level and to continually deliver new parts to the maintenance operations. These led to my support for this project…" (Interview data/The management of Alpha, 23.3.2004)

These contacted technology developers were motivated by personal career development opportunities (Interview data/The technology developer, 15.3.2004; Documents/Other, Profiles of the 'interviewees', 2011) and economic opportunities (see the quotation above) that the intelligent paper could offer them. These developers were working in physically distant locations both from each other and from the initiator. For the initiator this was however an insignificant issue. He had already at that time realised that combining and integrating cutting-edge expertise and enrolling critical human and nonhuman actors to the emerging network of intelligent paper was a very difficult if not an impossible task to achieve in just one locality. As a result, the initiator envisioned that the network around the intelligent paper should resemble the structure of the Internet. This would help avoid the heavy costs accrued from the acquisition of separately owned manufacturing equipment and attract the best human expertise and the critical nonhuman actors for the core technology development. In Finland, he planned for a bigger hub connecting specialists, customers, partners and subcontractors. In Italy, he planned for another bigger hub connecting internal and external local actors. Additionally, he envisaged one bigger hub in the U.S.A and another one in Japan, and, of course, 'thick main cables' between these hubs enabling and encouraging frequent interactions between its human members. (Interview data/The initiator, 18.3.2004)

Outside the paper-maker, the initiator turned to technology developers working in VTT and a few Finnish universities. The initiator was familiar with their activities; he had been collaborating with them many times during the past years (see the quotation at the beginning of this chapter) and had also been involved in certain patent applications (Documents/Other, Patents related to technology development, 2011).

The initiator anticipated that the enrolment of these technology developers together with those enrolled from inside the paper-maker were critical not only because they possessed certain special competencies but also because they could help enrol some other critical (nonhuman) actors into the emerging network of the intelligent paper. These were paper (and later also plastics), paper-making (calenders and flexography[22]), printing methods and presses (including the paper-maker's gravure presses) as well as

[22] Calenders are located at the end of the paper-making process (or are used separately from the process) and are a series of hard pressure rollers meant to increase the density, smoothness and gloss of paper or other materials ranging from fabrics to polymer sheets and polyethylene thermoplastics. Flexography is a specific printing process form in which flexible relief plates made of rubber, plastic and recently of light-sensitive polymer are used for printing on various substrates. (Interview data/The technology developer, 15.3.2004; Documents/Research publications, Varjus, 2012, p. 18; Documents/Other, Calenders, 2012; Documents/Other, Flexography, 2012)

Pico (several test apparatuses). With the help of the first (paper, paper-making and the printing presses), the paper-maker would easily accept the forthcoming solution and integrate it to its production lines. With the help of the latter (Pico), the initiator together with the technology developers would be able to produce an increasing amount of intermediaries (e.g., fabricate samples, test results, apply patents, and publish research articles). This would be the way to advance the initial agenda and diminish other critical actors' interest in other alternatives. The following quotations illustrate these actors' connections to the initiator's agenda of the intelligent paper:

> "… we [the technology developer and the initiator] shared a certain connection, because I was previously responsible for an area which was the development of a device called Calendars. And we had certain test machines, which [the initiator] could utilize in his own experiments so we cooperated a little." (Interview data/The technology developer, 15.3.2004)

> "P[23] [a technology developer] belongs to this unit of calenders which squeeze paper. Hence we can improve the gloss properties. In a way they were well in line with our optics embossing in which we squeeze these optical structures onto plastics and paper. P has advanced it powerfully. While we operate on the paper side, P on the other hand knows the products in the calenders' side, how to squeeze paper." (Interview data/The initiator, 7.11.2005)

> "In the network of S[24] [a technology developer]… there is Ma, R… so, in Ma, they practically have that first embossing unit and they advance these developments onto plastics from the embossing stage onward. They are a very critical partner at the moment for us. We achieve concrete physical evidence that things actually work. […] R is an instance that we have worked with together to advance this embossing pattern development. S has developed that device and R has worked with the etching stage, then. There are also some smaller firms involved, too, in these developments…." (Interview data/the bridge builder, 10.3.2004)

> "S [a technology developer] does our development work related to printing techniques, the printing technique of ink, and such things…." (Interview data/The code promoter, 23.1.2006)

> "In Finland, actually VTT Oulu and VTT Espoo have been in a key position in these developments. And naturally the Pico machine, which was delivered from Italy. S [a technology developer] designed it and delivered it there, it is important to us. We can test before we take the step forward to the manufacturing environment. We can experiment with it leisurely in some facilities without fears of big damage." (Interview data/The bridge builder, 10.3.2004)

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[23] Name is a pseudonym.

[24] Name is a pseudonym.

Consequently, together with these actors the initiator continued the early core technology development. Some development activities were subcontracted (such as the etching on imprinting rolls, the development of different kinds of lacquers used to trim the paper's surface, and a certain ink development), whereas some activities were processed with a more favour-to-a-friend mentality (such as trials undertaken with a special supplier of security threads who owned an embossing unit).

Besides collaborating with these technology developers, the initiator together with a few technology developers from the paper-maker also contacted one Finnish firm specialised in optics. They suggested that this firm could also become one of the technology developers among others. Although the firm was in general interested in the idea of the intelligent paper, they however refused to consider paper as a full-blown actor by itself in the emerging network. They suspected that the surface of the paper would not enable utilising the chosen fabrication method. Instead, they suggested that the fabrication of intelligent paper would be possible only if new actors were enrolled in the network. These actors such as plastic or aluminium could be used in coating the paper so that the lattice structures could be hot embossed onto it. The initiator however refused to accept the suggestion that these materials should be acted upon and therefore included in the emerging network. Instead, he insisted on trying to run experiments without any of the proposed materials. As it turned out a short time later, the paper was indeed willing to accept the actorial role proposed by the initiator in the first place. Hence, lattice structures could be hot embossed onto paper without any extra layers of other materials. (Interview data/The initiator, 18.3.2004) This event limited the possible operations of that particular technology developer within the emerging network of intelligent paper, but further strengthened the initiator's agenda.

During negotiations with this technology developer, two events occurred that caused the partial re-identification of the critical actors in the emerging network around the intelligent paper. These events related to a detected possibility and an observed problem during the early trials. Regarding the first, after enrolling the paper maker's gravure presses inside the paper-maker, the initiator and a few technology developers noticed that the paper maker's paper machines accepted the use of both paper and plastics. As a result, the early versions of intelligent paper were tested on both materials as illustrated in the following quotation:

> "… we saw that the printing machines of M were also quite focused on plastics, so we noticed that plastics are also worth taking along." (Interview data/The initiator, 7.11.2005)

Simultaneously with inducing and enrolling plastics into the emerging network of the intelligent paper through different kinds of trials the initiator contacted one potential customer company operating in the food industry that used plastic foil packages. This

company was interested right away. It pictured how the application of the intelligent paper could be utilised as an effective means to differentiate consumer packages in groceries. Although the paper maker's paper machines accepted the utilisation of plastic and the food company sought involvement for joint technology development, the plastic foils themselves refused to work with the proposed idea. The initiator suggested to hot emboss optical elements onto the company's fibreboard products. The food industry company had to turn the team down; it did not have enough fibreboard products that reliable consumer tests would have required. Despite the drawbacks, negotiations with this company continued slowly during the years. Also, plastic foils were later integrated into the network, but only after massive testing and modifications made to the technologies at hand. These actions can be seen as simultaneously both inducing and forcing plastic foils to accept the actorial role proposed to them in the first place. The following quotation illustrates these events:

> "With At[25] we have always been experimenting. Initially our plan was to make things [diffractive gratings] onto some plastic foil, but there have been challenges in the production – we have not been able to make it work properly– we could make these things [diffractive gratings] onto paperboard, so as to demonstrate that we manage to do these kinds of things. We tested things for a while and pondered whether our things could be fabricated to their paperboard packages. The company has so few paperboard packages that they said that they cannot run a reliable consumer test and they instead suggested that we could do those things onto their labels. These labels are produced in high volumes they would be able to do a consumer test. Then we had to say that it probably takes some time before we can implement the technology on labels. At the moment we know how to fabricate things [diffractive gratings] on labels, so we have again together been designing and thinking about how we could take it to the consumer test phase." (Interview data/The initiator, 7.11.2005)

With respect to the latter event, the observed problem, the initiator together with a few technology developers realised quite soon during the early trials that although the paper-maker's presses accepted the utilisation of both plastics and paper, they were too big to efficiently run small-scale experiments. This problem compelled them to consider the enrolment of other actors that would accept and enable the early experiments of the intelligent paper. The initiator contacted one technology developer from one Finnish printing house he knew from preceding research collaboration located near the paper-maker. Through this technology developer, he wanted to gain access to smaller scale presses, namely (heatset) offset presses. This technology developer and the machines he operated with were interested and accepted easily the actorial role proposed to them,

[25] Name is a pseudonym.

that is, to become the technology developer and test apparatuses for intelligent paper's fabrication. For the following couple of years, the early versions of the intelligent paper were jointly tested with heatset offset presses. Later, when the first product version of the intelligent paper was at hand, the big gravure presses were quite easily renegotiated to the emerging network, as they had already been interested and enrolled in the network in the first place. The following quotation illustrates these occurrences:

> "In Turku, we have quite a lot of these printing houses in which we run test drives. We simply buy printing time and make test drives. […] At one time we ran quite a lot of test drives in Italy, but they have now diminished; they have moved closer to us here in the Turku region. At the moment we are again trying little by little to run them in Italy. All in all, there have been signs that when we start to take the product forth from the development stage, we have to operate with quite small machines and we have to start from scratch. Because V R manufactured big gravure presses, it was naturally not the first one [in these developments]. […] like H, before they could utilize optical things in their bigger machines, the small printing houses in Turku had to be involved to take care of them in a good manner." (Interview data/The initiator, 7.111.2005)

By the time of contacting the first potential future customer and enrolling several (nonhuman) actors to the intelligent paper's network such as for instance paper and plastics, Pico, paper-making, and printing presses, the initiator also realised that the few internal recruits and the connections created though the participating human actors were not enough. Although having a relatively strong technology-end, the network of the intelligent paper lacked know-how on selling and marketing technology-based knowledge-intensive applications. Through internal recruitment in 2001, one person who had a higher education in international business joined the network (Interview data/The bridge builder, 10.3.2004; Interview data/the initiator, 7.11.2005).

Similarly to the few technology developers who were enrolled in the network from inside the paper-maker, this person who I call the bridge builder also felt that the agenda that the initiator was promoting provided him global scale career development opportunities. At a more personal level, the bridge builder saw opportunities to act according to his own beliefs, to promote a sense of community and open dialogue between people with diverse cultural backgrounds as illustrated in the following quotation:

> "My passion is in the idea that people all over the world would respect each other. It has been said that this is an utopist dream. I have spent my childhood in Atlanta and Martin Luther King as a person and his message was what made a remarkably great impression on me. I have read, in my teen years, all the literature on him that I managed to get access to. So, I personally believe that the world is a better place if we respect each other and difference; we respect the differences between

> people. I don't want the whole world to be just one brand, global brands, but I see brands as means of connecting us. Indeed, we have drunk that Coca-Cola and then I can tell about my nationality and be proud of being a Finn and talk with this Indian guy and get the same from him. The way I see it, we have to value other cultures and other ways of being." (Interview data/The bridge builder, 10.3.2004)

The bridge builder's main duty was right from the start to sell and market the intelligent paper to the identified critical actors. The first of these was the paper maker at the time when it started to debate the relevance of the intelligent paper's existence. Later, the identified critical actors were the other critical human actors such as potential customers, investors, partners, suppliers and subcontractors.

The early network of the intelligent paper is depicted in Figure 7. The type of network mapping that I apply in the figure is analogous to the way networks are mapped in social networks oriented studies in which actors are usually represented by dots and relationships that connect them (or not) by lines or (one or two-)headed arrows (e.g., Ahuja, 2000a; Conway & Steward, 1998; Kilduff & Tsai, 2003; Obstfeld, 2005; Powell et al., 1996). Instead of using these dots and lines, I have decided to label the actors by the names they themselves have given to each other. As such, I have not drawn the boundaries of the depicted network based on the network structure, but instead based on the perceptions of the actors involved in the network formation. Also, I have replaced lines or arrows with the spatial location of actors. Hence, the mentally closer actors for the intelligent paper are depicted close to each other, while the more distant actors are depicted accordingly as more remote.

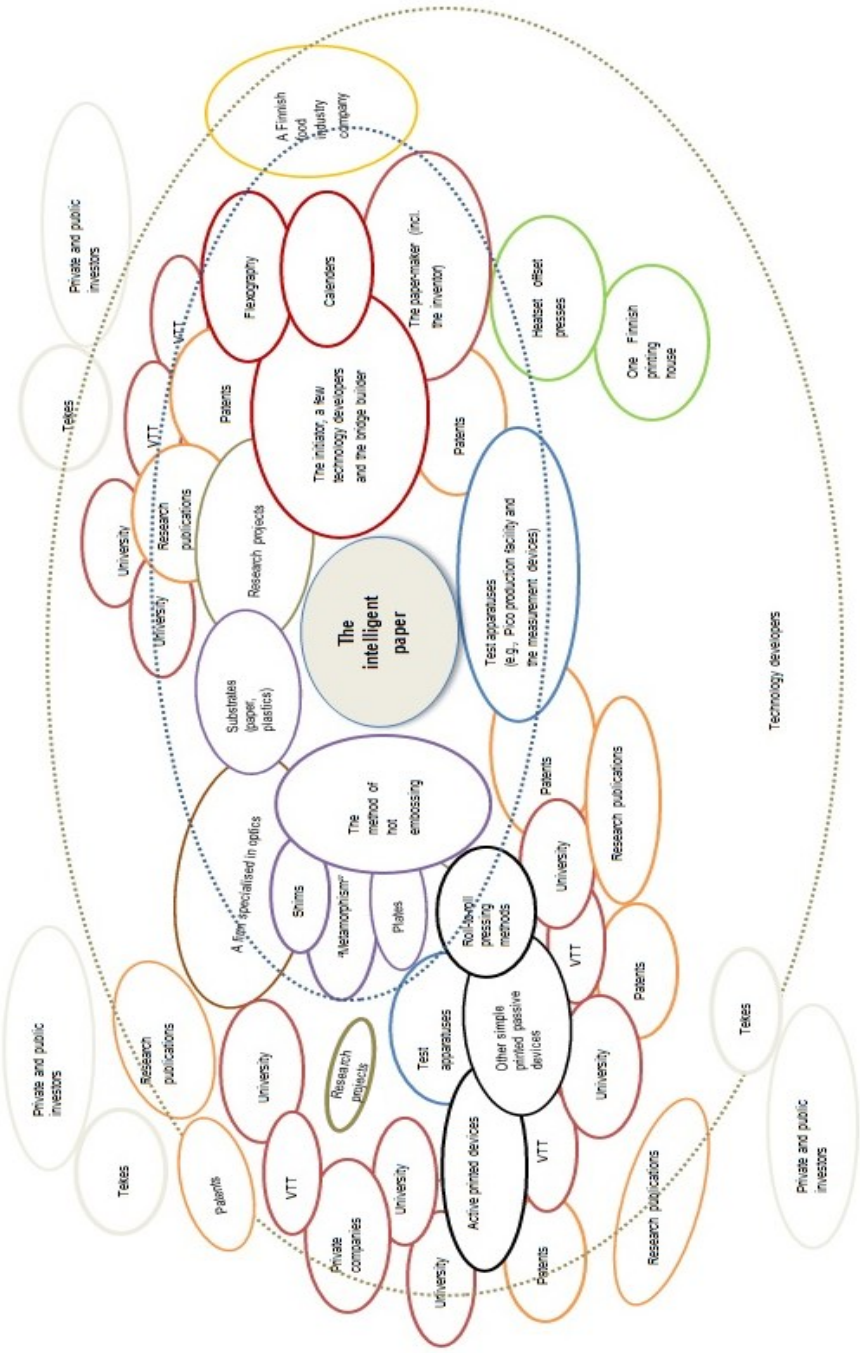

Figure 7. The early network of the intelligent paper

Consequently, closest to the intelligent paper – not physically but more or less mentally – are the technologies, devices and tools that enabled its 'birth', such as the (nonhuman) actors of the method of hot embossing, heatset offset press, and Pico. Besides these technologies, tools, and processes inside them, I have also depicted other actors in the figure and the relatedness of these actors through the oval shapes overlapping each other. These actors helped to form the intelligent paper during the early days. Hence, I have labelled them also as technology developers. The dashed triangular shape depicts the actors that were mostly involved in the intelligent paper's development at that time. Consequently, I have included the development work conducted within the paper-maker including the inventor, the initiator, a few technology developers recruited from the inside of the paper-maker, the bridge builder, and the two Finnish companies – one specialized in optics and the other operating in the food industry –in the intelligent paper's network being under formation.

Further, I have connected different actors to the emerging network of the intelligent paper for instance through different research projects in which the initiator was engaged at the time, VTT, universities, and consequently several researchers in Finland and abroad interested in printable optics and electronics, as well as different kinds of research and technology reports and journal articles labelled in the figure as Research publications. I have also depicted patents related to the intelligent paper in Figure 7 just as the other technological developments made in the field and relevant fields, that is, the development of other passive devices, active printed devices and the nanoimprint technology developments, and the processing methods, that is, the roll-to-roll processing methods. These actors are discussed in more detail within the next sub-phases.

Finally from the financing viewpoint, the figure illustrates the parties that invested monetary and intangible resources (mainly know-how on micro-nano systems) to the intelligent paper's network. These parties include notably the paper-maker, a few other privately owned companies, a few universities, VTT, and Tekes. With respect to the public research agencies (especially Tekes), these parties were throughout the initial pack formation phase treated as neutral actors toward the intelligent paper's agenda. The enrolment of these actors to the emerging network of the intelligent paper was thus based on their silent, 'punctualized' consent, to provide financing to the intelligent paper's emerging network. This continued throughout the study period.

4.3.2 Reforming the pack

In 2002, the initiator together with the recruited technology developers and the bridge builder (and consequently the network of the intelligent paper formed so far)

participated in a three-year PRINTO programme led by VTT[26]. This programme was one of the first research projects in Finland in which roll-to-roll related mass production techniques, optical, electrical, and optoelectrical components were simultaneously developed (Documents/Annual Reviews and financial statements, VTT overview 2005, p. 17). The following quotation illustrates in short this PRINTO programme that was running between 2002 and 2005:

> "VTT together with four universities have developed together novel electronical and optical parts to product packaging that enable new functionalities and intelligence. These parts can be manufactured with a common printing press. Packages utilizing the new technology include much broader information about the product's origin, quality and usage than the current packages. They can also act as security markings and thus function as a certificate of origin for the product. Information, which can contain tens of pages of text, can be stored for example in multiple languages into a couple of millimeters sized optical memory which is printed upon the surface of the package. The consumer can read product information in her/his own mother tongue with the help of a camera phone. […] In the R&D project, optical and electronical components were fabricated onto plastics and paper with test printing presses and VTT's PICO pilot press. These include for instance optical read-only memory for storing text, optical display memory, photoconductor, and basic electronical components. These developments strengthen the possibilities to develop into mass production multiple intelligent packages through using a printing technique. In the project, also active components, such as simple displays, solar cell power sources, and a game printed upon a package were manufactured with the printing technique. […] The project was funded by Tekes, seven Finnish companies and VTT. Research was conducted by VTT, the Universities of Joensuu, Jyväskylä, Lapland and Oulu in international collaboration with the Universities of Arizona and California." (Documents/Magazines and news, VTT News 2.2.2005)

The following quotations from a webpage (presenting different research projects including PRINTO) and a research publication (commissioned by Tekes; implemented in VTT) illustrate VTT's intermediaries that were utilized to bring forth this programme, more specifically to strengthen slowly the agenda of printed intelligence later discussed in more detail (see Chapters 4.4 and 4.5) at the beginning of 2000s:

> "Paper producers wonder how they could maintain the competitiveness of their product. Therefore new approach for research work must be applied. The

[26] I have included two research projects under PRINTO programme, namely Printable optics and electronics (PRINTO, 2002-2004) and its follow-up R2R Manufacturing technologies for Demanding Electrical and Optoelectronical Components (R2R2010, 2004-2005). (Documents/Research Publications, Tekes/ELMO – Miniaturising Electronics 2002-2005, pp. 179-183; Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, pp. 7-12).

utilisation of surface chemistry and polymer technology could offer new possibilities in this field. But changing only certain paper properties by adding a component is not easy without having effect on some other properties at the same time. It is also essential to remember that different characteristics of paper structure and surface properties are required depending on the printing method in use." (Documents/Other, VTT Information technology: Information Carriers, Projects, 2011)

"In recent years, together with the development of novel electronics and optics materials, such as polymers and hybrid materials, the roll-to-roll (gravure, off-set, flexo, and screen printing) techniques have emerged as promising future manufacturing techniques for fabricating electronics and optics components. The above mentioned techniques today enable the fabrication of simple passive and active components whose integration degree is at a modest level. However, roll-to-roll techniques enable extremely high-volume production which together with cost-effective production methods and low-cost substrate materials (paper, plastics) enable integrating produced components to daily consumer good packages and to different types of printed products. [..] Research in roll-to-roll manufactured… components will be directed in the future at remarkably thicker packaging rate than the current (100 μm bar breadth, size of a module, e.g., A4). Achieving this goal requires in-depth studies on roll-to-roll techniques and material technologies. Also, the integration of roll-to-roll manufactured one-off components and current technologies in use require significant investment. (Documents/Research publications, Lenkkeri et al., 2003, pp. 43–44)

The participation of this PRINTO programme introduced new actors that had to be negotiated to the emerging network of intelligent paper so that the initiator could strengthen this agenda and consequently diminish the critical actors' interest in other alternatives. In parallel with the introduction of these new actors, the paper-maker's refusal to follow the role proposed to it in the first place (i.e., to act as a resources provider to the intelligent paper), also affected the intelligent paper's network. The initiator was compelled to consider other critical actors who could fulfil this actorial role and through which the future existence of the network of the intelligent paper could be secured. Similarly, the enrolment of these new actors to the intelligent paper's network affected the roles of the already enrolled actors. It compelled them to also start renegotiations and re-enrolments among them. In Table 13 I summarize this second sub-phase called 'Reforming the pack'.

Table 13. Reforming the pack

Phase of forming the pack and performing various negotiations	Approximate year of occurrence	Principal actors	Agenda	Interested actors (enablers)	Reluctant/hostile actors (inhibitors)	Silent/Neutral actors
Reforming the pack	~2002– ~2005	The Initiator	The intelligent paper	The technology developers (those enrolled to the network of the intelligent paper in the previous phase) The bridge builder Methods for making intelligent paper (the integrated embossing) Paper-making The printing presses (heatset offset presses) Pico (test apparatuses The paper and plastics The lacquers and inks The diffractive grating (the product D) The product design	The paper-maker The technology developers (mainly some researchers from VTT and a few universities as well as a Swiss holography company) PRINTO programme (incl. roll-to-roll processing) The method of hot embossing (including tools and processes inside it) The plates within the integrated embossing The competing technologies	Investors (public research funding agencies)

The participants in the PRINTO programme's network mainly focused on the method of roll-to-roll processing which was initially aimed at creating electronic devices on a roll of flexible plastic or metal foil (Documents/Presentations, Kopola, 2005a; Documents/Presentations, Kololuoma, 2005; Documents/Other, Roll-to-roll processing, 2012). Thus, the initiator anticipated that in order to advance his agenda of the intelligent paper, this actor within the PRINTO had to be enrolled to the emerging network of the intelligent paper. This however meant that the already enrolled actor – the method of hot embossing (see Figure 6) – had to be renegotiated to the network. This re-enrolment involved the introduction of new actor called the integrated embossing (see Figure 8). The re-enrolment also meant that the initial method had to go through massive modifications to accept the new actor of roll-roll-processing into the network.

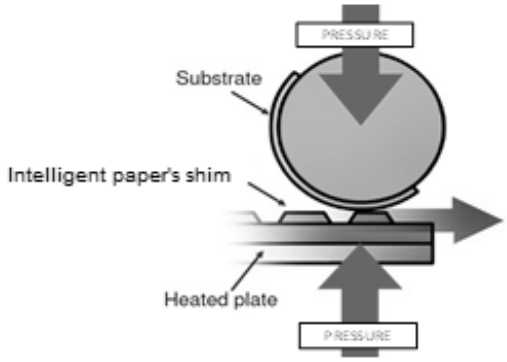

Figure 8. The method of integrated embossing

(Source: Documents/Presentations, Korhonen, 2005. Modified.)

This new actor – the method called integrated embossing utilised three different kinds of printing processes and machines, namely, offset printing, die-cutting and hot foil machines (Documents/Presentations, Korhonen, 2005). In the first, the printing and non-printing surfaces are on the same level (flat-on-flat) but their surface materials differ. The inked image is transferred from a plate to a rubber blanket and then to the printing surface[27]. The press concerning the intelligent paper is the heatset web offset press in which the inks are dried through evaporation in a dryer. (Documents/Other, Offset printing, 2012) With respect to the second, the die-cutting in the process of producing the intelligent paper refers to a cylindrical die[28] on a rotary press. A web of material is fed through the press into a special area, which holds a rotary tool that shears the web into smaller parts and shapes. (Documents/Other, Die-cutting (web), 2012) In the development work of intelligent paper, the solid engraved dies were used (Documents/Presentations, Korhonen, 2005). Finally, the specially shaped shims are integrated into the hot foil printing machine. This machine is usually used to dry printing in which a heated die and foil are used to apply graphics to a surface of the chosen material. (Documents/Other, Offset printing, 2012) The process that concerned the

[27] The most common offset machines are the sheet-fed and the web-fed offset. As these names suggest, the sheet-fed offset is used for individual sheets of paper or paperboard, whereas the web-fed offset uses rolls (or webs) of paper supplied to the printing press. The web-fed presses are further divided into two general classes: non-heatset or cold-set and heatset offset web presses, the difference being how the inks are dried during the process. (Documents/Other, Offset printing, 2012)

[28] Different dies exist; the generally applied dies to rotary die cutting are solid engraved dies, adjustable dies, or magnetic plate toolings (Documents/Other, Die-cutting (web), 2012).

intelligent paper differs from this, since this type of hot embossing required certain plates and tools in order to actualize the printing of micro/nano type structures to paper (see the next quotation).

Whereas the technology developers developed the specially shaped shims, the plates were subcontracted from a Swiss holographic company. The plates and shims however refused to accept the role proposed to them when the production volumes were increased – they got dirty. To solve the problem observed, the technology developers started to develop these particular tools by themselves. These actions were meant to bind the modified fabrication method more tightly into the intelligent paper's network. The following quotations illustrate these new critical nonhuman actors within the integrated embossing and their connections to the fabrication of the intelligent paper:

> "We have the ones that produce. They are called masters, designers; they know how optical structures can be made… one has been in Joensuu and then from England we have them, just like in Switzerland. There, a certain big plate is made; this Swiss company can make a big plate from it. We have a pattern which is small; it has been made with a specific laser beam printer or laser, a master. Then, that master is beaten with a specific mechanical device so as to make it into a bigger plate, which can then be installed to these printing presses. The Swiss company delivers these to us and then there is one firm which can coat it with the kind of stuff that does not get stuck with the lacquers. We have many lacquer suppliers, with whom we discuss the quality of lacquers and they are at the moment located in England, in Tampere there is also Si[29] […] we have put a lot of effort in developing a method, a method by which we attach these plates into the existing printing presses. Our idea is that we do not manufacture any printing presses; we do not do printing but we make tools which can be attached to the existing printing presses. […] And let's say, about a year ago we noticed in the D side, we have challenges in production. We were able to make just a few hundred pieces and then our tools became dirty and now we have been able to slowly increase production volumes again…" (Interview data/The initiator, 7.11.2005)

> "… they [the Swiss] manufacture all the plates we then use in the actual production, that is, in the embossing. At the moment, we are already designing those plates pretty much by ourselves but we still continually use the Swiss; we want some place to emboss the material onto a surface so we call them; we make an order and they deliver." (Interview data/The product design, 19.1.2006)

Consequently, during the PRINTO programme's existence the intelligent paper attained its first product shape, which was introduced to the market in early 2006. I call this as D. Next quotation illustrates its properties and functions:

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[29] Name is a pseudonym.

> "The optical effects of Alpha's D, diffractive optics and the integration of holography in product packages are based on hot embossing technology. […] The D effect is based on additive colour formation where nanoscale diffractive gratings reflect light to the desired viewing angle. These gratings form images without inks. The effects are manufactured using a hot embossing technology which can be easily integrated into the traditional printing processes. This enables the wide usage of D effects in different large-volume product packages and printed products." (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, p. 27)

The technology developers thus developed hot embossing technology for different substrate materials, lacquers, and inks. The work included the development of the hot embossing method as depicted above and the online quality monitoring system for the optical effects forming the essential parts of the first product version, which I henceforth call the product D. (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, p. 27) Some of these tasks were included in the PRINTO programme's research activities while some were subcontracted.

Besides engaging in these development activities targeted to strengthen the agenda of the intelligent paper, the technology developers (especially in VTT) in the PRINTO programme studied some of the intelligent paper's closest competitors, namely light guides and kinegrams. These competing technologies are shortly summarized by their core properties in Table 14. The development activities in which the intelligent paper can be located are depicted in italics.

Table 14. Alternative printed optics technologies and their core properties

Printed optics technology	Functionality	Inks needed	Printing methods	Reading technique	Applicability	Other notes
Light guide	Transfers light from one place to another, illuminating structures	Optical monomers and pre-polymers	Flexo, gravure, screen, inkjet	Human eyes	Packages	Require a light source
Hologram	3 D images	Aluminum particles	Flexo, gravure, screen, inkjet	Human eyes	Packages, security printing, publications	-
Kinegram	Variable image depending on the viewing angle	Metal particles	Flexo, gravure, screen, inkjet	Human eyes	Packages, security printing, publications	-
Diffractive grating (optical effect)	*Dynamic colour changes depending on the viewing angle*	*- (Special inks)*	*Offset, flexo, gravure, screen, inkjet, electrophotography*	*Human eyes*	*All kinds of printed products*	-

(Source: Documents/Research Publications, Lindqvist et al., 2008, p. 10. Modified.)

The competing technologies that were studied especially in VTT (i.e., the light guides and the kinegrams) together with the holograms can also be used for decorative and informative purposes. Whereas light guides transfer light from one place to another, the

kinegrams produce images depending on the viewing angle. (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, p. 10; Documents/Other, VTT Information Technology: Information Carriers, Projects, 2011) Holography technologies fabricating three-dimensional holographic images in which the image, that is, a hologram, changes as the viewing angle changes (Documents/Other, Holography, 2012) were not studied in the PRINTO programme although they can also be applied to printed matter.

The initiator together with the technology developers produced an increasing amount of intermediaries (e.g., test results and samples) to certify the superiority of the intelligent paper in relation to its closest competitors. This was considered to diminish these technology developers' interest (especially those operating in VTT and a few universities participating in the programme) in the competitors and to help enrol those developers more tightly to their actorial roles and to the agenda. Consequently, it was demonstrated that the intelligent paper as a diffractive grating (optical effect) was the only application that could be fabricated to all kinds of printed products (see Table 14). This was also done by using all roll-to-roll printing methods the technology developers in VTT considered as conventional (i.e., the gravure, the offset, the inkjet, the hot embossing, and the flexographic printing). (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, pp. 7–13; see also Documents/Research Publications, Lindqvist et al., 2008, p. 10) Also, no extra inks (or light sources) were needed in fabricating the intelligent paper, unlike in other alternatives[30]: The following quotation illustrates how one technology developer 'found' this while he was experimenting embossing onto paper board packages:

> "… I have always thought that a lot of mistakes are needed to take into account serendipity's role. I have this habit of when I bump into some packaging materials, I collect them and just test how they feel. This way, I have found remarkable things. To give an example, when we initially started our developments and we had these cooperative partners, they told us that okay, when we want to make optical embossing we need a hologram lacquer. That was some mystical lacquer which is required in the process in order to be able to emboss. And then that was made and developed and it is still under development, that's fine, it is still needed in some cases. But when we, or I, just experimented embossing on these paper board packages, I noticed that hey, wait a minute. There is a protection lacquer always on top of paper boards as default. So, I noticed that wait a minute, I've been embossing just fine and without any mystical hologram lacquers that were

30 By 2009, special inks were introduced and enrolled to the network of intelligent paper to avoid the destruction of the diffractive grating if rubbed with a finger (Documents/Research Publications, VTT/Research and Development 2009, pp. 20-21). This is depicted in the Table 14 by using the brackets in the section "Inks needed".

> argued to be required in these types of things." (Interview data/The technology developer, 15.3.2004)

The participation to the PRINTO programme did not only introduce new actors upon which the initiator had to act and negotiate them to the intelligent paper's network such as the methods of roll-to-roll processing and integrated embossing for fabricating the intelligent paper. The programme also brought closer some other actors that the initiator had initially neglected as not critical for the intelligent paper's existence. Novel to the technological research programmes so far, the University of Lapland joined the PRINTO programme to bring forth a user-oriented product development mind-set. These scholars, specialised in industrial design, brought both an aesthetic viewpoint and a functional perspective of the future user. These researchers were assigned the tasks of envisioning possible applications within active and intelligent packaging and printing products, introducing product development techniques as early in the process as possible, and enhancing the planning stage communication between the participating parties. (Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, p. 7; Documents/Other, University of Lapland, Ended R&D projects, 2011; see also Interview data/The bridge builder, 18.3.2004; Documents/Presentations, Kopola, 2005a)

The initiator had contacted potential customers and recruited the bridge builder early on to the network of the intelligent paper. Yet, after becoming involved with the researchers from Lapland University he together with the bridge builder felt strongly that it was the designers that were the important missing part of the intelligent paper's network. They could not only bring forth the aesthetic view to the development work, but they would also be able to anticipate and help the technology developers to understand the kinds of needs customers might have and the kinds of optical effects that would interest them the most. In common sense words, while researchers in optics were calculating how small structures can be effectively embossed to the surface of a substrate (i.e., paper and plastics), the designers would help understand the quality aspects of the future products and their potential value to the customer.

As a result, the actor of product design was incorporated into the network by cajoling one of Lapland's researchers participating in the PRINTO programme to join the team in 2003. Additionally, one designer was externally recruited to productize one potential application from the intelligent paper development activities in 2005 (the product D). The first designer continued working with the diffractive gratings and participated also in other tasks where his expertise in design was needed. In fact, he had diplomas both in engineering and design. This educational background and previous work experiences from the field helped him to speak a common language with the technology developers. He collaborated widely with the team members and provided his knowledge when it was

needed. Before the second designer had been recruited, he had helped the technology developers bring another technology closer to its productization. He had also worked closely with the bridge builder to visualize his power point shows for different interest groups such as potential customers and investors that were to be induced and enrolled to the intelligent paper's network. (Interview data/The bridge builder, 10.3.2004; Interview data/The product design, 19.1.2006)

In addition, in parallel with the ongoing core technology development activities intertwined closely with the research activities made within the PRINTO programme, the initiator together with the bridge builder started to map out alternative potential technology developers to be attracted and enrolled to the intelligent paper's emerging network. Until then (and despite the PRINTO programme) the network of the intelligent paper had only interested a few technology developers located mainly in Finland. These technology developers did not have a broad expertise on optics and its research, but all they had brought to the market so far were radically new and tailor-made solutions compared to other similar developers in the field. Although the initiator wanted to keep these technology developers enrolled in the network, it also wanted to interest new actors so that they could ease the continual pressures of renegotiations coming from VTT's side and slowly replace them in case VTT would not follow the agenda.

Hence, several different Italian and Swiss companies possessing expertise on different holographic solutions, inks and printing presses were contacted (Interview data/The bridge builder, 10.3.2004, 31.1.2006; Interview data/The initiator, 7.11.2005). One Swiss company was finally selected to be enrolled to the network, not only because it had for several years specialized in holographic images for high-security banknote applications but rather because it was able to supply the plates needed in the method of integrated hot embossing (the quotation used in describing the integrated embossing method illustrates also this point). As described above, this method had been developed as a response to the somewhat silent actor of roll-to-roll processing. Although this Swiss company supplied the plates needed and consequently can be included in the network of the intelligent paper, it continually showed reluctance to accept the planned actorial role which was to act as a technology development partner (as a technology developer) in the network of intelligent paper. This reluctance occurred throughout the process from the point in time when it was first contacted in the PRINTO programme to the later stages when the joint venture firm Alpha was established around the development activities of the intelligent paper.

Also, in 2002, the paper-maker decided not to continue investing alone in the intelligent paper but only as one investor among others. Although receiving funding from public funding agencies such as Tekes (a neutral, punctualized actor toward the agenda of the intelligent paper), the initiator together with the technology developers

and the bridge builder cajoled or recruited to the network of the intelligent paper were compelled to start searching for alternative potential investors to secure the future existence of the intelligent paper. These potential actors were mapped out by utilising these actors' personal contacts to influential experts and persons in the related industries to acquire financing. Finally two other future owner-investor companies were emerged as the most potential ones for future co-operation. Both the two companies were contacted fairly early in the intelligent paper's network building. One of them was H, a printing house in 2001 (the minority shareholder) initially contacted by the initiator as illustrated below:

> "H had already previously been our partner and I believe it happened already in 2001 that I started negotiating further with them. This company is the biggest printing house in Scandinavia. One can argue that they apply printing optics. Two people, L N[31], who is their development manager and J L[32] who is their development director were interested in these things and at that time they were asked whether they are interested in investing money and they were." (Interview data/The initiator, 7.11.2005)

The other was a telecom company (the other majority shareholder), which the bridge builder met accidentally at a conference quite short after the parent company's announcement of its reorganization in 2002 as illustrated in the following quotation:

> "In January 2003, I was in an intelligent packaging conference in Miami. There, I met the guys from N. We went all the way to Miami to meet other Finns. […] we noticed we have same interests. Although we have different perspectives, we have a lot of similar thoughts. We had in fact quite a lot to give them as input to their thinking and vice versa, we have received so much from them…" (Interview data/the bridge builder, 10.3.2004)

In March 2004, the joint venture agreement between three leading Finnish firms was signed:

> "Alpha was established on 25.3.2004. Due to arrangements on 30.4.2004 the company's shareholders became H (3, 614 %), M (48,193 %) and N (48, 193 %). The company's capital stock was raised in 11.8.2004 and at the same time, the required immaterial property rights and other possessions were transferred to the company." (Documents/Annual reviews and financial statements, Alpha/financial statement 22.4.2004–31.12.2004)

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[31] Name is a pseudonym.

[32] Name is a pseudonym.

These new owner-investors promised to finance Alpha for 20 months. In autumn 2004, after the approval from national and EU level competitive authorities to launch a joint venture firm, eleven experts in total joined Alpha mainly from the owner-investors companies and from the PRINTO programme (mainly from the VTT rather than other instances joined in the programme).

4.3.3 Forming the pack according to the redefined agenda

The establishment of the joint venture firm Alpha in early 2004 did not only change the initial agenda and the actors accordingly, but also compelled the management of Alpha to perform various kinds of negotiations and renegotiations with the (re-)identified critical actors so as to lock them in their places – just like the initiator was attempting to do in the earlier pack formation phases. These negotiations and renegotiations occurred approximately between years 2004 and 2005. I call this sub-phase 'Forming the pack according to the redefined agenda', summarized in Table 15.

Table 15. Forming the pack according to the redefined agenda

Phase of forming the pack and performing various negotiations	Approximate year of occurrence	Principal actors	Agenda	Interested actors (enablers)	Reluctant actors (inhibitors)	Silent/Neutral actors
Forming the pack according to the redefined agenda	~2004-~2005	Alpha (the management of Alpha)	Alpha as the mediator between the technological innovations' development and the paper-making business	The initiator The experts in the hard core The intelligent paper (the product D) Paper-making The printing presses (the heatset offset presses and the gravure presses) Contracts	The technology developers (mainly some VTT researchers and a Swiss holography company The friends and partners The customer-partners	The Investors (public research funding agencies) The investor-owners The investor-partners

The management of Alpha as the promoter of the redefined agenda anticipated that the re-enrolment of the network formed so far around the intelligent paper would be an easy task as long as the initiator and the intelligent paper accepted their redefined roles. The re-enrolment of these actors was advanced in the first place by allowing the initiator – who had already for years had a deep personal interest in the intelligent paper – to still continue acting as the principal carrier of the intelligent paper. Also, the initiator and the experts were prompted to continue their work as long as the technological developments could be seen as spurring from Alpha's technological basis. Following quotation illustrates this interpretation:

"…the kinds of visual indicators… we have already abandoned them or at least we now have to abandon that idea, but it maybe some other party will continue that development work. We have developed them in collaboration with VTT and we have some ongoing patent applications. […] regarding the electronics thing, we had certain very modest products or goals and then bigger ones, bigger goals that went much further. There are these RFID like intelligent stickers which need certain antennas, antennas with high conductivity, printed transistors etc., so we developed them and maybe we will yet continue to develop some parts of them. But now with Alpha, some of these new projects will be put on hold. One example is the printed organic OLED which we have for instance studied. Now, we probably have to put that on hold, too. […] It is a light emitting surface which can be fabricated by printing. OLEDs are used for creating different kinds of displays among other things. […] it was planned to be integrated onto packages and light would come out of packages and. But we also have, we have anticipated among other things these printed miniaturized power sources. We are participating in a Tekes funded project. We have to think through all of these in terms of which are the ones we will continue advancing and which we will let go." (Interview data/The technology developer, 15.3.2004)

Consequently, although Alpha was continuously pressured by VTT (who led the PRINTO programme run between 2002 and 2005), it also continuously tried to re-enrol the initial actors to the emerging network of the intelligent paper. It allowed the experts to produce numerous intermediaries (e.g., test samples, prototypes, and tests) in close collaboration with the VTT experts that demonstrated their compatibility with the redefined agenda. These also included the utilisation of different kinds of reports of technologies acquired from consultants specialized in these types of investigations (The Interview data/The technology developer, 15.3.2004; The Interview data/The management of Alpha, 16.1.2006) as well as patents (Documents/Other, Patents related to core technology, 2011) as proofs of Alpha's legitimacy.

For instance, during the ongoing PRINTO programme the experts started to develop a few other ideas around printable electronics (see the quotation from the technology developer above). These early developments included for instance the printed TTI indicators (for which the patent was obtained in 2011), the production of metal conductors (for instance copper conductor patterns as electronic components) on a paper (the patent for these was obtained in 2004), and a method for manufacturing an electronic thin-film component and an apparatus for implementing the method (a patent was obtained in 2004) (Documents/Other, Patents related to technology development, 2011). These examples of development activities in Alpha which were later narrowed down and concretised under the name of InkByte can thus also be seen as a strategy for the management of Alpha to re-enrol the intelligent paper in the network according to its redefined role.

The technology developers, the bridge builder and the product design were re-identified as experts. They were further distinguished into either the hard core of Alpha (experts getting monthly paid from Alpha) or friends and partners (experts bringing occasionally input to Alpha and its network). These instances were planned to be induced and enrolled to Alpha's network from its investor-partners as well as through the already enrolled experts' social relationships with other experts in relevant fields. Also, the management planned to continuously prompt the hard core to widely utilise their social connections to other experts external to Alpha (friends and partners) so as to acquire and sustain the cutting-edge knowledge needed and the contacts to critical nonhuman actors in the network. Additionally, the strategy of allowing the hard core to choose their physical location was yet utilised in order to attract and enrol the critical actors needed in the network.

As a result, the hard core of Alpha had a long working history in the fields of electronics, optics and printing and a deep personal interest in the continual deepening of their expertise (Documents/Other, Profiles of the 'interviewees', 2011). Later, each hired expert was scrutinised closely to assess if his/her expertise and connections to other actors was so relevant as to justify the management of Alpha hiring that person to its hard core or if the expertise and the connections needed could be subcontracted or acquired through collaboration. Following quotation illustrate this interpretation:

> "… so far, in all of our recruiting activities, we have strongly considered whether we really have to have that [competence] or could that be outsourced." (Interview data/The bridge builder, 31.1.2006)

The same principle applied to not having own manufacturing equipment. Alpha would build production through partnering and subcontracting as illustrated below:

> "… it is a remarkable financial resource that we do not own any factories; other parties own the factories in which things must be manufactured. We do not have to own them and we do not even want to own any. If someone wants to own a factory, so be it. Yes, it is totally a matter of finance; there is no need for fixed costs so one can be much more agile." (Interview data/The management of Alpha, 16.1.2006)

This decision was made early on in the process. Collaborative activities can thus also be seen as one enrolment strategy promoted by the management of Alpha in relation to the critical actors yet external to Alpha. The aim was to enable the utilisation of competencies – mainly knowledge, tools, devices and machines possessed by other companies and consequently, to lock these actors in their planned places. The following quotation illustrates Alpha's dispersed activities and its hard core's efforts to bind critical actors more closely to the network of Alpha:

"… internally we aim at having people work from their home. We do not even try to get them into offices because it would first of all simply be so expensive. And another point is that our business concept requires so broad competence that there is no way we can have such expert resources in house, such as the business know-how from all the different fields required. […] We do not even aspire to do that, how you could say, it would be too much, and generally speaking, no such persons can even be generally found that we would really need. For this reason, we search for different contacts all around, one could say that we operate in Europe. Together with different research institutes, customers, suppliers, we try to find them. And of course because customers are abroad, then, we should find partners that are able to serve them globally. […] we have started this search from something as simple as the internet or trade show or catalogues or through acquaintances and friends; for instance if I know this firm and you know that other firm and then on the internet we have found some party and ask them whether they are interested. There are plenty of personal relationships involved, too; I know lots of persons from the packaging and printing world and then [the initiator] knows the electronics world, he knows VTTs and all equivalent parties." (Interview data/The management of Alpha, 16.1.2006)

The friends and partners were also planned to be enrolled in the network by utilising the re-enrolled human actors' personal social connections to each other. By following this strategy, Alpha's experts easily found potential parties in the pool of friends and partners as illustrated below:

"This group we have here is so experienced that they figure it out quite quickly whether someone is really interested in this or are they just pretending, are they just being polite to us." (Interview data/The management of Alpha, 16.1.2006)

However, the actual enrolment of these friends and partners turned out to be much more demanding. The challenge for enrolling these actors in the network relates to the (re-)identification of the intelligent paper and to the multiplicity of actorial roles that single actors were supposed to take. Whereas the hard core was recruited to Alpha in the first place through offering them possibilities for deepening their expertise areas, as they engaged with the intelligent paper, they were not only more tightly bound to the redefined agenda. In addition, they also gradually forced the intelligent paper to accept its actorial role as a technological basis through which various novel technological solutions could be developed and commercialised. The multiplicity of human and nonhuman elements that these experts were drawing to the intelligent paper concurrently expanded the number of critical actors that could also be considered as friends and partners in the longer run. Following quotation illustrates this interpretation:

"… we have had some challenges as a firm to maintain our focus. While more people have joined and we have involved lots of partners which have other

possible interest areas, there tends to be a "pull-effect" from all directions." (Interview data/The bridge builder, 31.1.2006)

Consequently, the hard core reported a continuous lack of mental and physical input provided by Alpha to invest in the most promising relationships. They also experienced difficulties in finding a suitable partner for each occasion. Even though the hard core's strong expertise proved their trustworthiness and they were highly committed to maintaining it, not all potential friends and partners who were contacted had the necessary resources such as money, knowledge, and time to demonstrate in a tangible way the right mentality or the overall willingness and ability to accept the multiple actorial roles assigned to them. Following quotation illustrates this interpretation:

> "There are lots of firms that have potential, but they do not want to cooperate. Then there are firms which are willing to cooperate, but they are not big enough or their technology is not compatible or they are located geographically in the wrong place or something like that. Or maybe their ownership arrangements…some small family-owned firm, they could be extremely interested in this stuff to achieve something new but we know that they have no resources what so ever to invest. On the other hand, some big company does not bother to invest in this because they are the world-leading company, so they say just do your thing for a couple of years first and then come back to us; you will come back anyway because we are so big and we dominate the markets." (Interview data/The management of Alpha, 16.1.2006)

Related to the above, Alpha's hard core also had some difficulties in finding common and open dialogue with the potential human parties that were planned to take the role of friends and partners in the near future. The members were aware of business secrecy and not always sure about the kind of knowledge that they could share with these potential parties. Therefore, in short experimental projects trust between the members of Alpha and those (still) external to it was mainly based on personal contacts of individuals. In longer projects, a new critical actor – i.e. contracts – needed to be induced and enrolled in the network. Contracts were however perceived by the hard core as not necessarily capable of guaranteeing the successful completion of the projects. Although successful interactions and mutual interests between the collaborative parties strengthened trust and consequently the enrolment of the actors in Alpha's network, contracts were invariably needed at the beginning of co-operation. The following quotations illustrate this new actor and how its role was perceived by a few human actors (the Alpha's management and the bridge builder) already acting in the network of Alpha:

> "… at first, one should figure out whether there is any point for cooperation, are there common interests. And then when there are common interests, we make non-disclosure agreements right away. We do not go and do anything without

non-disclosure agreements. On the other hand, there is no worth in, like, the American way is not to say anything until a non-disclosure agreement has been made and then there is a million dollars liability for damages if someone offends this agreement or something like that. We have not approached it that way. At first, we check if there are any grounds for cooperation before we make any co-operation agreement. […] A co-operation agreement is always expensive. We can first make a non-disclosure agreement and then the co-operation agreement. The next phase is implemented together. At first, do we have something in common, can we talk and secondly, if we can, are there some things we might develop together [...] Then a non-disclosure agreement is made and we tell each other what we are doing. Then, it is checked whether the activities link or not. And if they link, then we can continue. There is no need to always have a co-operation agreement, we can also agree upon an hourly charge…" (Interview data/The management of Alpha, 16.1.2006)

"Well, from the short or intermediate time perspective, how I perceive it, there has to be trust at a personal level. Contracts do not guarantee anything. But if we speak of these bigger lines, longer developments … then, contracts are needed for sure." (Interview data/The bridge builder, 23.1.2006)

Multiple actorial roles were also assigned to brand owners as Alpha's customer-partners. The aim was not only to capture large volumes and profitability, but to utilize the global brand owners' resources to invest both in technological innovation development and technology mobilisation. The plan (already decided before the establishment of Alpha) was to approach brand owners with unfinished technological solutions which could then be further developed in close collaboration and accessed indirectly through the brand owners' value chains as illustrated in the following quotation:

"… before this Alpha thing came, we had the idea that in a way the first steps are needed on this path. So, when we develop those products, we develop them step by step so that the path will lead to the same end result. Others try to do directly. But we start with a very simple version, we make them continually better and we get revenue throughout the way and along the path." (Interview data/The technology developer, 15.3.2004)

The management of Alpha anticipated that the brand owners would enable technology dissemination if their interest was aroused because they could compel their own suppliers to adopt new techniques and technologies. Moreover, as large international companies they also had internal growth potential. Additionally, the adoption of technology by one or two large multinationals might encourage others in relevant consumer brand fields to licence the technology as well. These enrolment strategies were, however, quickly questioned by the experts (the hard core) operating at the customer-end when they noticed that the parties in the brand owners' value chains – more

specifically the brand owners' suppliers – were reluctant to accept the customer role assigned to them (see the first quotation below). The suppliers were, thus, reluctant to invest in a new technology unless their own customers (i.e., the brand owners) actually wanted it (see the second quotation below). Another strategy was then decided upon, namely to access the global brand owners both directly and indirectly through their value chains. Following quotations illustrate these shifts:

> "When we start moving toward the consumer chain, particular problems arise… For instance, if we go to a printing house, they are jealous because they think there is a risk that we will approach their customers directly and things like that. These are the difficulties that we face. Of course, our supplier partners, they see opportunities that hey, they can become involved in such a great thing. Suppliers don't see us as their competitors; rather, we are asking for their help. But when we start moving toward the customer-end, then the issue emerges that, let's take a minute, who is offering whom and what." (Interview data/The initiator, 18.3.2004)

> "… we have had the idea that we seek globally well-known high-volume consumer brands as our primary customers; firms which use lots of packages in terms of volume and to achieve broad visibility and the strategy was that we would have a few of these as our partners; we would create these relationships, deep relationships and we would create a such pipe for new innovation together with them in which we would primarily act with the packaging people, marketing people and be the party who brings new possibilities to printing. […] our strategy has been to start projects with them in which we search for use possibilities for technologies, run consumer tests with them and because they are big players by themselves we can contribute our own focus and resources a little bit more, because then we can disseminate this inside these companies […] And when they invite their subcontractors, their advertising agencies and others to join in these projects, then, we would be present all the time to train them and to watch over when investments are made in printing houses; to bring technologies to them in this way. Hence, we would go the other way around; we will not go directly and say that "hey, printing house, buy our technology". On the contrary, we say "hey, printing house, here is your customer, and it wants you in this project". That way, it is more likely for them to…we have already experienced that when you do it this way, they are more willing to join. And also, by doing it that way, they cannot demand any exclusive rights to the technologies…" (Interview data/The bridge builder, 31.1.2006)

Efforts were then made by the management of Alpha to promote customer cases by creating social relationships internally among the brand owners' internal actors and externally with their value chain partners (i.e., suppliers and other relevant and potential actors related to that value chain) to lock these human actors to Alpha's network, but with little success. To mitigate the enrolment of these reluctant customer-partners, the management finally decided to assign the bridge builder to focus solely on one global consumer brand while other customer cases where delegated to other people. This one customer contact was created already before the establishment of Alpha in 2003 (Interview data/The bridge builder, 31.1.2006). By the end of the year, two customer-partners were finally enrolled in the network. Through these relationships, Alpha was able both to test the prototypes and to acquire some cash flow as illustrated below:

> "… these brand owners with whom we were discussing pay us a certain licensing fee. This fee is very small; it is something like parts of a cent per package. That is the reason why we actually need high-volumes, to make our business profitable. There need to be lots of packages and these big brands have them…" (Interview data/The initiator, 7.11.2005)

The management of Alpha also planned for investors to take multiple roles in the network. The investors were thus no longer considered only as punctualized actors (Law and Callon, 1992) investing monetary or other resources to the network of the intelligent paper (i.e., investor-owners). Rather, they were considered as investor-partners concurrently investing in Alpha (with or without having a shareholder status) and participating in the technological development activities. The following quotations illustrate this:

> "… to act in a close collaborating relationship with VTT was actually a part of our strategy in Alpha …" (Interview data/The initiator and the bridge builder, 29.5.2009)

> "… other tools related to this [InkByte] ensemble have been made for instance with H, which is one of our owners and with N, which is another of our owners; so we collaborate with our shareholders. And, well, these can also be related to broader areas, especially H does not relate to the code reader but it relates to the whole system, to the printing side and well, to the design side." (Interview data/The code promoter, 23.1.2006)

> "… we had a project with [H]; we embossed these covers and half of the material was done with their graphics and then they printed it and took it through their packaging machine for free, on their own expense." (Interview data/The product design, 19.1.2006)

The interests of the three initially enrolled investor-owners (which can thus also be considered as the investor-partners) were aroused by their long-term business interest and willingness to secure their future technology basis and consequently the suitability of the technologies into their products. Hence, the management did not anticipate the re-defining of the agenda to affect their actorial roles but rather they assumed that it would be more consistent with the initial interests of investor-owners. The same concerned the investor-partners, more specifically VTT as the principal investor of the PRINTO programme. The strategy utilised by Alpha's management to re-enrol these actors in the network was therefore based on their silent consent, that is, they were considered to accept their roles without doubting the refined agenda.

In Figure 9, I illustrate from a focal firm perspective the social network of Alpha approximately in the late 2005. At that period of time, approximately twenty experts were employed by Alpha. The coloured triangular shape around the offices demonstrates the internal dispersion of the joint venture firm. Due to this dispersion, the bigger dashed line triangular shape illustrates the vacillating borders between Alpha and its network; it was difficult for Alpha's members to outline the actors that actually comprised Alpha and the parts that should merely be considered as parts of the network. The other dashed line triangular shape illustrates the main human parties that were involved in the activities of the core technology development in the late 2005.

Following Latour's (1996) argument that the social networks of human participants can also be included in actor-network accounts, I have also depicted in Figure 9 the different interest groups around Alpha (cf. Möller & Halinen, 1999) contrary to what has been previously discussed. I have labelled them as owners, investors, research institutes and universities, competitors, customers, partners, suppliers, and subcontractors, using the names the human participants of the intelligent paper's network have given to them. Some of these actors operate abroad, mainly in Europe. Some parties are closer to Alpha than others. Closeness does not depict physical closeness, but the closeness of collaborative social relationships that human actors have with each other.

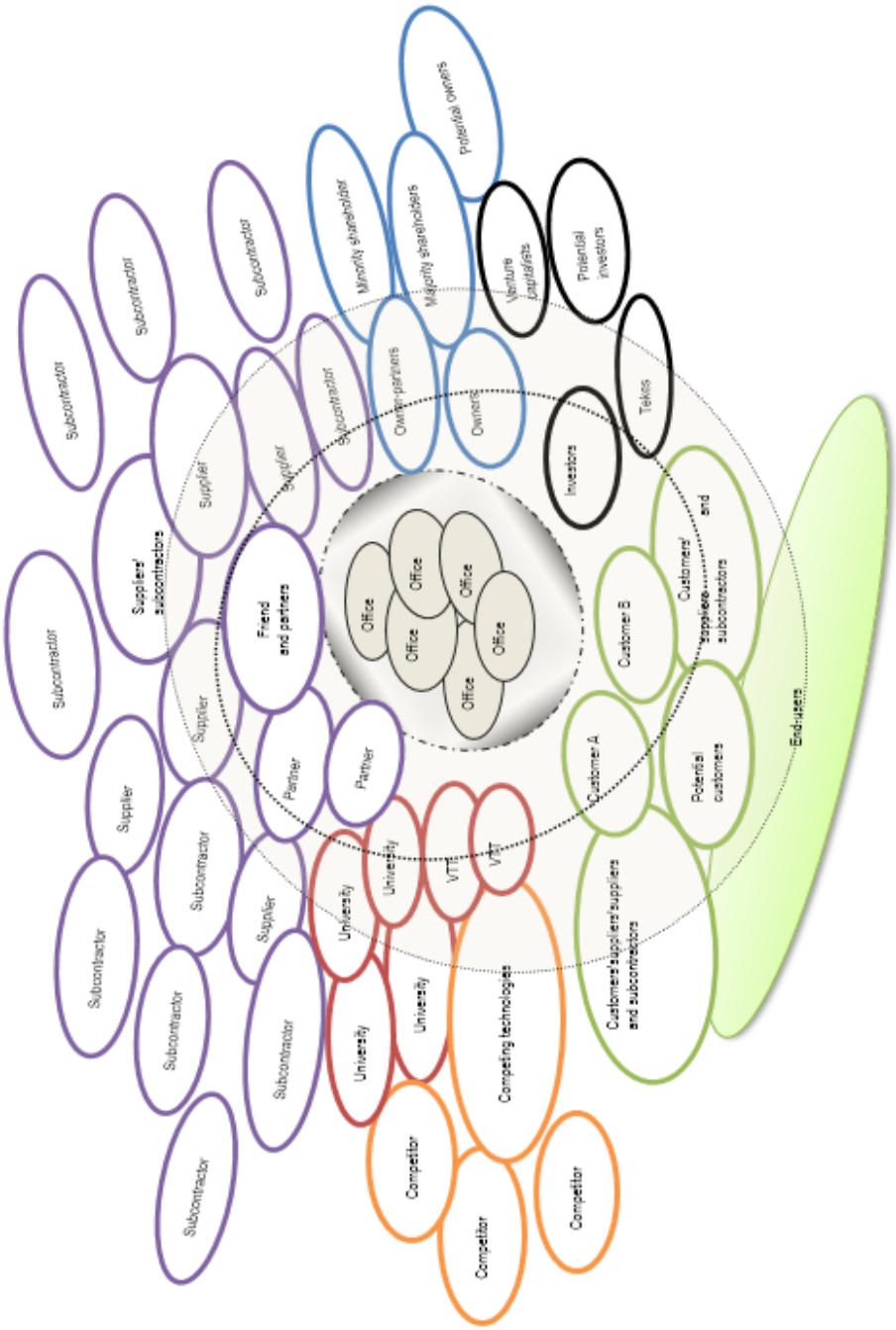

Figure 9. The social network of Alpha in the late 2005

Consequently, Alpha's experts operated in a diverse network, which included not only the key human actors creating the hard core, but also the human actors who were used when necessary (i.e., the friends and partners that actually showed reluctance to join into the network). The black dashed triangular shape illustrates the key human actors in the technological innovation development around the intelligent paper, whereas the other coloured dashed triangular shape depicts the blurring borders between the Alpha and its human networked actors, that is, those that the human members of Alpha considered as internal and external human parties.

4.3.4 Reforming the pack according to the redefined agenda

Approximately a year after the establishment of the joint venture firm Alpha the differences that potentially distorted the network compelled the management of Alpha to perform various renegotiations to stabilize the actorial roles of the (re-)identified and (re-)enrolled critical actors. These renegotiations that occurred approximately between years 2005 and 2006 focused especially on suppressing the increasing perturbation occurring especially among the experts in the "hard core" and the investors. The renegotiations considered more specifically the issues of who should actually be considered as part of Alpha's management and how to induce and enrol finances in the network around Alpha. As an example, the following quotations are related to these perturbations:

> "We have quite a lot of executives in this firm. They work hard, they do lots of things, but still the starting points and the backgrounds… This has personally bothered me all the time. When the firm was established I was enormously annoyed; we had nine workers and seven of them had a vice president title. Of course I was jealous because I did not have that but I was embarrassed to confront the customers; we went there and everyone put their vice president cards onto the table; it has to mean that there is something wrong with the firm if so many executives have to be present at the same time. But we had no one else in the firm." (Interview data/The bridge builder, 31.1.2006)

> "I feel we continually think about how we get that message through. How we can get things more effectively done; how we can focus more. We still have the problem that we are engaged in all sorts of things which are interesting but to do things that are productive, that is the problem. Everyone has their own playground in this kind of a job. Everyone is like an expert in his/her field so their own agenda emerges everywhere. To get that shared agenda through; I feel that is required for clarity's sake […] One has to know how to focus; this is what we are now doing; so that everybody would not be just tending their own garden, to focus on what we are actually doing. The way the firm operates has been changing. At first,

everything was small-scale, everybody had their own flower and wanted to water that flower. But now this is changing; there are financial pressures. It can no longer be the situation that everyone does their own stuff; the way things work has to be changed; clear results are needed from the work we do here." (Interview data/The management of Alpha, 16.1.2006)

In Table 16 I summarize this fourth sub-phase called 'Reforming the pack according to the redefined agenda'. This sub-phase is discussed in more detail during the next paragraphs.

Table 16. Reforming the pack according to the redefined agenda

Phase of forming the pack and performing various negotiations	Approximate year of occurrence	Principal actors	Agenda	Interested actors (enablers)	Reluctant/hostile actors (inhibitors)	Silent/Neutral actors
Reforming the pack according to the redefined agenda	~2005–~2006	Alpha (the management of Alpha	Alpha as the mediator between the technological innovations' development and the paper-making business	Those interested human and nonhuman actors mentioned in the previous phase except the experts in the hard core) The bonds and shares	Those hostile in the previous phase The experts in the hard core Finance Investors The investor-owners The investor-partners	-

Whereas the re-identification of the experts in the hard core had initially been considered as quite an easy task for Alpha's management, it was soon realized that this re-identification was closely intertwined with the identification of the management itself. To separate these two actorial roles more clearly from each other, the management started to rearrange the activities around Alpha. Firstly, it began to encourage centralized activities as it was accustomed to those responsible for the core technology development being close to a project manager, a clear line of authority, and easily available contacts. Then, it rearranged the experts' tasks by both delimiting the duties of some experts and implementing certain routine processes. These activities were hence aimed at clarifying the management's role as the author of Alpha. They also enabled the management to better control the dispersed technological innovation development activities in terms of the social relationships of the experts. It allowed the management to assess whether these social relationships were properly utilised to boost the development and commercialisation of the chosen technologies. For some experts of Alpha, these rearrangements meant a decrease in autonomy and executive power, and an increase in reporting obligations. For others, it meant liaising more with the actors surrounding Alpha.

Despite these organizational rearrangements, the management still had continual difficulties to sustain its redefined actorial role as illustrated in the following quotation:

> "… we have had some old-fashioned ways of operating because of the management; they are used to hierarchies and a certain way of doing things due to their backgrounds; coming to run this firm, it has probably been a shock to them that young guys outsmart them and go running about around the world. […] luckily we have not had extremely heavy reporting systems although there has been an effort to try such things, and describe heavy processes […] At the same time we have definitely had a longing for some kind of centralized governance, so as to have a strong management who would know what is happening in the firm as broadly as possible and it would operate in consensus but for one reason or another that activity has also stumbled…" (Interview data/The bridge builder, 31.1.2006)

Additionally, they had however little effect on the relationships between the experts from the Alpha side (the 'hard core') and those operating within VTT/printed intelligence (the friends and partners); the experts who were initially assigned to promote the intelligent paper were still closely working with the technology developers of the printed intelligence until the end of the PRINTO programme, thus until 2005. Following quotation illustrates this interpretation:

> "I have noticed one thing, especially with VTT; we work a lot with them and VTT people are beginning to be well known to all of us; many of us work with the same persons from VTT and occasionally there is no.. I think that VTT people do not always know the priorities and to get that under control, it is occasionally challenging. Of course VTT people do things the way we say that something should be done. But, well… these things cannot be cast in stone beforehand; to say that only these things can be done; and the other things should not be done, because you can never know for sure; the situation changes all the time; it is challenging to control it so that the right things would get done and control would be maintained." (Interview data/The code promoter, 23.1.2006)

The initiator together with a few other experts tried to convince the management that instead of favouring centralized development activities, an internally and externally collaborative mode of operation and the building of 'hubs' near to the critical actors would pay off. They would enable the avoidance of heavy investments and the cost-effective internalisation of expertise of external parties and critical (nonhuman) actors attached to them, even in the case of firm growth. Additionally, decision-making would be quicker, which would demonstrate Alpha's agility and cutting-edge know-how. (Interview data/The initiator, 7.11.2005; Interview data/The bridge builder, 31.1.2006; Interview data/The technology developer, 8.2.2006).

The management of Alpha however refused to believe that one single human expert could trust external human experts' knowledge and skills as much as they trust their own and/or that of their co-located colleagues. In line with the actions of the management, some experts of Alpha also argued that in certain sectors it would be more favourable to internalise the needed competence through acquisition rather than through the existing social network relationships

Related to this, the management had already at that time realised that despite the initiator's state-of-the-art idea of attracting the best (human and nonhuman) actors by letting the humans work where they wanted, throughout the years of promoting the agenda of the intelligent paper it had mainly interested only Finnish experts. I attribute that to the initiator and the experts' personal social relationships to the same people working in certain Finnish research centres and universities.

In parallel with clarifying the actorial roles between the management of Alpha and the experts in the 'hard core', the management started to lock finance into its planned place. Finance was going to act as a certain monetary guarantor which would enable technological innovations' development and their dissemination in the longer run. Besides already getting finance from the investors-owners and investor-partners, the management issued special bonds and shares in order to further strengthen Alpha's capital stock and liquidity (Documents/Annual reviews and financial statements/Alpha/financial statement 1.1.2005–31.12.2005).

It also rearranged tasks in the customer-end in order to promote cash flow generation from the customer-partners and urged the experts from the technology-end to choose the most promising technologies under development so that they could direct expertise in them and boost their commercialisation. Two of the most potential technologies were filtered from the discussions with the experts. Two experts were then assigned to take care of these development activities. Their other technology development activities were either delegated to other experts or encouraged put on hold. One designer was also hired to boost the commercialisation of the first chosen technology (the product D).

To fulfil the requirement of the original investor-owners (which were also investor-partners) and consequently, to bind in particular finances more tightly to Alpha's network, the management of Alpha re-identified the investors. Whereas in the first place these actors were planned to take multiple actorial roles simultaneously, the management now started to search for parties that were considered more as punctualized actors (Law and Callon, 1992), primarily providing finance to Alpha. The following quotations are examples of this shift:

> "… we have to get more money next year; the owners have given us financing for 20 months which basically means that it ends in March. Our owners N and M will invest more but they want there to be other owners, so we have had international venture capitalists. There has been a certain financing round […] especially N

states that there should be some foreign instances involved because Finnish investors are too small. They do not have the money…they may have it initially but not in the longer run." (Interview data/The initiator, 7.11.2005)

"… when a firm grows, it needs more money. So, it is likely that then also other owners are needed. Because the starting point here has been that the technology is not limited to the use of shareholders only but we as a firm have the right and permission to disseminate this to others; it is natural that there will be new owners involved. This is not in that sense like some outsourced product development unit but a firm that aims at making its own profit." (Interview data/The code promoter, 23.1.2006)

A few parties were showing interest, namely an institutional and some private venture capitalists in Finland with whom the management started financing negotiations. The first expressed interest in funding Alpha. In the spring of 2006 – after the management realised that the contacted private Finnish venture capitalists showed no interest in joining Alpha – the management approached European independent venture capitalists to find suitable funding partners. After many discussions with these offshore potential investors, one British venture capitalist finally showed interest. The Finnish investors interested in Alpha, however, expressed distrust of that party and refused to cooperate, mainly because the fundraising was unfinished and supposed to end only in the autumn of 2006. After unsuccessful financing negotiations with the potential investors and as the original investor-owners one by one decided not to continue financing the operations around the Alpha, in autumn 2006, Alpha's management was compelled to discontinue operations. Following quotation illustrates these events from the viewpoint of one human expert (the bridge builder):

"… at that time, we negotiated with both customers and investors; we planned for the next financing round which was a type of a financing package that was achieved in the summer of 2006 or we made it happen during the spring time but then one of our two initial investors decided to withdraw; they said that they did not want to invest in us after all. […] after this we had to start negotiating about a new financing package, it was good we managed to gather it together in the summer and again we thought that everything was ok, but then when we came back from summer holidays, there had been an exchange of people and the Finnish investor thought that the English party was not reliable because they were going to invest from their forthcoming pledge and not from what they had collected at that time; so after that it fell apart too and this was the way we were handling things at that time; we tried to search for a customer and investors and finally it came down to running Alpha's business down." (Interview data/The initiator and the bridge builder, 29.5.2009)

The personnel were laid off and the initiator was given the task of selling Alpha's possessions such as the intellectual property rights, furniture, and computers. He found a suitable buyer for Alpha's pending patent applications, but the offered price was too low for the original investor-owners (the investor-owners-partners). The ownership was then split and one of the original investor-owners (the investor-owners-partners) received part of the intellectual property rights while the other part was retained in Alpha, now owned by two of the initial investor-owners. The other assets were quickly disposed of.

4.3.5 Forming the pack according to the refreshed redefined agenda

The closing down of Alpha's operations in the late 2006 did not however break down the network of the intelligent paper. Instead, a few parties were still deeply interested in acting within this network. Separately from each other and according to their own agendas they started locking the critical actors (those considered only as enablers or inhibitors to their agendas) into their places, thus revitalising the intelligent paper's network formed so far. In Table 17 I provide a summary of this fifth sub-phase, next discussed in more detail.

The first party that still wanted to continue acting within the network of the intelligent paper was the initiator and the code promoter as the promoter of the firm called Beta which was established short before Alpha's activities were abandoned. This firm was envisioned to focus on bringing technological solutions based on printed, transparent electrical codes, and their reading to the product identification market (Documents/Other, Company webpages of one spin-off, 2010), thus to extend the agenda of the intelligent paper from its then existing stance.

As illustrated in the third sub-phase of setting the agenda, the critical actors related to the birth of InkByte were during Alpha's existence to a large extent already induced or forced to accept their roles in the intelligent paper's network. Hence, the initiator together with the code promoter started to lock a few other critical actors in their places which were yet absent. These actors included the potential investors and customers who had not previously been enrolled in this extended network of the intelligent paper.

At first, they approached the potential investors. They utilised their personal social relationships with a few of the most potential parties – namely VTT Centre for Printed Intelligence and two Italian companies (one nanotechnology developer and one ink manufacturer) – and consequently negotiated financing from these instances. Besides being owners of the company, these parties also provided services to Beta, namely the code reader (a patent obtained by VTT in 2009, licensed to Beta) and a certain ink technology development work (Interview data/The initiator and the bridge builder,

29.5.2009; Documents/Research Publications, VTT/Research and development activities in printed intelligence 2008, p. 7; Documents/Other, Patents related to technology development, 2011; Documents/Other, Company webpages of one spin-off, 2010). These investors were thus considered simultaneously as investor-owners (investing in Beta in terms of having a shareholder status) and investor-partners (giving finance to Beta's operations and engaging in its development activities).

Table 17. Forming the pack according to the refreshed redefined agenda

Phase of forming the pack and performing various negotiations	Approximate year of occurrence	Principal actors	Agenda	Interested actors (enablers)	Reluctant/hostile actors (inhibitors)	Silent/Neutral actors
Forming the pack according to the refreshed redefined agenda	~2007–	Beta (the initiator and the code promoter)	The intelligent paper extended	The investor-owners and investor-partners One customer-partner The network of InkByte (e.g., the electronic code, a code reader, software to read the electronic data, demos, inks as well as a few technology developers and a few experts) The network of the intelligent paper (e.g., paper, paper-making hot embossing, different kinds of inks, Pico as well as a few technology developers and a few experts) The intellectual property rights of Alpha	(The actors inhibiting the network of the intelligent paper) The unobtrusive Ink for imprinting invisible barcodes The investors (expect one party) The customer-partners	-
		The Paper-maker	To secure the future paper-making business	The plans VTT One Finnish technology consulting company	(The actors inhibiting the network of the intelligent paper)	-

Next, they started to scout for potential customers. These customers were also planned to take multiple actorial roles in the same way as in the previous sub-phases. Thus, they were not only to be considered as customers, but also as customer-partners, securing concurrently both the cash flow generation and technology development. One potential offshore customer-partner showed interest; this actor wanted to find a solution for

diminishing the counterfeiting of receipts prevalent in the country they operated as illustrated in the following quotation:

> "We had an idea of going to the product authentication markets, because in China, there was an interest in printing electronic codes to receipts, because there is a big problem of counterfeit receipts. So there would be specific readers with which that electronic code is read. The electronic code interested the Chinese because the government noticed that counterfeiters always learn the old techniques so this could be something new that the counterfeiters are not yet able to do." (Interview data/The initiator and the bridge builder, 29.5.2009)

The first commercial solution was called InkByteCode[33]. It was a code printed with a certain electronic ink, which contained controlled unique digital information to be read with InkByte RF reader[34] authenticating and decrypting InkCodes[35]. These codes could be printed with standard industrial or office printing machinery and tooling. This technological solution was seen to offer various advantages over the competing authentication technologies, such as cost-effective production and ability to produce into large areas (i.e., multiple codes per one printed item) also suitable in high-volume low cost items, which too have become a subject to counterfeiting. (Documents/Brochures, Printed electronics for Authentication and Tracking: Our contribution to a safer world, 2011; Documents/Other, Company webpages of one spin-off, 2010)

The ultimate strength of InkCode and how it differed from its nearest competitors in the market (i.e., the RFID technique and certain bar codes) was the fact that it could be hidden with low cost so as not to disturb other information imprinted on the surface of the product. Nevertheless, the initiator together with the code promoter had challenges in enrolling the unobtrusive ink to the emerging network. Even with the help of technology developers, they were thus unable to develop a certain unobtrusive ink which would actually enable imprinting of the invisible barcodes. They turned to one of Beta's investor-partners for getting help in forcing this nonhuman actor to join the network. They were turned down; all that the human actor could deliver was the black carbon-based conductive ink. (See the quotation below)

To overcome the pitfall occurring in the technology end and to induce the potential customer-owner to join Beta's network mentioned above, a few trials were run with lottery tickets in which the black carbon-based conductive inks were embossed under normal black ink imprinting. This was done after the initiator suggested to this potential customer-partner that a barcode readable with a barcode reader could be imprinted onto

33 The name is a pseudonym.

34 The name is a pseudonym.

35 The name is a pseudonym.

the lottery tickets first by using conductive ink and then by imprinting another barcode over it with unconductive ink. After this, an extra layer of normal ink could be imprinted that finally would blur the barcode so that it would be unreadable with bare eyes. (See the quotation below)

> "We had the idea that we should have made a certain invisible ink to able to say…to be able to print a certain bar code which is invisible. When the Italians could not make it, I ran tests with the Chinese last summer. In the receipts there are lots of dark areas so in the tests we put ordinary ink on top of it. There's this black conductive ink and then the black ordinary ink, so, that kind of a concept seemed to satisfy the Chinese; and this was when we were able to reach the situation that we could use ordinary carbon-based conductive inks." (Interview data/The initiator and the bridge builder, 29.5.2009)

After the successful trials, an agreement for a pilot market test was made with this customer-partner. Further, since this actor (one customer-partner) was satisfied with the test trials and certain critical actors were experienced as being more easily negotiated to the emerging network of Beta (i.e., the black carbon-based conductive inks, the unconductive inks, and the normal inks), the initiator together with the code promoter decided to delay the development efforts that aimed to force the unobtrusive ink to join this extended network of the intelligent paper (Interview data/The initiator and the bridge builder, 29.5.2009).

In the early 2008, the customer-partner informed that the pilot had to be delayed. After hearing about the delay, the two of the three investor-owners (and investor-partners) refused to continue funding Beta. The remaining one investor-owner (and investor-partner) – VTT Centre for Printed Intelligence – decided to merge Beta's emerging network with the network of printed intelligence. This was done by dismissing the initiator and the code promoter, and enrolling finance to the network via a Finnish venture capital investment company which served as the hub for public early-stage venture capital investments and via few other business angles operating already in the network of the printed intelligence. From VTT Centre for Printed Intelligence's perspective, through these arrangements it was able to initiate the first company from the network of the printed intelligence based in part on technologies which were developed during the PRINTO programme and later patented by VTT (Documents/Research Publications, VTT/Research and development activities in printed intelligence 2008, 4, p. 7). In 2009, the firm was still operating. Next quotation illustrates Beta from the viewpoint of VTT:

> "[Beta] is the first start up from VTT's printed intelligence developments. While VTT's work has been fundamental in the founding of other startups in the printed intelligence market this company is the first to be based in part on VTT

technology." (Documents/Research publications, VTT/Research and development activities in printed intelligence 2008, p. 7)

While the initiator together with the code promoter continued acting within the intelligent paper's network, the paper maker (now comprising of two initial investor-owner and investor-partner companies of Alpha) turned to VTT and one Finnish technology consultancy company specialised in R&D and business strategy in the area of nanotechnology and advanced materials. Together they started to gradually build both technology and business plans based on the intelligent paper as the core technology basis. These plans also included the investigations concerning the business potentials that the intelligent paper could offer as well as the identification of new customers, investors, and the technology development partners. Following quotation is an example of this actor:

"The first phase development plan of Alpha is the following:

1. Focusing on D and scouting of its business potentials. We will make a business development plan with the help of an external consultant party.

1.1. Becoming familiar with the level of technology and business development regarding printed electronics – the formulation of a business plan.
- Review of our own D portfolio and detailed identification of relevant technology areas.
- Meetings with potential customers, investors and development partners.
- Consultant report on D portfolio's business potential (utilization potential of technology, brand value, technological development areas and weaknesses of the portfolio, potential partners and investors etc.).
1.2. Finding new partners based on the business development plan and its actualization.
1.3. Activation/investment decisions of practical development projects.
1.4. Alpha's situation analysis in the shareholders' meeting and decisions regarding the second phase development plan." (Documents/Annual reviews and financial statement, Alpha/financial statement 1.1.2007–31.12.2007)

Between 2008 and 2009, these plans were going to be further developed into certain technology areas that were considered as the most potential ones emerging from the discussions with VTT and the consultancy company, and for which tests and pilots were to be conducted. These testings and pilot projects were planned to be made together with VTT and those potential partners. Additionally, a decision was made to hire one person to run Alpha's operations. (Documents/Annual reviews and financial statements, Alpha financial statements 1.1.2008–31.12.2008, 1.1.2009–31.12.2009)

Although these plans were aimed at strengthening the agenda of the paper-maker, they however further strengthened the printed intelligence's agenda and consequently its network.

4.4 Potential betrayals

In the forming of the network, the critical issue for the principal actors is whether or not the critical actors are following the agenda and consequently the roles assigned to them. If one of more actors does not follow the agenda and their roles, the network becomes unstable and may fall apart. (Callon, 1986a, 1991) Quoting Callon (1991, p. 148), "A successful process of translation thus generates a shared space, equivalence and commensurability. It *aligns*. But an unsuccessful translation means that the players are no longer able to communicate. Through a process of *disalignment* they reconfigure themselves in separate spaces with no common measure.".

The network formation for the principal actors is, thus, not only about setting the agendas and drawing the critical actors together, but also about acting upon disalignment. Disalignment means the differences potentially distorting the functioning of the network under formation. In this study, I call these potential betrayals. In contrast to the original four-phase translation model (Callon, 1986a), I present potential betrayals as a separate phase preceding the final phase of the network formation of technological innovation, namely the filtering of the spokesperson. The reason for this derives from the empirical observation I have made in this study which is also supported by recent actor-network studies (Giesler, 2012; Nicolini, 2010; Schneider et al., 2012) that potential betrayals do not necessary result in the breaking down of the network, but rather in its constant revitalisation. I have interpreted this revitalisation to have occurred both within the multiple agenda setting and pack formation phases identified and discussed above.

In this study, the potential betrayals took place almost right from the start till the end of the study period. More specifically, they were mainly related to the events in which different critical actors started doubting and questioning the actorial roles assigned them by the principal actors. Table 18 sums up these main potential betrayals that I detected in terms of the actorial role which is questioned and how this questioning was solved or tried to be solved. In particular, these resolutions transformed the network formed so far, compelling the principal actors to continuously perform various negotiations and renegotiations in order to stabilize the network under formation. These resolutions in terms of continual pack formations were already discussed in the previous chapter. This is why the next paragraph focuses only on briefly presenting the main critical actors who potentially distorted the network formation and their actorial roles which were acted upon during the study process.

Table 18. Potential betrayals and the activities for the resolution

The critical actors in the potential betrayals	The actorial role questioned	Approximate year of occurrence	The activities for resolution
The paper-maker	The resources provider (multiple actorial roles)	~2001	The inducement and enrolment of other parties which provided resources to the intelligent paper; The establishment of the joint venture firm Alpha in which the paper-maker is one investor-owner (and investor-partner)
VTT (the PRINTO programme), the experts	Technology developers for the intelligent paper	~2002 onwards	The inducement and enrolment of various actors (e.g., the offshore technology developers, heatset offset presses, the gravure presses, integrated embossing, plates, inks, test samples, patents, and devices); the collaborative work of experts; subcontracting (special parts in core technology the development such as plates and inks)
Roll-to-roll processing	The method for fabricating the intelligent paper	~2002 onwards	The enrolment of the integrated embossing in the network of the intelligent paper (later roll-to-roll hot embossing)
The initiator, the experts and the management of Alpha	The author of Alpha	~2004	The organizational rearrangements (rearranging the tasks and duties of the experts in Alpha)
The investors	The finances provider (from multiple actorial roles to a more punctualized actorial role)	~2005 onwards	The organizational rearrangements both in the technology-end and customer-end (e.g., rearranging the tasks and duties of the experts in Alpha; the issue of special bonds and share; the search for more punctualized actors which only provide financial resources to the intelligent paper)
The customers (the friends and partners)	The customer partners	~2004 onwards	The organizational rearrangements in the customer-end (rearranging the tasks and duties of the hard core in Alpha); the search for new potential customers both in Alpha and Beta
The human participants in the network of the intelligent paper (mainly Alpha's investors and customers)	Alpha as a mediator between technological innovations' development and the paper-making business	~2005	The organizational rearrangements both in the technology-end and customer-end as described within the investors and the customers
The human participants in the network of the intelligent paper (mainly Betas investors and customers)	The resources provider (multiple actorial roles)	~2008	The search for potential customers and investors
The optical effect, the paper	The intelligent paper	~2004–~2008	Introducing and enrolling the special coatings into the intelligent paper's network in approximately 2008

Quite shortly after setting the initial agenda of the intelligent paper, approximately in 2001, the paper-maker started questioning its actorial role as the resources provider to the intelligent paper's network. At first, it started debating about the business unit in which the intelligent paper together with its human participants could and should actually operate. The initiator found this question pointless; already at that time the activities bound to the intelligent paper occurred in many places that differed in their nature. The activities were also further affected by the surroundings where they originated. If located in one place, some (development) activities might cease to exist, not only because some technology developers were reluctant to move, but also because these activities were linked with certain critical actors (e.g., paper-making, Pico and printing presses) which were difficult if not impossible to be easily transferred closer to each other. The following quotations are related to this observation:

> "The newest [paper-maker's] R&D center for packaging presses was opened at Casale, in Nothern Italy a month ago. Casale's pilot coating machines are used to print, laminate, and die-cut different packaging materials." (Documents, Magazines and news, Tekniikka&Talous 19.6.2002)

”It is not just about people acting together but there we examine some of the devices that have been made.” (Interview data/The initiator, 18.3.2004)

”In Turku, we have quite a lot of printing houses in which we run test drives. […] I do not know whether the printing houses have emerged in the Turku region especially or whether it is due to the fact that L [H’s development manager] is from that region… ” (Interview data/The initiator, 7.111.2005)

”… small desk, those kinds of laboratory devices and then the kinds of, well, we have that roll-to-roll machine and then the production machines so we have all of these; this cannot be produced with any single machine.” (Interview data/The technology developer, 15.3.2004)

“In the development work of D optical effects, a roll-to-roll-pilot production facility, Pico, has been used. Pico is a research and development environment for printed electronics and optics owned by Alpha, but it is installed in VTT’s clean room environment.” (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, p. 27)

”In Finland, running roll-to-roll presses can be found in every printing house. There are much less presses available for the use of printed intelligence. […] Four R2R presses are in VTT, in Oulu. […] PICO, which was installed in 2003, is the first roll-to-roll press in VTT. […] ROKO press has been in use since 2007.” [36] (Documents/Research Publication, Varjus, 2012, p. 19)

Further from 2002 onwards, the paper-maker was faced with financial challenges (Documents/Annual reviews and financial statements, One of Alpha’s shareholder/Annual review 2002, p. 9, 2003, p. 6; 2004, pp. 3, 6). As a result, one business unit was decided to be sold off. This business unit was a downstream operator V R, developing solutions for instance for packaging materials and paper-making processes in which the intelligent paper was initially located and for which a new product line was to be built (the sale actualized finally in January 2004 after the approval from the national competitive authorities). Hence, there was a necessity to make a decision about locating the work around the intelligent paper. The paper-maker felt that the activities concerning the intelligent paper were distant from its own core competence areas. Nevertheless, it wanted to be involved in the ongoing network of the intelligent paper, but only as one owner (a majority shareholder). In the following quotation, the initiator explains the paper-maker’s competencies (and what it lacked from the viewpoint of the intelligent paper):

[36] I have only quoted here the printing production facilities which were developed and installed within the study period of ~1997-2009. Later, two production facilities have been installed, namely NICO and MAXI (R2R-Pilot line) (Documents/Research Publication, Varjus, 2012, pp. 21-23).

> "And especially, when we go on and talk about electronics and how the electronics materials are printed on paper. Then, in M, the management sees it as a foreign area to them, [and wonder] whether M's competence is sufficient enough for that type of thing. As they see it, of course, they mainly employ machine builders. And then, when it comes… a machine builder can still understand the optics where it is squeezed, even if it concerns the structures of hundreds of nanos, a machine builder can understand going from millimeters to a few hundred nanos, it is still the same kind of thing. It can be figured out somehow. But if we start from the way electricity operates here which you cannot see, then, it becomes hard for a machine builder to feel that their competence is sufficient. Then it is preferable to find cooperative partners. And on the other hand, people see it as such a huge thing that even money does not suffice so there should be partners; to find a broader financing base. The financing competence is not sufficient. But basically as I see it, it feels like the interest is in there that M wants to be part of this but only as one competence among others. And I think it is probably a good decision." (Interview data/the initiator, 18.3.2004)

This potential betrayal was solved by engaging in activities that led to the establishment of the joint venture firm Alpha in 2004. A few persons from the investor-owner and investor-partner companies were appointed as Alpha's management. This actorial role was defined as the one who speaks over the seemingly voiceless Alpha who in turn acts a mediator between the technological innovations' development and the paper-making businesses. The actorial role was however quickly questioned by other actors in the intelligent paper's network, namely the experts in the hard core. At the same period of time, the management of Alpha was also confronted with one actor who had previously been considered as a subordinate by the investors, namely finance. As the investors had multiple roles to perform in the network besides allowing the utilisation of this nonhuman actor within the network around Alpha, finance itself slowly showed an increasing reluctance to accept the role of only one actor among others comprising the investor. Instead, it was to be exclusively treated as critical.

By the end of 2005, Alpha faced a second financing round with its investor-owners. Despite the changes made in the customer-end to boost the creation of new customer relationships when commercializing certain technology developments, these actors were dissatisfied with the business opportunities produced in Alpha during the 20 months they had originally promised to fund. At first, the two investor-owners required a wider ownership base. Shortly later, one of the original investor-owners – the paper maker – decided to abandon the deal, but financing was guaranteed until the end of the summer of 2006. When the original investor-owners of Alpha one by one decided to stop funding its operations, other potential investors became wary as illustrated in the following quotation:

> "There were many turns of events; it is always problematic when the investors that have initially started investing suddenly start retreating. It is always easier to get more money when the current investors are playing along; they want to contribute and they want new parties to join in. But if they have the mentality that they do not want to continue financing but they would allow newcomers to join in; then, the newcomers become wary whether everything is in shape if the current parties no longer have faith." (Interview data/The initiator and the bridge builder, 29.5.2009)

While the investors and consequently finance showed increasing reluctance to accept the redefined agenda, potential customer-partners also continuously doubted whether the intelligent paper is worth their serious interest. The experts (the hard core) in the customer-end had difficulties in convincing them that although involving mainly Finnish experts, the technologies under development were global in their true nature and therefore suitable to be applied to their future products. More importantly, they were trying to convince the customer-partners that by accepting the actorial role assigned to them, that is, being part of the ongoing development activities and thus act as the providers of resources, they would be able to affect the ongoing technological innovation's development activities. They could in this way bring forth their needs and wants during core technology development.

During various negotiations with these actors, in the early 2006, Alpha launched its first product version D from the core technology development activities that had run for almost 10 years. The plans were to launch the second generation during the same year in close collaboration with specific customer-partners, and finally automatize the production process by 2007. These plans were however challenged by the refusal of the optical effect as part of the intelligent paper to work effectively with another actor, namely the paper's surface (see the quotation below). This pitfall led to the situation in which one of the two customer-partners refused to make a deal with Alpha:

> "… with G[37] in the summer of 2006; they held a presentation in some authentication conference in which they praised our optical product a lot and indeed they invited us to negotiate a three-year letter-of-intent with them. Then, a turn of events took place. They insisted a market test to be run in the Middle East first before signing this contract. They told us that these packages are extremely important in terms of how their surfaces behave with grease, since there is lots of sand; people use grease in their hands and the medications are in the grocery stores; people touch the packages. They had problems with metal surfaces because finger prints remain on metal surfaces and as a result, the packages look unpleasant. Then, they said that when our packaging is wiped with a greasy finger,

[37] Name is a pseudonym.

> the grease goes to the narrow holes of the effect which are hundreds of nanos structures so grease goes to these holes and then the effect can no longer be seen. So there's no way it's going to work. That issue had been told to them beforehand but perhaps they had not realized it before this last phase; so that did not work and thus it fell apart, this G case, around September 2006." (Interview data/The initiator and the bridge builder, 29.5.2009)

Furthermore, another customer-partner accepted a local consumer test on the German market despite the difficulties with locking the (nonhuman) actors in their places. The original investor-owners of Alpha were however dissatisfied with having only a local and not a global deal as illustrated by the following quotation:

> "Well, we negotiated with C[38]. They wanted to utilise this [product D] in one of their brands. They intended to take it to global use, but they wanted to do a market test in Germany first; we would install the devices there and we would do that in Germany. That was not sufficient enough to Alpha's owners; instead of getting a global deal with the brand owner there would only be a local test so the negotiations with them stopped there. The brand owner did not want to make a global deal without having a local test first." (Interview data/The initiator and the bridge builder, 29.5.2009)

Additionally, different kinds of organizational rearrangements were made, new potential (human) instances were scouted for and (nonhuman) actors were induced and enrolled (the special bonds and shares) to Alpha's network to lock finance and other critical actors into their places. Nevertheless, the management of Alpha was compelled to discontinue Alpha's operations in 2006.

Beta encountered similar challenges a few years later especially in relation to its customers and investors. The two of the three investor-owner and investor-partner companies refused to continue funding Beta after hearing about the delay in the pilot delivery to one customer-partner. (See the quotation below.) Then, the remaining one investor-owner and investor-partner – VTT Centre for Printed Intelligence – dismissed the initiator and the code promoter and started to promote Beta by itself as illustrated in the following quotation:

> "Yet again, I established a firm in which we started to advance the electric code. VTT partly owned the firm and then the Italian parties which produced that ink. […] Yes, the code promoter was involved; we negotiated half a year with VTT and the Italians but VTT made that code reader for us and the Italians made that ink thing. […] But, then, we could not reach the stage of piloting the project within half a year as we should have had when we managed to make a deal with VTT and

[38] Name is a pseudonym.

> the Italians in summer 2007, then, at the beginning of year 2008 we should have had the pilot delivery and that was delayed because of the Chinese and then in 2008 which was last summer, the Italians did not want to invest more money in the spring, but we survived somehow, and in the end they did not want to invest more money because there was no pilot delivery. Then we noticed in the summer that we have run out of money; we cannot continue anymore so after that we, the code promoter and I, were put aside and then VTT managed to find an investor party with whom they have together with the Italians now continued the thing in some manner." (Interview data/The initiator and the bridge builder, 29.5.2009)

Going once more back to the year 2002, thus a few years before the joint venture firm Alpha was established, VTT electronics and VTT Information Technology had launched together a three-year research programme called PRINTO on printed optics and electronics in collaboration with Tekes, universities of Joensuu, Oulu, Jyväskylä and Lapland, and seven private partner companies. This research programme was an avenue opening project in which the focus was on the continuous roll-to-roll capable mass production technologies (i.e., gravure, offset, flexo, and ink-jet) This research programme was an avenue opening project in which the focus was on the continuous roll-to-roll capable mass production technologies (Documents/Annual reviews and financial statements, VTT overview 2006, p. 14; Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, pp. 4, 7; Documents/Presentations, Kololuoma, 2005; Documents/Presentations, Kopola, 2005a, 2005b; Documents/Magazines and news, VTT News, 2.2.2005)

Throughout the years, VTT had gradually invested in this area mainly through its two units mentioned above by letting its researchers study and develop both micro-electronical and hybrid media solutions. In fact, these development activities date back to the early 1990s when a few VTT researchers from the graphic laboratory internally proposed a project around interactive printing products, more specifically the interactive newspaper. These researchers wanted to create a system in which a user could get additional information to the printed paper by reading it with a specific reader. (Documents/Research Publications, Södergård et al./Printed intelligence, 2007; Documents/Presentations, Södergård, 2004) Without going into details, these development activities together with those made within the micro-electronics and its materials were now partly combined together into this new research programme, to gradually boost the generation of a new business sector.

Although the agenda of the intelligent paper was strongly strengthened during the PRINTO programme, by for instance modifying hot embossing toward roll-to-roll processing (i.e. the integrated hot embossing, later the roll-to-roll hot embossing) and by producing an increasing amount of intermediaries (e.g., test samples, an online monitoring system for the optical effects and patents), the PRINTO programme also

entailed a potential betrayal. This was the gradual rejection by VTT and its researchers to adopt the actorial role that was initially proposed to them. The initial role was for VTT to merely be one technology developer among others. However, the emerging network of intelligent paper now became involved in the ongoing actions aimed at traversing another agenda introduced by VTT. Similarly to the intelligent paper, the initiator attributed the emergence of this agenda to the paper-maker (cf. (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, p. 4). Following quotations illustrate this interpretation:

> "When you look at it from the viewpoint of VTT; when M started these and M was active toward VTT, VTT received a kind of stimulus in 2004…" (Interview data/The initiator and the bridge builder, 29.5.2009)

> "… VTT achieved a good international position because it started this early enough. And perhaps it was really due to M's project; because M is such a customer and a company which is always demanding something from VTT. As a result VTT perceives that they should go onboard because the company is insisting. They gave a kind of a boost to VTT, to start with this thing." (Interview data/The initiator and the bridge builder, 29.5.2009)

This new agenda was intertwined with the idea of combining different kinds of components and systems so as to bring forth new functionalities onto printed (flexible) matter that would extend its functions beyond visually interpreted text and graphics (Documents/Presentations, Kopola et al./Technologies, Innovations and New Business Opportunities in Printed intelligence, 2007). This agenda was called *printed intelligence*, and produced by the roll-to-roll printing techniques. Besides technological developments, the interest was also on turning these technologies, processes, and methods into profitable business activities which would further act as the means to advance the generation of a new business sector (Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, p. 4; Documents/Presentations, Kopola et al./Technologies, Innovations and New Business Opportunities in Printed intelligence, 2007).

Moreover, the experts who were initially negotiated into the intelligent paper's network were tightly involved in activities related to other agendas than that of the intelligent paper. One of these was related to the printed intelligence's agenda as initiated by VTT and the other was that of Alpha during the PRINTO programme. Hence, the experts could easily pursue developments according to their own interests. It seems that the efforts related to both personal career development and economic opportunities were slowly directed towards the emerging network of the printed intelligence. The collaborative development work made together with the VTT researchers paved the way; although the activities were initially aimed at promoting the intelligent paper and later

Alpha, the joint development activities can also be seen as the efforts of VTT to ease the willingness of experts to traverse their own agenda of the printed intelligence.

To further weaken the links of the interested critical actors to other alternatives, after the closing down of the PRINTO programme, in 2006, a spearhead innovation programme was launched around the development activities made within the PRINTO programme and VTT Centre for Printed Intelligence was established as illustrated by the following quotation:

> "VTT has raised its recent strategic process 'Printed Intelligence' to the status of a VTT-wide strategic initiative and established the Centre for Printed Intelligence [CPI], I august, 2006, to coordinate and exploit the operative efforts toward our goal – 'Global Leading Innovation Centre in Roll-to-Roll Printed Intelligence'. (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, p. 4)

This centre was supposed to act as a bridge between the traditional paper and printing industry products and the ICT/electronics industry and to boost the development of a wide range of applications that could be used as the means to add new functionalities to flexible substrates, basically to paper and plastic. (Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, p. 4; Documents/Presentations, Kopola et al./Technologies, Innovations and New Business Opportunities in Printed intelligence, 2007; Documents/Magazines and news, Tuotanto ja Teknolgia, 2007). It thus aimed to become an important actor in the emerging printed intelligence markets.

4.5 Filtering the spokesperson

In the final network, all critical actors are locked into the places proposed to them and acting according to the roles set to them. The question is then, following Callon (1986a, 1986b, 1991), whether the agenda – run in the first place by the principal actor, now the spokesperson – became irreversible or fell apart. In this case, both agreements and potential betrayals distorting the functioning of the network were present throughout the study period. Similarly, many actors were trying to set agendas that deviated from each other, compelling the principal actors to continuously perform various negotiations and re-negotiations to stabilise the network around their agendas. As happened in this case, the initiator, the management of Alpha, and the initiator together with the code promoter in Beta were compelled to make a variety of movements and re-movements in order to stabilize the network around the promoted agendas. This led to a situation where a more stable network was filtering among the actors and finally divested the

formerly formed network. This relational and somewhat metaphorical word of filtering has not been previously utilized in actor-network theoretical research (or the network studies in business context). During the analysis and interpretation processes of the study, I however found it as useful word to refer the slow divesting of competing packs. It can thus be compared to the sociomaterial processes occurring during (the final stage of) translation that finally enable a sole spokesperson – 'the author' – to slowly emerge, come out, to take care of the interests of others, to speak in their name, and to render them mobile, that is, to say what these entities are, what they want and experience (see Callon, 1986a, 1986b; Callon & Latour, 1981, p. 279; Latour, 2005). This more stable network was the printed intelligence authored by VTT Centre for printed intelligence that had for years alongside with the intelligent paper been involved in these types of activities as illustrated in the following quotations:

> "VTT has investigated and developed technologies for printed intelligence, electronics and optics and their applications from 1999 with a vision that *'electronics from inks', manufactured by printing like 'continuously running' roll-to-roll (R2R) methods, enables cost efficient integration/embedding of simple intelligence everywhere.* We are filling the gap between traditional paper and printing industry products and ICT/electronics industry…" (Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, p. 4)

> "VTT strongly believes in the emergence of new printed intelligence markets and therefore, we continue to strongly contribute to the development of technologies, solutions and applications in this field. We are strong believers in the power of collaboration and relentlessly working to build stronger and stronger consortia both within research and industry. Ultimately the printed intelligence markets are being driven by new start-ups and spin-offs, as well as existing enterprises looking to expand their markets and add value to their products. […] VTT wants also to proactively participate in closing the existing gap between technology and market application and business needs, and to more actively help drive the transition from laboratories to commercial solutions. For this purpose VTT is establishing a printed intelligence commercialisation program (starting in 2010). The aim of this program is to increase business developments efforts aimed at commercialising new innovations and creating new business." (Documents/Research publications, VTT/Research and development activities in printed intelligence 2009, p. 6)

In Table 19 I summarize in an illustrative manner the starting point of this 'final' phase of the network formation of the intelligent paper, thus, the situation before VTT Centre for Printed Intelligence gradually divested the intelligent paper's network. What should be pointed out here (discussed in more detail in the next paragraphs) is the fact that this divesting did not mean that the network of the intelligent paper fell apart for good. Rather, I argue that it was revitalized.

Table 19. Filtering the spokesperson

Principal actors	Agenda	Interested actors (enablers)	Reluctant/hostile actors (inhibitors)	Silent/Neutral actors
VTT Centre for Printed Intelligence	The printed intelligence as the mediator between the technological innovations' development and various industries	The technology developers (e.g., VTT researchers and the researchers near VTT, such as the researchers in certain universities) The investors The PRINTO programme together with its human and nonhuman actors (e.g., technology developers, universities, patents, test results, research reports, research publications, and Pico) The method of roll-to-roll processing (including processes, tools and devices inside that method) The methods to fabricate intelligent paper (incl. paper-making, the integrated embossing and the roll-to-roll hot embossing)	The intelligent paper together with its (human and nonhuman) actors (e.g., the initiator, the bridge builder, the experts, the method of hot embossing, inks, patents, paper, test results, simple printed devices like the diffractive gratings, active printed devices like the InkByte)	-

In 2006, while Alpha (and later Beta) struggled with the challenges emerging from the fact that the critical (re-)identified and (re-)enrolled actors were not yet following the defined and redefined agenda, VTT Centre for Printed Intelligence was established (see the quotation at the end of the previous chapter). It connected many actors together. Thus, technologies that had been to some extent previously developed separately from each other, but which were enabled by the printing technologies, especially continuously running roll-to-roll methods, were combined. This enabled VTT Centre for Printed Intelligence to more effectively promote the economic exploitation of research results of the applications developed by the technology developers and the experts of Alpha over the years with varying business success.

The enrolment strategy utilised for locking the technology developers (including the initiator and the bridge builder) of the intelligent paper to the printed intelligence's network was mainly based on seduction. The experts of the intelligent paper, later Alpha and Beta, were thus gradually enrolled in the printed intelligence's network by mainly letting these actors closely work with the printed intelligence's technology developers and by that way diminishing their interest in other alternatives. This strategy was further strengthened by these actors' deep interest in their personal career development that the collaborative activities further enhanced. The following quotations are examples of this enrolment strategy:

> "VTT has for several years been developing hot embossing technology for different substrate materials, lacquers and inks for [Alpha]. Moreover, the work also includes the development of hot embossing tools and online quality

monitoring systems for the optical effects." (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, p. 27)

"VTT produces…they have devices that no one else has, so they can run short series. They also have manufacturing devices and analysis devices; they can analyze results better than others and probably that is the idea and then there are different instances; so, inside VTT there may be somewhere something made, was it 14 different persons that were working in one project; so, there are also little projects; it is not just one person but they themselves see that they can create, they can make; they have a larger number of persons to do that thing. And then, these [projects] are also taken care of by different people depending on its phase; many persons from us may be in contact with VTT, it is not just one person." (Interview data/the management of Alpha, 16.1.2006)

Different kinds of patents (Documents/Other, Patents related to core technology, 2011), yearly research activity reports (e.g., Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, 2008, 2009) and presentations (e.g., Documents/Presentations, Kopola, 2005a, 2005b; 2006, 2007), just to name a few examples that these developers produced while working together throughout the study period also ensured the acceptance of the actorial role proposed to them by VTT and later VTT Centre for Printed Intelligence. Thus, although these intermediaries were initially introduced to a different network, which was the network of the intelligent paper, Alpha, and Beta for advancing the idea of imprinting optics and electronics onto paper, they can also be considered as one enrolment strategy for VTT and later VTT Centre for Printed Intelligence. These intermediaries weakened the links between the interested ones and the others so as to gradually seduce the technology developers from the intelligent paper's side to join the printed intelligence's network.

Some investor-owners and investor-partners funding the operations around the intelligent paper continually doubted the worth of the agenda promoted by the initiator and later redefined by the management of Alpha as well as the initiator together with the code promoter. However, throughout the study period it was VTT and later VTT Centre for Printed Intelligence that showed continual (and in some cases silent and punctualized) interest in accepting the actorial roles of investor-owner and investor-partner in the network of the intelligent paper. This situation did not change after the printed intelligence divested the network of the intelligent paper. Instead, VTT Centre for Printed Intelligence was still actively funding the operations around the printed intelligence. Also, by allowing its members to participate widely in printed intelligence development activities, VTT Centre for Printed Intelligence continually promoted a new business sector creation. The following quotation is an example of these activities (see also the second quotation at the beginning of this chapter):

> "Since its inauguration in 2006 VTT's Center for Printed Intelligence (VTT/CPI) has seen growth of over 40 % in volume. In 2007 alone our activities totaled 75 manyears of R&D labor. In addition increased VTT investments in own initiated basic research, innovation and IPR creation, we made remarkable new openings in publicly funded research. […] Significant steps were taken also in the commercialization of new printed intelligence technologies, through the founding of N, VTT's first start-up company in this field and with the first commercial roll-out of a printed intelligence product on the market by a long-standing customer. The printed intelligence R&D infrastructure at VTT was expanded with various equipment installations and facility upgrades, the most important being the new pilot machine infrastructure in Oulu. […] Within VTT there are now 12 knowledge centers from 5 different knowledge clusters, which are coordinating CPI-projects. […] At the national level VTT/CPI is currently coordinating or a major contributor in several key research projects together with major universities and a portfolio of over 20 partner companies. At the European level VTT/CPI is one of the most visible contributors in the EC/FP7 […] In 2007 VTT/CPI also joined both the Organic Electronic Association and Plastic Electronic Foundation." (Documents/Research and development activities in printed intelligence 2008, p. 4)

This deep commitment of VTT and later VTT Centre for Printed Intelligence to continuously promote the agenda of the printed intelligence also acted as the main enrolment strategy for other investors and investor-partners to join the printed intelligence's network (including also those that had previously invested in the intelligent paper, Alpha, and Beta). VTT and later VTT Centre for Printed Intelligence had also previously collaborated with several private and public investors as well as with private companies. These parties were enrolled to the network firstly by counting on their silent consent and the previous relationships established through letting the humans occupying these instance work together and be regularly in touch with each other. Secondly, the enrolment was also facilitated by continuously convincing them with the help of various intermediaries (e.g., scientific papers, research publications and reports) that printed intelligence is worth investing in. Printed intelligence could in fact provide good prospects in the near future from the point view of business and society alike (Documents/Annual reviews and financial statements, VTT overview 2007, p. 29, 2008, p. 8, 2009, pp. 31–32; Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, 2008, 2009; Documents/Research publications, Södergård et al., 2007; Documents/Research Publications, Lindqvist et al., 2008; cf. Interview data/The 'initiator', 7.11.2005; Interview data/The initiator and the bridge builder, 29.5.2009).

The question of how to bundle the critical (nonhuman) actors of the intelligent paper and consequently Alpha and later Beta to the network of the printed intelligence was

basically related to the fabrication of the intelligent paper. As long as the optics and the electronics could be fabricated by using the roll-to-roll processing, the intelligent paper and via that many other actors could and should be negotiated into the network of the printed intelligence. This technique was seen among VTT researchers as the only method capable to fulfil the need of the printing industry to increase its production volumes. It was also anticipated that this method would easily accept its actorial role and therefore could also be easily and at low cost integrated into the existing production processes of companies operating in the field. (Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, p. 7)

Consequently, the enrolment of the fabrication method of hot embossing was critical. To accomplish this, the method needed to accept roll-to-roll processing. This however required massive modifications to be made to the embossing method itself. Although the method of integrated embossing developed in Alpha's network (see Figure 8) was a response to the roll-to-roll processing proposed by VTT and its researchers in the first place, these modifications to the basic method of hot embossing (see Figure 6) can also be considered as initial enrolment strategies for VTT and later VTT Centre for Printed Intelligence to lock the hot embossing method to the printed intelligence network (as one fabrication method among others in the fabrication of printed intelligence), as it showed gradual interest in joining it.

Figure 10 illustrates this fabrication method which was finally enrolled to the printed intelligence's network. Unlike in integrated embossing, in this method of roll-to-roll hot embossing two rollers are used: the hot embossing roll and the pressure roll. Both rolls are solid and stable. The pressure roll is of a softer material. The patterns are processed by using a mould, which imprints patterns to a web. The rolls are heated and pressured together, and with the help of a mould the patterns are created onto the web. (Documents/Presentations, Kopola et al./Technologies, Innovations and New Business Opportunities in Printed intelligence, 2007; Documents/Research Publications, Varjus, 2012, p. 17)

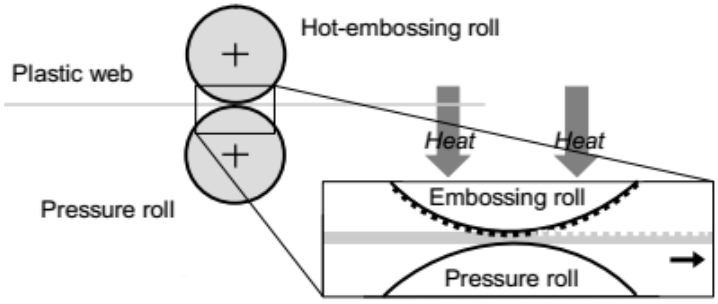

Figure 10. The method of roll-to-roll hot embossing

(Source: Documents/Presentations, Kopola et al./Technologies, Innovations and New Business Opportunities in Printed intelligence, 2007)

Henceforth, this method was a (potential if not actual) fabrication method for various printed intelligence applications which included optical, mechanical and electrical structures (Documents/Research publications, VTT/Research and development activities in printed intelligence 2006, 2008, 2009) and not just the method for fabricating the intelligent paper. The following quotations are examples of this actorial shift:

> "…hot embossing is indeed a general technology. VTT has now been making microfluidistics which are located in biosensors; VTT has made these things by the method of hot embossing and the method of hot embossing will probably start to become used in these electronic structures as well. In a way this core technology has many applications. While in Alpha we searched for the optical thing, now its' application possibilities have kind of expanded." (Interview data/The initiator and the bridge builder, 29.5.2009)

> "Hot embossing is a general production technology that can be used for many different end uses, including to produce optical effects on a nanoscale, to make channels for microfluidistics on a microscale and to make surface forms on packaging on a macroscale. Nanoscale hot embossing is similar to nanoimprinting technologies. […] The difference is that embossing is done on surfaces of several square meters, while nanoimprint is typically applied to areas measuring a few square millimeters. […] Nanoimprint aims to make top-quality nanoscale electronic structures. Roll-to-roll embossing is used in applications where larger surfaces with structures of a lower quality are acceptable." (Documents/Research publications, VTT/Research and development activities in printed intelligence 2009, p. 20)

> "VTT wanted to show that the embossing technique can be integrated into a printing machine. Three items are important in reaching this goal: solution-based protective coating, embossing sleeve and process control. […] Embossing can be integrated into a printing line so that high volume low-cost production is

possible." (Documents/Research publications, VTT/Research and development activities in printed intelligence 2009, p. 21)

Further, VTT and its researchers imagined that future products related to the technological developments spurred within the printed intelligence's network would either simply entertain and impress the users (i.e., the diffractive gratings) or act as more interactive means to for instance help the logistics of packages and to monitor the quality of those products (i.e., the active devices studied and developed from the PRINTO research programme onwards such as the InkByte) (Documents/Research Publications, VTT/Research and development activities in printed intelligence 2006, pp. 7, 10–11). The enrolment of these actors to the printed intelligence's network occurred in a in a similar way as the hot embossing method – by modifying and adjusting the components around it and by letting VTT researchers closely work with Alpha's and Beta's experts. Consequently, whereas for instance an online quality monitoring system and different kinds of lacquers and inks were developed in order to initially promote the agenda of the intelligent paper later redefined by Alpha's management and the initiator together with the code promoter in the case of Beta, these (development) activities can also be considered as enrolment strategies for VTT and later VTT Centre for Printed Intelligence to advance the agenda of the printed intelligence.

As an example, just like with plastic foils in the early network formation phase, the diffractive gratings that do not vanish if rubbed with a finger were finally integrated into the printed intelligence's network. This was only possible after forcing massive modifications onto the surface of the paper so that it accepted the fabrication of optics and electronics onto it. This was done at a later stage, approximately in 2008, after the operations of Alpha and Beta were abandoned and VTT Centre for Printed Intelligence managed to cajole the initiator to join the network of the printed intelligence. Then, the initiator together with a few other technology developers developed various kinds of coatings and utilised a special laser device built in VTT in the tests to demonstrate the applicability of these new actors to the network of the printed intelligence. Following quotation illustrates these events:

> "Because the nanoscale optical structures are sensitive, a special protective coating is required. Several variations of the basic coating formulations were prepared and tested. […] To control the embossing process, some measurements are required. […] The embossing pressure is measured on both ends of the cylinder and the temperature is measured near the surface of the cylinder. The quality of the embossing is analysed by using test gratings on the edges of the wed. These are measured by a laser device developed at VTT. […] The clear optical effects are destroyed if rubbed with a finger. When the protective coating was applied, the surface withstood rubbing." (Documents/Research publications, VTT/Research and development activities in printed intelligence 2009, pp. 20–21)

Although they received promising results demonstrating the diffractive gratings' (i.e., optical effects such as the product D launched to the markets in 2006) willingness to accept these new actors to be included in it (i.e., the protective coatings can be applied either before or after the hot embossing), the technology developers yet had difficulties in enrolling the protective coatings to the network. Difficulties emerged when utilising different materials in the fabrication of the diffractive gratings. (Documents/Research publications, VTT/Research and development activities in printed intelligence 2009, p. 21) Despite these challenges, these activities that aimed at locking diffractive gratings into the printed intelligence's network were, however, further strengthened by applying one patent (Documents/Other, patents related to technology development, 2011) and by contacting potential offshore customer-partners (Interview data/The initiator and the bridge builder, 29.5.2009). These partners showed interest in the ongoing development activities (compared to the existing solution launched to the market in early 2006) around it and consequently, were interested in joining the printed intelligence's network (Interview data/The initiator and the bridge builder, 29.5.2009).

Whereas the potential customers and customer-partners were contacted already at an early stage in the process of the network formation, they continuously doubted whether the intelligent paper, Alpha, and finally Beta should be taken seriously and considered as the main potential direction for future business operations. In the case of the printed intelligence, VTT and later VTT Centre for Printed Intelligence were from the beginning acting as the main mediator between the new technology development and various industries that were interested in the development activities in the name of the printed intelligence.

Based on its strategy to spur business from its core developments (and thus to create printed intelligence markets in which it could act as a principal actor/author), VTT and later VTT Centre for Printed Intelligence started to gradually direct these developments toward being considered as a certain technology or bettering the more service-oriented transfer projects that could be easily harnessed by potential customers. This was a common path that it had previously taken with various other technological developments. In other words, it was common for VTT to be involved in R&D activities with large companies when they needed it. In this case, they considered that this type of operations would advance the agenda of the printed intelligence, too. At the end of the study period, in 2009, these activities concerning the potential customers as parties to whom different kinds of transfer projects could be handed to, at least momentarily silenced the mutiny among them. Following quotation illustrates this interpretation:

> "… this ventures organization was launched in VTT in 2006. At that time, there was an idea that is not only about selling the researcher's time but also about a kind of spin-off business activity and patents licensing. And now this year, an idea of services has emerged. Different kinds of more productized services are

conceptualized of which a kind of technology transfer project could be one. And again, people have started to think about the possibility of a firm related to hot embossing. Well, if someone wants to do that, be my guest, I will not stand in the way. However, the way I see it, based on my experience with these couple of firms, there should really be an existing customer. In Finland, there should be an existing customer for business to work. Finland cannot be compared to for instance England where you can goof around for ten years, throw money away without any customers. No, there has to be a customer and the product. Like in hot embossing that we have been working with. It is not yet ready enough; it is not sufficiently advanced. If one could get one customer. But a firm needs many customers. So, is it such a niche thing that VTT can offer as a technology transfer project; there are a few projects per year. But if there were tens of projects per year, perhaps then a firm could be viable. It could survive. I feel that it is always a problem in firms when so many experts are needed and then the burn rates are unreasonable. Even if only a few things need to be done, an expert is needed in every case. Then, a VTT type of organization where people can be involved in other projects and gathered together when there is a need to do so. This could be a more reasonable mode to operate." (Interview data/The initiator and the bridge builder, 29.5.2009)

The bridge builder who had been induced to VTT Centre for Printed Intelligence after the closing down of Alpha together with a few other technology developers (including the initiator) however continuously worried that neither in the firm, national, nor international level the value of the customer and technologies' commercialization was recognized enough over the core technologies' development. The initiator joined in this line at the later stage, after the experiments of two spin-offs. Following quotations are examples of these concerns (see also the above quotation):

"… I have strongly promoted the issue that we should have enough of our own designers; that we do not only look at the technology but have the ability to speak from the use perspective and the ability to direct the customer in that; to know the technical limits and sometimes when wild ideas come up, to channel that, in the sense that "here is the realism". It is one of our valuable services; all our last year's cash flow actually came from design services; it is one way that helps us to create relationships, name, quality and a path for the technology which is nevertheless our core…" (Interview data/The bridge builder, 31.1.2006)

"It feels that when you look at VTT; it runs lots of EU projects; there are millions of euros involved; the share of VTT is many millions and then there are other partners who have millions. So, if we compare… or start negotiating about productizing our results and then to think about where one could get the 100 000 euros, 200 000 euros to invest in it in order to productize. At first you conduct research and use many millions yet somehow it feels that the lesson is, as I have also previously been arguing that if a couple of millions are devoted to research and then a couple of ten millions to productization, then when you run a big

business there will be hundreds of millions money in there. We have it somehow the other way round, we invest lots of money to the research and then we have no money to run the business." (The initiator in the Interview data/The initiator and the bridge builder, 29.5.2009)

"… we have to suffer from a disadvantage compared to other research institutes because they have spin-off activities. With these big instances, things progress but it is so slow. We have managed to find big internationals, but it is slow. Compared to the Cambridge region, the Dresden region, and increasingly in the U.S. too, there are spin-offs and they are hungry; they advance the development with great speed. […] In Europe, the current situation is that there is not much venture capital available, exceptions can be found, there are business angles who are interested, but the model has been that the governments in Europe are starting to support these. […] I see it as a way to build up the infrastructure; they engage in building grounds for spin-offs to operate. Cambridge and Dresden are starting to be the areas in our field where governments have made investments and now it can be seen that firms are coming there. They are competing in a market-based economy already. They [the governments] have built grounds from which these firms can start advancing. It is interesting to see how Finland can compete in this development; we have been first-movers, we have been among the first experts, now we should transform that into product and cash flow." (The bridge builder in the Interview data/The initiator and the bridge builder, 29.5.2009)

5. DISCUSSION

This chapter summarizes the empirical findings and reflects upon them. First, I will pinpoint how the network studies in business context have lacked theorizing about heterogeneity in terms of sociomateriality and power plays occurring while forming the network of technological innovation. These inter-related key outputs of this study are discussed in more detail by regarding the case of the intelligent paper as a process of translation and as a sociomaterial network trajectory. As a result, these steps enable providing discussion on how they contribute to the networks as processes view generally and the strong process view to networks specifically.

5.1 Interpreting the intelligent paper's case

In studying the network formation of technological innovation, I have engaged myself with a stream of research in which the focus is on the one hand generating a reality of the lived experiences and on the other hand, a representation of that reality (Latour, 2005; Law, 2004). This reality in terms of network formation of technological innovation called the intelligent paper has not existed 'out there' to be captured by a researcher. Instead, the reality of the intelligent paper has been enacted by those who have engaged in its network, including also myself (Law, 1991b, 2004).

To picture this reality, I have generated, analyzed and interpreted 708 pages of research data. Multiple times I have asked myself the questions of: What is this a case of? What is it that I am actually describing and analyzing? This process of generating questions and answering them is an inherent part of any research process and a rather typical way to solve the mystery in research (Becker, 1992), also when engaging in case research (Eisenhardt, 1989).

Starting from a 'thing' of the intelligent paper and stepping into its development 'in medias res', thus while it was developed (Latour, 2005, p. 196), I began to ask questions about what it all means. How can the analysis of actors involving both humans and nonhumans as well as their disagreements be interpreted? Through interpreting this analysis by heuristically utilizing the four-phase model of Callon (1986a) added with certain relational and somewhat metaphorical words of pack and filtering, I was able to demonstrate multiple packs and multiple dialectical movements of actors in their packs while forming the network and consequently the technological innovation. But what is

this interpretation about at a more general level? As I delineated the research gap in the literature on networks in business context (i.e., social networks, business networks and entrepreneurial networks), I noted that this literature was lacking theorizing about heterogeneity in terms of sociomateriality and the continual power plays occurring while forming the network and consequently the technological innovation.

To fulfil these gaps, the actor-network theoretical view to network formation of technological innovation was adopted. This research stream does not treat the network as a predefined set of actors and relationships which connect them (Fombrun, 1982), later extended to also consider the lack of relationships between the actors (Brass et al. 2004, p. 795). Instead, it sees networks as sociomaterial processes; as isomorphic heterogeneous networks made up of multidimensional and constantly – not necessarily evolutionarily or teleologically but certainly dialectically – evolving entanglements of actors (both humans and nonhumans) and their interconnected relationships (e.g., Latour, 1999, 2005; Law, 1999).

More specifically, conceptualization of the network formation of technological innovation as the process of translation has enabled to deconstruct dualisms between human and natural phenomena, micro and macro, and content and context. It has also allowed introducing certain relational and somewhat metaphorical words (i.e., pack and filtering) within the network formation of technological innovation. The emphasis has thus been on continually unfolding packs (heterogeneous networks) and consequently continually unfolding sociomaterial processes; both humans and nonhumans are active players in the building of the network and consequently the technological innovation. I have also noted (in line with actor-network studies) that as the actors engage in these activities, their size gets determined by the influence they have on the activities and entities around them. The power of actors is thus generated and maintained in a relational and distributed manner and 'measured' via the number of entities networked (Latour, 2005). Since the structuring of power plays (including filtering) takes place in these packs (heterogeneous networks), these key outputs of this study are linked.

During next paragraphs, I provide a reflection of these key outputs of this study. Firstly, I compare the empirical findings to the four-phase translation model of Callon (1986a). In doing so, I describe and analyze the case of the intelligent paper as the process of translation. Then, I discuss the dynamics of the network formation of technological innovation through the sociomaterial network trajectory and how it broadens the current understanding of the networks as processes view (Ahuja et al., 2012; Halinen & Törnroos, 2005; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock & Coviello, 2010) generally and the strong process view to networks specifically (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012).

5.2 The intelligent paper's case as the process of translation

This chapter discusses the results of the activities investigated in this study. It describes and analyzes the intelligent paper's case as the process of translation during which some actors succeeded in pursuing a character and some managed to even acquire the status of an 'author', while others remained the objects of some actors' actions (Callon 1986a, 1991; see also Czarniawska & Hernes, 2005, p. 9). The sizes of the actors in this narrative resulted from a long struggle of sociomaterial processes occurring during network formation of technological innovation. The more entities (such as relations, modes of thoughts, habits, and objects) one actor could lock into their places, the more power that actor had in the network (Callon & Latour, 1981). The power of actors was therefore generated and maintained in a relational and distributed manner and 'measured' via the number of entities networked (Latour, 2005).

Basing heuristically on the four-phase translation model by Callon (1986a), the network of the intelligent paper was identified to form through four distinct phases as illustrated in Figure 11. These phases depicting the network of the intelligent paper are in bold font and presented at the top of Figure 11 as follows: (1) setting the agenda, (2) forming the pack through performing various negotiations, (3) potential betrayals and (4) filtering the spokesperson. The dashed arrow below these four main phases illustrates the overall direction of the network formation. In particular, the arrows depict the network formation in the case of the intelligent paper between the mid-1990s and 2009.

Hence, the network formation of the intelligent paper started in the mid-1990s when the initial agenda was set. Then, it proceeded through multiple sub-phases of pack formations and agenda settings affected by multiple potential betrayals throughout the way to the final filtering of the spokesperson, the 'author', in around 2009. The spokesperson found the places for critical actors and managed to keep them there. In this case this 'author' was the printed intelligence; it managed to suppress the others and to speak in their name.

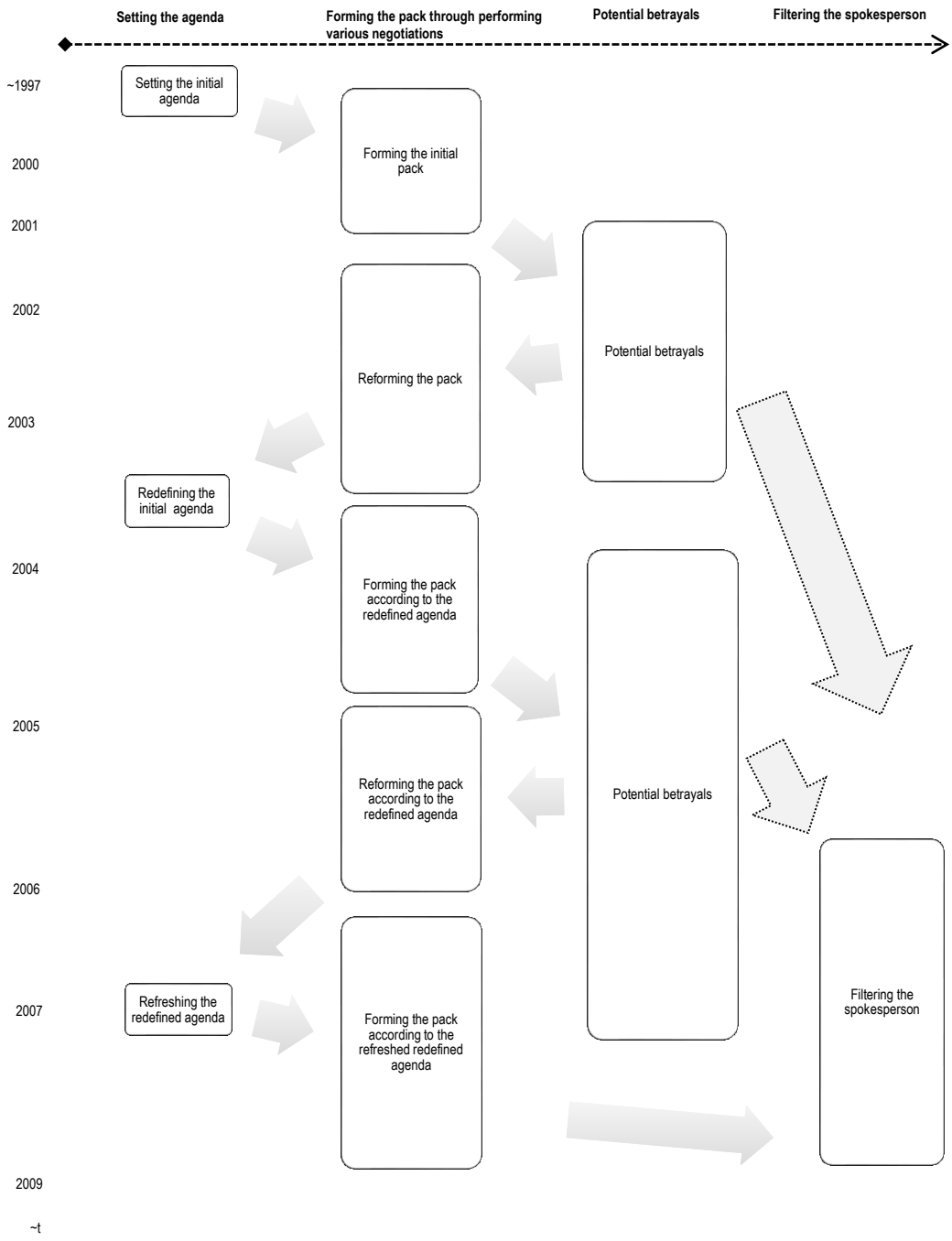

Figure 11. The network formation of the intelligent paper ~1997–2009

In this study, the original four-phase translation model by Callon (1986a) acted as a point of departure while analyzing and interpreting the network formation of the intelligent paper. However, while Callon (1986a) in his article pointed out four main phases of translation, the phases I identified are slightly different from the original model. They are different in three ways as illustrated at the top of Figure 11: 1) the phases of forming the pack and performing various negotiations are bound together, 2) multiple sub-phases are identified in the phases of agenda setting and forming the pack through various negotiations, and 3) the phase of filtering the spokesperson has been separated into two distinct phases, namely the phases of potential betrayals and filtering the spokesperson.

Additionally, I utilized certain relational and somewhat metaphorical words that have not been previously used in actor-network theoretical accounts (or the network studies in business context) while providing the analysis of the network formation of the intelligent paper, namely the words of pack and filtering. The first word (i.e., pack) referred to heterogeneous networks equipped entanglements of humans, nonhumans, and their interconnected relationships. It was thus compared to 'ally' (Callon, 1986a) or 'group' (Latour, 2005) within the process of translation. The second word (i.e., filtering) referred to the slow divesting of competing packs. It was compared to the sociomaterial processes occurring during (the final stages of) translation that finally enabled a sole spokesperson, 'the author' (the printed intelligence), to slowly emerge, come out, to take care of the interests of others, to speak in their name, and to render them mobile, that is, to say what these entities are, what they want and experience (see Callon, 1986a, 1986b; Callon & Latour, 1981, p. 279; Latour, 2005). These words enabled me to sustain the study's ontological and epistemological stances; to become sensitized to already existing network formations within the network formation of technological innovation without the risk of confusion with the studied actors' own idioms. They thus allowed me to focus on 'things' (involving humans, nonhumans, and multitude of intermediaries) already created as well as processes already taking place but of course not forgetting that they had not always been there. Using these words, hence, I was able to emphasize organized collective actions, tensions emerging within a certain pack and between competing packs, and mechanisms of network (re)production, more specifically continual power plays occurring while actors are engaging in the network formation of technological innovation.

Firstly, when engaging with the case of the intelligent paper, I found that it was difficult to clearly separate the phases of forming the pack and performing various negotiations (Callon 1986a) from each other. As a result, I made the decision to bind these two phases together with an emphasis on empirically demonstrating the continual contradictory movements within the phases rather than the actual moments when the actors are finally locked. Consequently, some of the sub-phases I identified in this study are debatable; they could be presented as separate phases one after the other (i.e., the

phase of forming the pack preceding the phase in which the actors are actually locked into places). Both phases involve actions through which actors try to stabilize the identity of other actors according to the agenda which does not necessarily lead to pack formations. However, I solved this pitfall by focusing on the continual reconfigurations and the contradictory movements occurring while forming the network of the intelligent paper – an aspect somewhat neglected in the networks as processes view (Halinen & Törnroos, 2005; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock and Coviello, 2010; see also Aarikka-Stenroos et al., 2014).

Secondly, the multiple sub-phases of 're' are in this study identified within the two first main phases of the intelligent paper's network formation as illustrated in Figure 11 and summarized in Figure 12, namely redefining, re-forming, and re-performing.

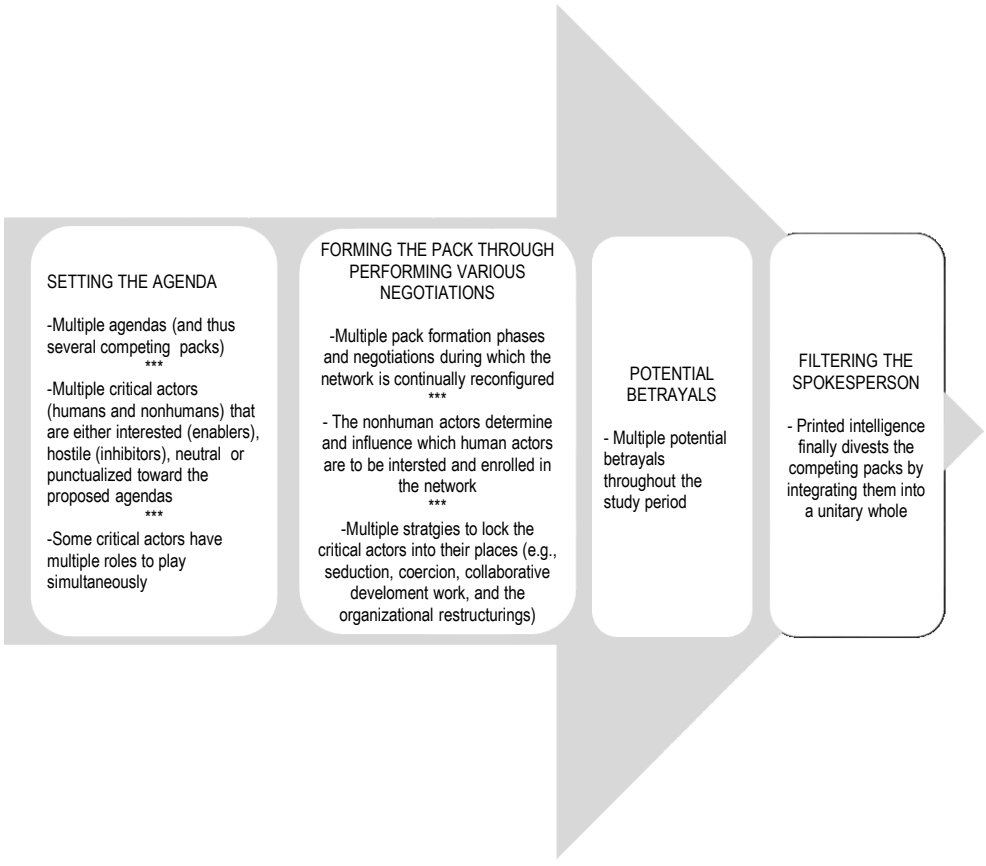

Figure 12. The case of the intelligent paper as the process of translation

Three different sub-phases in the main agenda setting phase were identified in this study (and thus several competing packs). Within these sub-phases (more specifically within

the first and the third sub-phase), multiple agendas (and consequently several competing packs) were also identified. The case of the intelligent paper thus involved no single agenda, that is, no one pack, that is, no one heterogeneous network, but several agendas and consequently several packs confronted each other throughout the study period. These packs involved several developers and decision-makers, and a multitude of materials.

Consequently, the agendas and consequently packs were filled with human and nonhuman actors that I classified as interested (critical actors which accept the agenda), hostile (critical actors which inhibit/hinder the agenda) or neutral (critical actors that do not make a difference to the agenda, or better saying, they serve only a certain function). I also further classified these actors as punctualized, if they were serving a specific function. These actorial shapes changed on a continual basis, pinpointing simultaneously actors' interconnected relationships to each other; thus how their actorial shape at certain time point hindered and/or enabled others to acquire their own actorial shapes (Law & Callon, 1992) while engaging in the activities of the network formation of the technological innovation.

With respect to the second phase (i.e., forming the pack through performing various negotiations), five distinct sub-phases were identified. During these phases, the network of the intelligent paper was continually reconfigured and transformed. Potential betrayals in which certain actors started disagreeing on the actorial roles given to them took place both within the agenda setting and forming the pack phases. Thus, as a result of these potential betrayals, some actors (at first the initiator, later the management of Alpha and the initiator together with the code promoter as authors of Beta) were compelled to continually negotiate and re-negotiate with the critical actors to stabilize the network of the intelligent paper. These negotiations involved seduction (related especially to the technology developers' personal career development opportunities), pressuring (e.g., the modifications made to existing nonhuman actors), the introduction of new critical actors (that in turn enforced re-negotiations with the already enrolled ones), the organizational restructurings, and the collaborative work between the technology developers enrolled to the intelligent paper's network (which actually continually strengthened another network which finally filtered out and divested the intelligent paper's network, namely the printed intelligence). This pack was convergent; despite its heterogeneity, the activities of the critical actors and their agendas fitted together. The common denominator was roll-to-roll processing, upon which all the critical actors agreed, and consequently took for granted (i.e., black boxed). The competing packs (i.e., the intelligent paper including Alpha, Beta and the paper-maker) did not however cease to exist. Rather, they were revitalized by integrating them into this more coherent network.

Together these empirical observations extend the view that technological innovation should be located in the networks of multiple humans and their relationships (e.g.,

Howells, 2005; Huggins, 2010; Håkansson, 1987; Håkansson & Waluszewski, 2002; Raesfeld et al., 2012; Rampersad et al., 2010). The case of the intelligent paper illustrates that the imagination of the humans intertwined with the allowance of the technologies to be treated as multiple (Latour, 2005, p. 116) is actually the locus of technological innovation; they together determine the boundaries of the network of technological innovation (cf. Halinen & Törnroos, 2005). As long as new ideas were brought up also new actors emerged which were either neglected or acted upon. This continued throughout the study period until one pack (the 'author') – the printed intelligence – was finally filtered; the one who slowly managed to lock other packs (other heterogeneous networks) into their places, thus rendering them mobile.

My observations also provide support for the argument that human actors have deviating motives and interests for joining the network that is being formed (e.g., Ahuja, 2000a, 2000b; Ahuja et al., 2012; Oliver, 1990). Perhaps more importantly, however, my empirical results highlight the role of nonhumans in the network formation of technological innovation. Nonhumans should not be treated as mere instruments. In the case of the intelligent paper, they had a determining role in contacting and enrolling the critical (human) actors in the network. They provided both possibilities and challenges for the principal actors to strengthen their agendas and lock the other critical actors into their places in the packs. Also, together with the humans they both enabled and eroded the formation of the power bases for those in charge, temporarily both stabilizing and biasing the network during its multiple formation phases.

Thirdly, whereas Callon (1986a) has bundled the third and fourth phase together, arguing for the irreversibility of the network formed, I have presented them as two separate phases as illustrated in Figure 11 and summarized in Figure 12. Firstly, in the potential betrayals phase the critical actors engage in questioning their actorial roles and can potentially – but not necessarily as demonstrated in this study – distort the network formation of technological innovation. Secondly, in the filtering of the spokesperson phase, one sole actor finally gets filtered and manages to build an irreversible network.

With respect to the first, the multiple actorial disagreements potentially distorting the network formation of the intelligent paper affect the network formation in terms of pack formations (i.e., the sub-phases in the main phase of forming the pack through performing various negotiations) and the sub-phases identified within the agenda setting. The network formation of the intelligent paper was thus almost from the beginning continually pressured by certain critical actors that could not be neglected. The initiator, and later the management of Alpha and the initiator and code promoter as authors of Beta, had to act upon them. These disagreements concerned to a large extent the multiplicity of roles (especially in relation to resource provision) played by single actors.

Consequently, constant negotiations were performed to settle the disagreements of who should be considered as the ones delivering non-monetary (i.e., competencies,

knowledge as well as tools and devices of many kinds) and monetary resources to the network of the intelligent paper. Also, there were also disagreements on who should have a more punctualized role (Law & Callon, 1992) to play in the network of the intelligent paper (especially regarding finance), and who should ultimately speak on behalf of the network (the initiator, the management of Alpha, or the initiator together with the code promoter in Beta). These negotiations changed the network of the intelligent paper and its critical actors on a continual basis and compelled the principal actors to negotiate and renegotiate with the critical actors so as to keep them in their places.

Regarding the latter, the constant turbulence surrounding the network formation of the intelligent paper throughout the study period resulted in a competing pack slowly taking over, to filter among others. The three dashed arrows (two from the potential betrayals and one from the final pack formation phase) in Figure 11 toward the filtering of the spokesperson illustrate this viewpoint, summarized in Figure 12. In this study, this actor was the printed intelligence. It was able to legitimize the relevant actions and transform the critical actors and intermediaries into a unitary whole. This divesting did not however result to the breaking dawn of the network of the intelligent paper formed in the first place. Instead, it was revitalized by 'merging' it to a more coherent network of printed intelligence. This observation gets support from the recent empirical actor-network studies (Giesler, 2012; Nicolini, 2010; Schneider et al., 2012).

To conclude, the case of the intelligent paper as the process of translation provides a multifaceted and empirically grounded understanding of the network formation of technological innovation which full of noise and disturbances. In doing so, it engages in developing the issue of a process within the network studies in business context (Ahuja et al., 2012; Halinen & Törnroos, 2005; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock & Coviello, 2010) generally and the strong process view to networks specifically (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012). It thus lays grounds for not only approaching the network formation of technological innovation as a holistic and over time unfolding process. Rather, it urges to see the network of technological innovation as continually unfolding packs equipped with multiple humans, nonhumans and their interconnected relationships (thus continually unfolding heterogeneous networks). This network (involving multiple packs) forms continually over time – not necessarily evolutionarily or teleologically but certainly dialectically – as these packs are questing for a character. As a result, power relationships between the packs are continually enacted/produced before one pack manages to divest them by suppressing the other packs and by speaking in their names. In the case of the intelligent paper this pack was printed intelligence. This speaking over the other packs does not however mean that the pack formed in the first place would fall apart. On the contrary, it can be revitalised by integrating it to a more coherent pack as happened in

the case of the intelligent paper. I open up this dynamics in more detail during the next chapter, while I present and discuss the case of the intelligent paper as the sociomaterial network trajectory.

5.3 The intelligent paper's case as the sociomaterial network trajectory

In reflecting upon the complexity of networks in business context (from the viewpoint of business networks), Halinen and Törnroos, 2005, p. 1287 have stated: "If it is accepted that business networks are, at the same time social, technological, economic and political in character, does it then make sense to study only one aspect of a network at a time to master network complexity? The answer to this question from the actor-network theoretical viewpoint is no. It makes no sense. The complexity involved in the network formation of technological innovation from the actor-network theoretical viewpoint cannot solely be reduced to structural complexity. It is not enough to only describe several human actors and several links that together constitute the network of technological innovation (structure). Nor can one only consider network embeddedness connoting the human actors' positions in the network, their relationships and (inter-)dependence on each other, thus describing what flows through and between the actors' ties (relationships). Rather, both of these aspects together with the nonhumans (and their interconnected relationships to each other and to humans) should be taken into account. Also, the efforts should be put in scrutinizing how they *together* participate in the network formation of technological innovation. I argue that this is a way to holistically and process driven manner depict the network formation of technological innovation as a real-life 'system', which is by definition 'social, technological, economic, and political in character' (cf. Halinen & Törnroos, 2005).[39]

To scrutinise more closely this argument, I regard the intelligent paper's case as the sociomaterial network trajectory. It is the opposite of rather linear network trajectories constructed from the network studies in business context during which a technological innovation gets construed in the hands of people who join the innovation development activities for opportunistic reasons and who bring their past relationships into the network, striving for better innovation performance (through their embedded, inter-dependent inter-organizational linkages). Instead, it follows the premises of actor-

[39] Although neglecting the aspect of sociomateriality emphasised here, this argument gets a support from Slotte-Kock and Coviello (2010, pp. 49–50). In their discussion, the researchers prompt to study network processes through a multifaceted lens; a lens which enable integrating multiple theoretical perspective in one study.

network theory. It involves complex and continuously unfolding socio-techno-economic-political processes aimed at future profit during which heterogeneous elements are bound together on a rather temporary basis through the interconnected actions of multiple actors. It is thus a trajectory that emphasises heterogeneity – networks are continually unfolding sociomaterial processes involving entanglements of humans, nonhumans and their interconnected relationships – as well as the continual power plays of actors as they engage in the activities of a network formation and consequently in that of a technological innovation. In Table 20, I provide a summary of this trajectory.

Table 20. The sociomaterial network trajectory of technological innovation

Network trajectory	Key underlying logic of action	Enablers/disablers	Key driving forces	Direction for network formation of technological innovation
Sociomaterial	Constantly enacted power relationships between the actors	Packs (heterogeneous networks)	Filtering	Multiple; constant circulation of competing networks which get stabilized on a temporary basis

Firstly, *the sociomaterial network trajectory is concurrently enabled and constrained by the packs*. These packs are heterogeneous networks. They are not only equipped with people and their relationships, but also nonhumans and relationships of those usually considered as 'merely technical'. Consequently, actantiality is to be given to both humans (e.g., persons and firms) and nonhumans (e.g., different kinds of machines, diffractive gratings, paper, and plastics as for instance in the case of the intelligent paper), which together constitute the network of technological innovation. As a result, the network of technological innovation concerns packs to which multiple (human and nonhuman) actors participate as well as technological innovations to be advanced toward a commercial end. It is thus as imbroglio as the packs and consequently the technological innovations it forms. Every novel device, tool and process that is introduced in this network reveals simultaneously the identities of the other actors already participating in that network and the nature of the relationships maintained in that network (Akrich, 1992; Akrich et al., 2002b; Law & Callon, 1992; Nicolini, 2010; Schneider, 2012).

Secondly, *network formation in the sociomaterial network trajectory is driven by filtering and consequently constantly enacted power relationships between the actors*. This relational and somewhat metaphorical word of filtering refers to the slow divesting of competing packs. It can be compared to the sociomaterial processes occurring during (the final stages of) translation that finally enable a sole spokesperson – 'the author' – to slowly emerge, to come out, to take care of the interests of others, to speak in their name, and to render them mobile, that is, to say what these entities are, what they want and experience (see Callon, 1986a, 1986b; Callon & Latour, 1981, p. 279; Latour, 2005). It

thus relates to pack formations and consequently how they are enacted during the network formation of technological innovation, next discussed in more detail.

Regarding how the packs get formed, contrary to the networks as processes view (Ahuja et al., 2012; Halinen & Törnroos, 2005; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock & Coviello, 2010) generally and the strong process view specifically (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012), network formation processes within the sociomaterial network trajectory are not only enabled and driven by human interaction. Nonhumans and their relationships with each other and with humans have also an important role to play in these processes, which also solves the alleged deterministic view prevalent in the literature on networks in business context (Kilduff & Brass, 2010, pp. 335–336) and technological innovation (Vergragt, 1988). As happened in the case of the intelligent paper, nonhumans allow humans to follow their (strategic) interests and beliefs (e.g., to develop their careers, acquire competencies, and/or pursue economic interests) and to detect other technological possibilities outside a certain paradigm in which they together with the humans are primarily embedded (cf. Dosi, 1982). In doing so, they also both enable and erode the network formation of technological innovation. They allow or hinder humans to strengthen their agendas over competing others, to lock/unlock the other humans and nonhumans into their places in the packs, and consequently they together with the humans enable or hinder the formation of the power bases for those in charge, which at least momentarily stabilizes or oppositely biases the networks around them. Quoting Lanzara and Morner (2005, p. 89) which have studied artifacts in the coordination of complex activity systems from the actor-network theoretical viewpoint, "They [artifacts] produce "ruling" effects in variety of ways: directing attention, channelling action, mediating communication, facilitating sense-making, and anchoring and organizing memory".

These observations also get a support from the recent work which has scrutinised the role of objects in cross-disciplinary collaboration. Although not adopting the actor-network theoretical lens (but a pluralist approach including research on boundary objects, epistemic objects, activity objects, and material infrastructures) and the focus on network formation processes, Nicolini et al. (2012) have argued that nonhumans have an active role in cross-disciplinary collaboration, both for and against. Besides constituting the fundamental infrastructure of (the activity of) collaboration, they can provide motives (e.g., by enabling scientists to fulfil their need to know more) and drive collaboration to emerge (e.g., through joint research papers). At the same time, however, they can also impede the advancement of collaboration (e.g., through tensions emerging from divergent interests and temporal misalignments).

Regarding how these packs are enacted, the power relationships get constructed by treating the packs as isomorphic; the actors within these packs have equal potential to

affect the network formation of technological innovation. Through engaging in the network formation and consequently in the technological innovation, they grow in size – thus become more influential – by managing to displace others through the process of translation. These displacements are then presented as the process of translation during which some actors succeed in pursuing a character while others remain objects of some actors' actions (Callon 1986a, 1991; see also Czarniawska & Hernes, 2005, p. 9). Thus in common sense words, the longer the list of actors one actor can hold still, the more powerful this actor is. Conversely, the shorter the list the less powerful the actor is.

As happened in the case of the intelligent paper, power plays occur while actors engage themselves in the network formation and consequently the technological innovation activities. They get settled on rather temporary basis when one actor manages to filter out among others and divest the others by suppressing them and speaking in their names. They also involve multiple strategies, which are utilized to lock the critical actors into their places and to maintain the pack (heterogeneous network) formed. These strategies include seduction – in the case of the intelligent paper related especially to the technology developers' personal career development opportunities which has not acknowledged in the previous actor-network studies – and pressuring (e.g., the modifications made to existing nonhuman actors) as acknowledged in the previous actor-network studies (Callon 1986a, 1986b, 1991; Law & Callon, 1992; Porsander, 2005). Besides these strategies, they also involve the introduction of new critical actors (that in turn enforce re-negotiations with the already enrolled ones as in the case of the intelligent paper) – a viewpoint supported by Schneider et al. (2012) as well as organizational restructurings – a viewpoint supported by Harrisson and Laberge (2002). What this study adds to these strategies – besides the technology developers' career development opportunities as a means of seduction – is the collaborative development work. In the case of the intelligent paper, thus, this strategy among others were utilized to strengthen certain actorial roles and diminish some others in the network formation of technological innovation.

Consequently, power relationships which get constructed through the process of translation and with the help of different strategies within this sociomaterial trajectory do not treat power as a reservoir from which people can draw (structural power), as a means of enabling people to influence the outcomes of networking activities between people (power use as a behavioural attribute of human actors) or as an instrument affecting the amount and distribution of networking activities over the courses of interactions between people (the outcomes of power) (Molm, 1990). On the contrary, power is produced, made up (Latour, 2005, p. 64); it is exerted 'in actu' (through others who actually perform actions/activities) (Latour, 1986, p. 264). Similarly to the actors that are empirically made to fit one's pack, the production of power and thus the asymmetry between the actors does not emerge as an automat through utilising specific

tools such for instance dependency, uncertainty and reciprocity or by limiting the research focus onto intentionally developed specific groups of human actors as certain 'spaces' for network management (e.g., Jarillo, 1995; Möller & Rajala, 2006, 2007; Möller & Svahn, 2006) as it is argued within the previous network studies in business context. Instead, it is an effect of long-term entanglements of actors in their quest for a character in these packs (heterogeneous networks); it gets added to them if the actorial quests lead to a situation in which one actor can suppress the others and speak in their name. As Latour, (1991, p. 128) has aptly stated: "Unlike scholars who treat power and domination with special tools, we do not have to start from stable actors, from stable statements, from a stable repertoire of beliefs and interests, not even from a stable observer. And still, we regain the durability of social assemblage, but it is shared with the nonhumans thus mobilised".

Finally, *the sociomaterial network trajectory offers a broader explanatory frame to potential and actual courses of network formation of technological innovation than network trajectories identified from network studies in business context* (the three network trajectories heading either to a closed network, an open network or to a mixture of these two as depicted in Chapter 2.2.4). The sociomaterial network trajectory is concurrently enabled and constrained by the overlapping packs (heterogeneous networks), which means that it is headed right from the start to multiple directions as happened in the case of the intelligent paper. This multiplicity of directions should not be mixed with the structural sociological view to homophily and heterophily, to say that these packs are becoming increasingly similar (a closed network) or oppositely as becoming increasingly different (an open network). Rather, they are different right from the start but in the courses of the network formation they are (empirically) made equivalent (Law, 1999) to fit the agenda of the 'author'. Equivalency refers here to the intensity of connections these packs can maintain in the courses of the network formation of technological innovation.

Furthermore, whereas the sociomaterial network trajectory involves simultaneously numerous packs and consequently numerous heterogeneous networks, these packs can be seen as a continually moving arena for multiple networks/technological innovations to potentially evolve – a viewpoint supported by quite recent actor-network studies (Nicolini, 2010; Schneider et al., 2012; for a related remark see also Nicolini et al., 2012, p. 622).[40] These packs overlapping (and competing) each other get temporarily settled

[40] This viewpoint of seeing the network of technological innovation as a continually moving arena for other networks (and consequently other technological innovations) to take wing comes also close to the actor-network oriented organization studies. Utilizing the concept of an action net to emphasize this never-ending act of organizing, researchers have demonstrated that the process of translation does not necessary have to lead to the construction of a macro actor. On the contrary, the construction depends on the degree to which the connections between the actions become stabilized and whether or not there is a spokesperson

by one pack, which seizes the produced power relationships. It thus manages to filter out among others and divest the competing packs either by breaking them down or revitalizing them by integrating them into its own pack as happened in the case of the intelligent paper. These resolutions, however, last only as long as this one pack can maintain its produced power. As soon as the actors locked into this specific pack start questioning the actorial roles given to them, this network becomes unstable. This questioning thus raises the need to renegotiate within that specific pack, but it also provides possibilities for other packs to take over, to divest the produced power from that actor that currently holds it. As a result, the sociomaterial network trajectory involves endless sociomaterial processes – numerous packs and consequently numerous heterogeneous networks – concurrently competing against each other just like in the case of the intelligent paper. The network formation of technological innovation within that trajectory is to be considered as an achievement rather than a stable order of things – a viewpoint strongly supported by the previous actor-network studies (e.g., Akrich, 1992; Giesler, 2012; Nicolini, 2010; Schneider et al., 2012).

to represent such an actor-network. (Czarniawska, 2004; Czarniawska, 2008; Lindberg & Czarniawska, 2006)

6. CONCLUSIONS

In this final chapter, I will first provide a summary of the study. Then, I will discuss the theoretical contribution of the findings, followed by the managerial implications. Fourthly, I will evaluate the quality criteria of this study. Finally, I will conclude by providing suggestions for future research in this research area.

6.1 Summary of the study

The purpose of this study was to describe and analyze the network formation of technological innovation. To achieve this purpose, I asked:

> *How does the network of technological innovation form?*

and thus

- *What kinds of actors can be defined and how are they related to each other in the network formation of technological innovation?*
- *How do the actors and their interconnected relationships shape the network trajectory?*
- *How does the concept of translation inform the trajectory?*

Studying the network formation of technological innovation as processes generally and as sociomaterial processes specifically called for approaching network formation of technological innovation in a holistic and process driven manner. This view was captured by adopting material constructionist research philosophy (Demeritt, 1998) and consequently materially relativist style of thinking (Law, 1991b, 2004). These approaches gave an opportunity for me to become sensitized to materiality, process, conflict, and interests when I scrutinized the network formation of technological innovation both theoretically and empirically. I situated this study in the context of construction (Hammersley, 2011); I drew analytical insights from many sources – business networks, social networks, entrepreneurial networks as the network studies in business context, actor-network theory and the empirical case of the intelligent paper – and used these in describing and analyzing the network formation of technological innovation.

Consequently, the conceptual background of the study consisted of network studies in business context including social, entrepreneurial, and business network studies. I

presented two different ways of theorizing networks, namely the level of analysis (i.e., the actor or the whole network) and the focus of the study (i.e., the causes or the consequences of the networks). Building on these two ways, I categorized the literature into two theoretical angles depicting the network formation, namely reasons (enablers/disablers) for network formation and network formation in different levels leading finally to the theoretical model in which the network formation of technological innovation was conceptualised as a network trajectory. In the model, three different network trajectories were identified: the goal-based, opportunity-based, and integrated network trajectory as summarized in Table 3.

This conceptual view to the network formation of technological innovation was then theoretically enriched by adopting actor-network theory. More specifically, I conceptualized the network formation of technological innovation as a process of translation and provided analytical insights to the network formation of technological innovation from the actor-network theoretical viewpoint, including the introduction of certain relational and somewhat metaphorical words not previously used in actor-network theoretical accounts (or the network studies in business context), namely pack and filtering. As a result, I argued that (1) both humans and nonhumans are active participants in the network formation of technological innovation, (2) their size gets determined by the influence they have on the activities and entities around them when they are engaging in the network formation of technological innovation and (3) a network equals with a technological innovation and vice versa.

The actor-network theoretical view to the network formation of technological innovation called for an understanding of the social as flat (Latour, 2005). This was done in this study by adopting the basic ideology of case research which was complemented with certain distinctive principles from actor-network theory. These principles were agnosticism, generalized symmetry, and free association. The orientation to methodology in this study was hence holistic, meaning that the analysis stayed at the level of actor-networks rather than individuals participating in the network formation of technological innovation.

The research data for this study consisted of interviews and documents (e.g., annual reviews and financial statements, research publications, presentations, patents, and company webpages), 708 pages in total. The studied period was approximately 13 years, thus from 1997 to 2009. The case was the network and consequently the technological innovation called the intelligent paper. The analysis and interpretation of this research data took place in two main phases which were inductive content analysis and actor-network analysis. Both induction and deduction guided this process.

I narrated the network formation of technological innovation on the basis of this data together with the conceptualisation of the network formation of technological innovation as a process of translation and the heuristic utilisation of Callon's (1986a)

four-phase translation model. This model was complemented with certain relational and somewhat metaphorical words (i.e., pack and filtering). This narration provided a multifaceted and empirically grounded understanding of the network formation of technological innovation, which was full of noise and disturbances. It displayed several competing packs and consequently several competing heterogeneous networks including multiple human and nonhuman actors, their actions, as well as their interconnected relationships while forming the network and consequently the technological innovation. It also revealed multiple phases during which these packs got continually reconfigured, transformed, and finally revitalised into one more coherent pack as well as different strategies through which actors continually tried to stabilise these configurations.

With the help of this narration, I was able to communicate to the reader how (and why) a network of technological innovation forms. Interpreting the case of the intelligent paper as the process of translation (Figure 12) and as the sociomaterial network trajectory (Table 20), I pursued the thought that the network formation of technological innovation concerns continually unfolding packs. These packs are heterogeneous networks; they are equipped with entanglements of humans, nonhumans and their interconnected relationships. The formation of these packs is played out as a process of translation and gets depicted as a sociomaterial network trajectory. I discuss this thought in more detail in the next chapter, where I discuss the study's contributions.

6.2 Theoretical contribution

6.2.1 Network formation of technological innovation concerns packs

This study was situated in the context of construction rather than in the context of discovery (Hammersley, 2011). The context of construction means that knowledge creation does not occur by uncovering the reality via going to places where relevant events and processes are found and then reporting back to interested audiences who have not themselves visited these places. Instead, knowledge creation is constitutive; the documented truth is not independent of the process of discovery. Knowledge production is thus not only a matter of going to relevant places and digging beneath appearances to find a reality. Rather, the researcher must draw on whatever sources available and use these to identify and make sense of evidence. This indicates that in the research report, the researcher constructs a particular experience of the lived world for the readers rather than the intactness of the discovery in question. (Hammersley, 2011, pp. 124–131)

To sustain this view, a holistic and process driven view to network formation was adopted in this study. I crafted, combined, and contrasted several research streams, methodologies, and methods in order to be able to describe and analyze the network formation of technological innovation. As such, this study contributes first and foremost through the strategies of questioning and revising. Questioning means that this study revises the taken for granted idea of human action as the determinant factor in the network. Instead, the study builds a revised understanding of the network formation of technological innovation. The emergence and maintenance of networks does not only reside in the hands of people, but also in those silent ones, that is, nonhumans that are largely neglected in the network studies in business context – and this maintenance work is continuous.

Consequently, this study broadens the networks as processes view (Ahuja et al., 2012; Halinen & Törnroos, 2005; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock & Coviello, 2010) generally and the strong process view to networks specifically (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012). It gives a multifaceted and empirically grounded view to network formation, which is full of noise and disturbances. Considering both humans and nonhumans as active participants in the network formation of technological innovation, this study argues that networks are to be considered as continually unfolding sociomaterial processes in their nature. More specifically, the study demonstrates that a network and consequently a technological innovation concerns continually unfolding packs. These packs are heterogeneous networks. They are made up of multidimensional and constantly unfolding entanglements of human (individuals, firms and organizations) and nonhuman (e.g., machines, methods and apparatuses of many sorts) actors and their interconnected relationships. While these actors engage in the activities of network formation of technological innovation through the process of translation, their interconnected relationships either hinder or enable them to acquire their actorial shapes. As such, a network and consequently a technological innovation is to be considered as an achievement of long struggles and power plays occurring during its development rather than a static structure to/from which humans (rationally) add and subtract connections.

This idea that objects and artefacts should be included in theoretical accounts when studying organizational phenomena is far from being new. This study however provides a few contributions to this area. Firstly, a moderate methodological contribution is provided by joining in line with those studies which have adopted the methodological principles of actor-network theory and merged them with the basic ideology of a case study research (e.g. Giesler, 2012; Harrisson and Laberge, 2002; Martin & Schouten, 2014; Nicolini, 2010; Schneider et al., 2012). Secondly and more importantly, this study contributes to actor-network theory by providing a more refined understanding of the phases and sub-phases involved in the process of translation. In doing so, it also

elaborates the use of certain relational and somewhat metaphorical words not previously used in actor-network theoretical accounts, namely pack and filtering. Thirdly, the study also provides a few strategies to lock actors into their places in the packs as well as to keep them locked. These strategies have not previously been discussed in actor-network theoretical studies while scrutinizing the translation process, namely the technology developers' personal career development opportunities and the collaborative work. Fourthly, the study also enhances the understanding on concrete development paths opened up and guided by the nonhuman actors in technological innovation processes. Finally, since the techniques to explore and visualize actor-networks yet lack documentation (Venturini, 2009), I have carefully described the process of analysis and interpretation so as to contribute on my part to how actor-network analysis can be conducted and visualized (i.e., the tables and the network mappings when narrating the network formation of the intelligent paper).

Bringing actor-networks to the landscape of networks in business context is, however, a novel approach. Quoting Kilduff and Tsai (2003, p. 121, italics added), "One poststructuralist approach *almost neglected* by network researchers is the actor-network perspective…". Although these researchers pinpoint the neglecting of the actor-network theoretical view while studying social networks, the same argument applies to other network studies scrutinized in this study, namely business networks and entrepreneurial networks. Consequently, enriching the conceptual view to network formation of technological innovation with actor-network theory (added with certain relational and somewhat metaphorical words of pack and filtering), this study provides a novel way to approach network formation of technological innovation. In particular, the adoption of the actor-network theoretical perspective goes beyond existing network studies in business context, namely by theorizing about heterogeneity in terms of sociomateriality (packs as heterogeneous networks) and power plays (including filtering) while forming a network and consequently a technological innovation. These two issues are discussed next.

6.2.2 Packs are played out as the process of translation

Interpreting the intelligent paper's case as a process of translation and comparing empirical findings to the four-phase translation model of Callon (1986a) outlines the second theoretical contribution of this study. The concept of translation was adopted from actor-network theory, referring to "all the negotiations, intrigues, calculations, acts of persuasion and violence, thanks to which an actor or force takes, or causes to be confronted on itself, authority to speak or act behalf of another actor or force" (Callon & Latour, 1981, p. 279). This concept was identified as a way to conceptualize the

network formation of technological innovation. It was thus a specific analytical tool to capture sociomateriality involved in the network formation of technological innovation. It enabled detecting sociomaterial processes during which some actors – by becoming involved in network formation/technological innovation and chained together in a logical succession – succeeded in pursuing a character while others remain objects of other actors' actions (Callon 1986a, 1991; see also Czarniawska & Hernes, 2005, p. 9).

Conceptualizing the network formation of technological innovation as a process of translation and adding certain relational and somewhat metaphorical words not previously used in actor-network theoretical accounts (i.e., pack and filtering) shifted the focus onto continually unfolding isomorphic packs – continually unfolding isomorphic heterogeneous networks – equipped with entanglements of human, nonhuman and their interconnected relationships as the locus of the network formation of technological innovation. The technological innovation called the intelligent paper was thus not considered as a distinct artefact existing in a stable state a priori to its diffusion or as a 'thing' to be first generated and then disseminated into markets or organizations. Rather, it was seen to concern packs in which multiple human and nonhuman actors together with their interconnected relationships were participating. In these packs, both technological innovation generation and dissemination occurred simultaneously. It was by definition social, technological, economic, and political in character, thus a socio-techno-economic-political 'system' by itself (cf. Halinen & Törnroos, 2005).

Consequently, this view of a pack as a continually unfolding heterogeneous network extends the current view which has so far located technological innovation in the networks of multiple humans and their relationships (e.g., Howells, 2005; Huggins, 2010; Håkansson, 1987; Håkansson & Waluszewski, 2002; Raesfeld et al., 2012; Rampersad et al., 2010). The network and consequently the technological innovation do not only get construed through its human participants (cf. Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012). Instead, the researcher also needs to take into account nonhuman actors. Also, this network involves no one but several packs (several heterogeneous networks) and consequently multiple technological innovations competing against each other. The continual movements occurring within these packs get solved on a temporary basis when some pack manages to divest others and speak in their name. The network of technological innovation thus forms in a dialectical manner through many phases, before one spokesperson gets filtered. As this study however demonstrates – in line with recent actor-network studies (Giesler, 2012; Nicolini, 2010; Schneider et al., 2012) – this filtering and consequently the divesting of the network formed in the first place does not, however, necessary lead to the breaking down of the network but rather its constant revitalization.

As a result, the size of actors participating in the activities of network formation and consequently technological innovation cannot be designated a priori as argued within

actor-network theory. On the contrary, they get revealed during the process of translation in which actantialities of actors are forged and (re)negotiated. At the same time, the underlying power relationships between them become revealed. Contrary to Callon (1986a), the study demonstrates that this progression involves four main phases – setting the agenda, forming the pack through performing various negotiations, potential betrayals, and filtering the spokesperson – and within these phases multiple sub-phases of 're'. During these phases, the network of the intelligent paper was continually reconfigured and transformed. The actors were compelled to constantly utilise different strategies to stabilise the packs and thus keep the critical actors in their places in the network of technological innovation. What this study adds to those already acknowledged strategies, are the collaborative development work and personal career development opportunities of the technology developers.

Furthermore, one of the competing packs finally slowly divested and consequently revitalised the network of the intelligent paper. Contrary to previous actor-network theoretical accounts, in this study this slow divesting of competing packs is called filtering. This relational and somewhat metaphorical word is a novel way to approach sociomaterial processes occurring during (the final stages of) of translation, next discussed in more detail.

6.2.3 Packs are depicted as the sociomaterial network trajectory

The interpretation of the case of the intelligent paper as a sociomaterial network trajectory and the discussion on its key underlying logic of action, enablers/disablers for network formation, key driving forces to network formation as well as the potential and actual courses outline the third theoretical contribution of this study. The concept of network trajectory to which this interpretation bases was identified as another way to conceptualise the network formation of technological innovation. This concept was considered as an analytical tool to simultaneously capture a network, that is, actors and relationships which connect them (Fombrun, 1982) and dialectical movements occurring within it across space and time (see Jenkins & Floyd, 2001, pp. 947–948; Kilduff & Tsai, 2003, p. 88; cf. Dosi, 1982, p. 152). In this study, this idea was complemented with the key underlying logic of action, enablers/disablers for network formation, the key driving forces to network formation, and the potential and actual courses of the network formation (cf. Kilduff & Tsai, 2003; Purchase et al., 2014).

This sociomaterial network trajectory complements the other three network trajectories – the goal-based, the opportunity-based, and the integrated network trajectory – identified from network studies in business context. It shows the packs – heterogeneous networks – and the continual power plays occurring while the actors are

engaging in the network formation of technological innovation (thus, how the packs get formed and enacted, including filtering). It broadens the current understanding of the networks as processes view (Ahuja et al., 2012; Halinen & Törnroos, 2005; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock & Coviello, 2010) generally and the strong process view to networks (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012) specifically by providing three key suggestions. These three key suggestions are delineated in Figure 13.

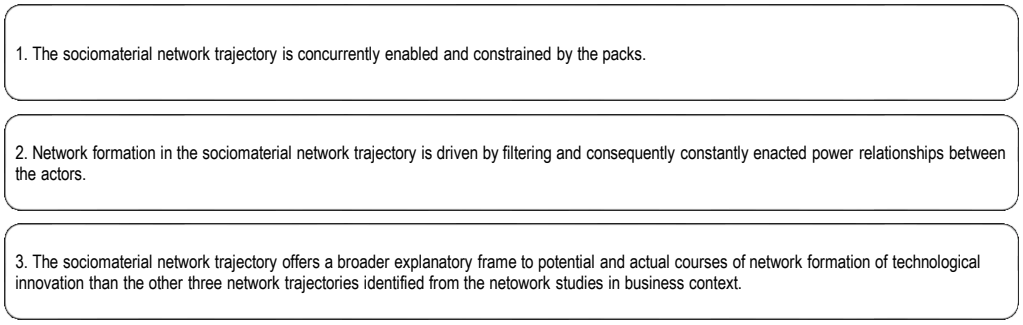

Figure 13. 'Propositions' of the sociomaterial network trajectory

The 'propositions' provide an alternative view to the network studies in business context which have largely been based on cross-sectional analysis and structural views of network formation. The same applies also to the few studies that have utilized qualitative methodologies and longitudinal research data and those which have focused on a networks as processes view from a methodological and/or conceptual viewpoints. Based on these suggestions, I argue that the sociomaterial network trajectory depicts the network formation of technological innovation in an extensive way.

Firstly, the sociomaterial network trajectory is concurrently enabled and constrained by the packs. These packs are heterogeneous networks. They concern continually unfolding sociomaterial processes, which are equipped with entanglements of humans, materials (nonhumans) and their interconnected relationships.

Secondly, network formation in the sociomaterial network trajectory is driven by filtering and consequently constantly enacted power relationships between the actors. This relational and somewhat metaphorical word of filtering refers to the slow divesting of competing packs. It can be compared to the sociomaterial processes occurring during (the final stages of) translation that finally enable a sole spokesperson – 'the author' – to slowly emerge, to come out, to take care of the interests of others, to speak in their name, and to render them mobile, that is, to say what these entities are, what they want and experience (see Callon, 1986a, 1986b; Callon & Latour, 1981, p. 279; Latour, 2005).

Consequently, it relates to pack formations and how they are enacted during the network formation of technological innovation (and consequently to continual power plays occurring while forming the network and consequently the technological innovation).

Regarding the first, network formation processes do not only reside in the hands of humans and their embedded relationships. Nonhumans and their relationships with each other and with humans also have an important role to play in these activities. Nonhumans allow humans to follow their (strategic) interests and beliefs (e.g. to develop their careers, acquire competencies, and/or pursue economic interests) and to detect other technological possibilities outside a certain paradigm in which they together with the humans are primarily embedded. In doing so, they also both enable and erode the network formation of technological innovation; they allow and/or hinder humans to strengthen their agendas over competing others, to lock/unlock the other humans and nonhumans into their places in the network, and consequently they together with the humans enable or hinder the formation of the power bases for those in charge, which at least momentarily stabilizes or oppositely biases the networks around them.

With respect to latter, the isomorphic packs are confronted by continual power plays of actors as they engage in the activities of forming the network and the technological innovation. These power plays can be detected and revealed by conceptualizing network formation of technological innovation as translation; a process through which multiple actantialities are (re)forged and (re)stabilised before one actor manages to divest the others by suppressing them and speaking in their names. This study emphasises that this process is dialectical. It involves multiple phases and sub-phases of 're' during which the network of technological innovation gets continually reconfigured and transformed. Several strategies are also utilized in this process to lock the critical actors into their places. This study adds the technology developers' personal career development opportunities as well as the collaborative development work to these strategies.

Finally, the sociomaterial network trajectory offers a broader explanatory frame to potential and actual courses of network formation of technological innovation than the other three network trajectories identified from the network studies in business context, namely the goal-based, opportunity-based and integrated network trajectory. This trajectory can be seen as providing a continually moving arena for progressing a certain pack (a certain heterogeneous network) and consequently a certain technological innovation as well as a continually moving arena for also other packs (other heterogeneous networks) and consequently other technological innovations to potentially evolve – a viewpoint supported by quite recent actor-network studies (Nicolini, 2010; Schneider et al., 2012; for a related remark see also Nicolini et al., 2012, p. 622).

6.3 Managerial implications

The core managerial implication of this study is that the network formation of technological innovation is a continually unfolding sociomaterial (heterogeneous), and multifaceted process. Companies engaging in technological innovation activities should be open to what they perceive as a technological innovation or a technological innovation process as well as who they think are the critical actors for advancing novel ideas toward commercial ends.

This study demonstrates that the technological innovation is actually the network and vice versa; it was as imbroglio as the network it formed. From the managerial viewpoint, this means paying attention to the actors considered as constituting the hard core of the network within which the technological innovation is to be developed. Together with their networks, the actors are in fact the technological innovation. The actors include, however, both humans and nonhumans that are developed and utilised during the process. As such, the success or failure of the technological innovation becomes a subjective issue and dependent on the specific actors' perspectives.

This study demonstrated that the technological innovation development did not only involve many human actors and decision-makers, but also many nonhuman actors that enabled and assisted both the generation and dissemination of the original ideas. Also, both processes of innovation generation and dissemination occurred in this study simultaneously. As a consequence, managers should value all 'things' (e.g., ideas, devices, processes, research publications, patents and tools) produced during a technological innovation process and not just one or a few coming out of that process. These 'things' are not only the means to disseminate the innovation internally to those engaging in its development, or externally to other parties not involved in the actual innovation process. They are also the seeds for next technological innovations and consequently the seeds for constructing and maintaining suitable networks for future technological innovation generation and dissemination.

Furthermore, managers should also be careful when engaging their employees in collaborative development work, since these joint development activities have an effect on the generation and dissemination of technological innovations. The same concerns also personal career development opportunities of these individuals. As happened in the case of the intelligent paper, the strategies of collaborative development work and the technology developers' personal career development opportunities were applied to strengthen certain actorial roles and diminish others while forming the network formation of the intelligent paper. They however concurrently eroded the functioning of this specific network and consequently the intelligent paper itself, leading finally to its divesting. What should be however noted here is that this divesting did not mean that the intelligent paper fell apart. Rather, it was revitalized by including it to a more coherent

heterogeneous network (the printed intelligence). As a result, these movements still provided opportunities for some technology developers to both engage in joint development activities and develop their personal careers.

Finally, the understanding that both a technological innovation and a process of technological innovation are equipped with humans, nonhumans, and their interconnected relationships urges managers to also pay attention to matter (and materiality in broader terms). Objects and artefacts also influence power plays occurring during technological innovation development and dissemination. This was foregrounded in this study, since they actually had a determining role in the decisions of which actor should and could be contacted and enrolled to the network and consequently to the technological innovation. So, managers should critically ponder the role of nonhumans in technological innovation processes they are engaged with, since the fate of these innovations rest in each and every one participating in the process, whether human or nonhuman.

To conclude, this study also urges managers to understand that networks do not last without paying attention to their maintenance work. This work includes paying attention on a continual basis to every new idea, person, process, tool, and device introduced in a process, since they all bring forth (re-)negotiations that may erode a technological innovation progressed so far. The power plays are, thus, present throughout a process.

6.4 Evaluating the quality of the study

Any systematic attempt at description and explanation, without regard to its ontological, epistemological, and methodological stances, needs to address many critical questions in order to be regarded as scientific. Traditionally, the criteria used to evaluate one's study have focused on internal validity, reliability, and generalization (external validity). Whereas the first should detect the errors of truth production in terms of presenting the logicality and consistency of interpretations, the third focuses on assessing whether the research findings can be extended to a wider population. The second, in turn, focuses on evaluating how well the research methods that have been used actually describe the research phenomenon and whether another researcher using the same research methods would end up with the same results. (Eriksson & Kovalainen, 2008, pp. 291–292; Lincoln & Guba, 1985)

According to the ontological, epistemological and methodological choices, the researcher is not an objective party making observations, collecting the research data, and analyzing it. Instead, the researcher is participating in the whole research process and cannot remove her/his influence on the researched subject (Mir & Watson, 2001, pp. 942–943; Law, 1991b, 2004). As such, the criteria for assuring the readers that the

study is of a scientific nature cannot be the same as in quantitative, positivistic research. The concepts of reliability and validity need to be substituted with something else.

Lincoln and Guba (1985) have offered the concept of trustworthiness. This concept puts an emphasis on the social construction of knowledge, especially on humans in constructing knowledge and discovering truths which cannot be objectively defined. In doing so, it neglects considering nonhumans in these knowledge production processes. To overcome this pitfall, I will evaluate the quality of this study through the criticism that actor-network theory has received. As the focus of this study is on an inter-organizational setting and dispersed technological innovations, I will utilize critical articles that have been published within these regimes, namely the works of McLean and Hassard (2004), Miettinen (1999), and Whittle and Spicer (2008).

Basically, the main criticism of actor-network theory has focused on the treatment of humans and nonhumans (i.e., the generalized symmetry, the exclusion/inclusion of actors as well as the nature of privileging nonhumans), and the translation process (McLean & Hassard, 2004; Miettinen, 1999; Whittle & Spicer, 2008). Critics of actor-network theory have argued that the division of humans and nonhumans leads to an impossible task of gathering proof about the properties of nonhumans without the aid of humans (Whittle & Spencer, 2008, p. 615), of selecting the actors and consequently their relationships without relying on the assumptions on what is 'out there' and how it can be known and communicated (McLean & Hassard, 2004, p. 504; see also Miettinen, 1999, pp. 181–182) and to neglecting the fact that the nature (nonhumans) is understandable only through mutual determination of the subject and the object through activity (Miettinen, 1999, p. 175). Additionally, it has also raised questions of boundary making practices (Whittle & Spicer, 2008, pp. 615–616), privileging nonhumans over humans (McLean & Hassard, 2004, p. 506), and of neglecting politics and moral issues underlying technological innovations (McLean and Hassard, 2004, pp. 510–515; Whittle & Spicer, 2008, pp. 620–623).

Next, I will reflect this study according to these arguments presented above. At first, I will reflect upon the choices of the study. I will discuss how my understanding of the network formation of technological innovation has been advanced in this study together with its potential pitfalls. Then, I will provide the discussions on the treatment of nonhumans and humans as well as the process of translation and the sociomaterial trajectory to which they are 'embedded'.

6.4.1 Reflecting upon the choices of the study

Before starting this research process, I had some pre-understanding on business and social networks as well as content analysis. This pre-understanding mainly derived from

my master's thesis, which focused on market entry strategies to China. To broaden this understanding and to mitigate the likelihood of presenting assumptions too early and forgetting contradictory results, I have reviewed the network studies in business context – studies on social networks, business networks, and entrepreneurial networks – and advanced my understanding on network research methodology and methods. Also, during these processes, I have participated in courses dealing with these issues (e.g., courses of social network analysis, business networks, the methods for network research, and qualitative business research). These courses helped me build my understanding of networks and potential theoretical approaches to study them.

Consequently, with the help of this understanding, I was able categorize the network studies in business context (the literatures on social networks, business networks, and entrepreneurial networks) through two theoretical angles to network formation. These angles were reasons (enablers/disablers) for network formation as well as network formation in different levels. In particular and with the aim to say something new, by conceptualising the network formation of technological innovation as a network trajectory – the first way I identified to describe and analyze the network formation of technological innovation – this study has value for others. It offers a theoretical framework for the network formation of technological innovation. This model depicts three distinct network trajectories (i.e., the goal-based, the opportunity-based, and the integrated network trajectories) and within these trajectories their key underlying logic of action, enablers/disablers for network formation, key driving forces to network formation, and the courses of the network formation.

Quite early in the process I came across actor-network theory. I found it interesting, but doubted whether it would be ontologically, epistemologically, and methodologically too difficult to grasp for a beginning researcher like me. The more I familiarized myself with it, the more interesting outlook to the network formation of technological innovation it gave to me. It broadened the conceptual understanding of the network concept and consequently provided a view of actors as heterogeneous collectives rather than dots and lines. More specifically, it allowed me to theorize in a way that transcended the prevalent view of actors and network formation within network studies in business context: Who are actually the critical participants in the network formation of technological innovation and how are they intertwined with the process of translation? In other words, through the concept of translation (added with certain relational and somewhat metaphorical words not previously used in actor-network theoretical accounts or the network studies in business context, namely pack and filtering) – the second way to describe and analyze the network formation of technological innovation – I was able to provide interpretations about packs – heterogeneous networks – as continually unfolding sociomaterial processes equipped with entanglements of humans, nonhumans and their interconnected relationships, how they were formed and enacted (through the

process of translation as the conceptualisation of the network formation of technological innovation, including filtering) as well as present them in a novel way as the sociomaterial network trajectory.

On the other hand, the deep personal interest in knowing more about actor-network theory may have potentially blinded me from seeing other alternatives suitable for studying the network formation of technological innovation. Despite this potential pitfall, the introduction of actor-network theory to the network studies in business context is a novel perspective. In particular, it offers new vocabulary to those interested in processual aspects of networks in business context, especially in terms of actors and their interconnected relationships as well as power plays occurring while forming a network and consequently a technological innovation.

To conclude, by adopting material constructionist research philosophy (Demeritt, 1998) and consequently materially relativist style of thinking (Law, 1991b, 2004) as well as situating the study in the context of construction (Hammersley, 2011), I was able to holistically and in a process driven manner capture the complex research phenomenon under study both theoretically and empirically. (I have preserved both the data and the analyses including the story-like descriptions, thus providing a possibility to review them later if needed). This holistic view also fit with the epistemological assumption that the functioning of the network in terms of its formation cannot be fully understood through reducing it to its parts or collections of parts. Instead, by trying to keep all the pieces together, a holistic view to network formation in technological innovation was to be achieved. This assumption was also supported by actor-network theory (Latour, 2005, p. 189).

As this study has taken this holistic stance and the complexity in by underscoring the packs (heterogeneous networks) and consequently continually unfolding sociomaterial processes equipped with entanglements of humans, nonhumans and their interconnected relationships as well as (dislocated) actions within these packs in their quest for a character, that is, the translation process, this study has value for others working with the network formation phenomena and the networks as processes view. In doing so, it however raises some further questions that are next discussed so as to sustain the trustworthiness of this study.

6.4.2 Quality of the analysis

6.4.2.1 Treatment of humans and nonhumans in the network formation of technological innovation

Although I have carefully discussed how humans and nonhumans were approached in this study, a few crucial remarks yet remain. These can potentially erode the innovativeness and usefulness of this study.

Firstly, Whittle and Spencer (2008, pp. 615–616) have pointed out that the separation between humans and nonhumans in actor-network accounts are neither natural nor inevitable but an outcome of specific social acts during which materials are given voice through a human act – an act which includes the researcher (see also McLean & Hassard, 2004, pp. 500–501; Miettinen 1999, pp. 181–183). So, although I have pointed out that actors have no fixed boundaries in theory, the empirical analysis and the interpretations have partly relied on some boundaries – for instance the initiator, the bridge builder, the technology developers, and VTT Centre for Printed Intelligence (people) as well as printing presses, methods for fabricating the intelligent paper, and patents (materials). Also, while categorizing the actors as either interested, hostile, or neutral and further as punctualized if serving a specific function, I have not only made the human act of categorizing them, but I have also concurrently engaged in their re-creation and re-maintenance. My role as a human actor has been active in determining for instance the point of time when some technologies have shown interest to join the network, resisted its functioning, or remained neutral (thus only serving a certain function).

I have tried to overcome this potential pitfall of reinforcing the same dualisms I have claimed to deconstruct by putting emphasis onto the actors as heterogeneous collectives. I have thus continually repeated the notion that the packs and consequently the networks are not only to be seen as involving either human or nonhuman but rather they should be seen as having properties of both, as heterogeneous networks. In doing so and despite the potential pitfall, I see my study as providing value for others. By playing with the contrast between humans and nonhumans, I have identified the unifying idea of the sociomaterial network trajectory which views the networks as packs – as heterogeneous networks – and which complements the network trajectories identified from network studies in business context, especially in terms of these heterogeneous networks (packs) and the continual power plays while forming the network of technological innovation (including filtering). Hereby, my study provides a synthesis which goes beyond identifying the common themes in theory and/or the data.

Secondly and related to the above, one of the most recent works in which the four-phase translation model by Callon (1986a) has been heuristically applied discusses

motivations. In their limitations and future research opportunities section, Martin and Schouten (2014) raise the issue of the ingredients constructing the actantiality of humans. They suggest that emotions such as for instance desire and fear should also be considered as potential actors. This is an interesting suggestion also from the viewpoint of the network formation of technological innovation. In the case of the intelligent paper, certain technology developers were deeply devoted to the network of the intelligent paper throughout the study period. Following Martin and Schouten (2014), it can be pondered whether this devotion should be considered as belonging in the realm of the humans or as another actor among the others. So, what makes us human if desires, interests, fears, and devotions are taken away from us?

In this study, this devotion and for instance the personal interests of the technology developers and the experts to develop their career were considered as properties of the humans, not as actors themselves. This consideration did not emerge to me after massive amounts of reading or analyzing and interpreting the case of the intelligent paper. Rather, the very idea of people as 'things' which can be comprised of physical and mental matters such as desires, beliefs, and interests was taken-for-granted. This can be seen as a consequence of focusing on the nonhumans so as to better understand their relationships to the humans. Thus, the focus on the nonhumans in the empirical analysis and interpretation has potentially blinded me from seeing more in the humans' side when scrutinizing the network formation of technological innovation.

This potential pitfall of taking the humans for granted and of privileging the nonhumans empirically can however be overcome at least partially if not entirely by continually highlighting that both are important in the network formation of technological innovation. Rather than emphasizing their inherent constituencies and the parts that can be extracted from them, it is important to understand the 'story' *as a whole* (Latour, 2005, p. 189). In doing so, I have tried to take seriously what Latour (1993, p. 136) has stated about the interconnectedness of humans and nonhumans: 'So long as humanism is constructed through contrast with the object that has been abandoned to epistemology, neither the human not the nonhuman can be understood.'

6.4.2.2 Network formation of technological innovation as a process of translation and as a sociomaterial network trajectory

Actor-network theorists have also been accused of downgrading the meaning of political action by promoting the status of nonhumans, of reducing meaningful action to concern utility maximisation and of evading the commitment to emancipation (Whittle & Spicer, 2008, p. 622). Quoting Whittle and Spicer (2008, pp. 622–623), "[…] ANT [actor-network theory] brings with a tendency to legitimize hegemonic power relations, ignore

relations of oppression and sidestep any normative assessment of existing organizational forms". This has been argued to result in fallacious accounts in which political and moral issues underlying technologies are not studied in detail, for instance by questioning who are the representatives of nonhumans (Whittle & Spicer, 2008, p. 620) and how and why some actors go along with the will of the others and some actors resist being enrolled (McLean & Hassard, 2004, p. 512).

Firstly, to avoid the criticism of the universal utilisation of Callon's (1986a) four-phase translation model (Whittle & Spicer, 2008, p. 618), this study has approached the model in a heuristic manner. This has meant that the model has not been adopted as it stands. On the contrary, it was at first theoretically opened in relation to what other researchers utilising the model have said about it and the phases it includes. Then, it was applied in the case of the intelligent paper. In my application of the model, the main phases were different than in the original model, but also multiple sub-phases were identified and carefully reported. Also, while applying the model heuristically, I introduced certain relational and somewhat metaphorical words not previously used in actor-network theoretical accounts (or network studies in business context), namely pack and filtering. Together, they enabled me to sustain the study's ontological and epistemological stances. This meant that I was able to sensitize myself to already existing network formations within the network formation of technological innovation, focus on 'things' involving humans, nonhumans, and the multitude of intermediaries already created as well as processes already taking place (but of course not forgetting that they had not always been there). More specifically, using the words of pack and filtering, I was able to emphasize organized collective actions, tensions emerging within a certain network and between competing networks, and mechanisms of network (re)production, more specifically continual power plays occurring while actors are engaging in the network formation of technological innovation.

Despite the advantages, the adoption of the actor-network theoretical view to network formation of technological innovation in general, and the heuristic application of Callon's model (1986a) to the case of the intelligent paper in particular, was also reported as challenging. This difficulty may have potentially eroded the empirical analysis, the interpretations as well as the implications to the network studies in business context. The same concerns also the utilisation of relational and somewhat metaphorical words of pack and filtering. These words may also have potentially eroded the issues mentioned above.

To conquer these potential pitfalls, I have openly reported the 'conversion' made during this process (the adoption of the actor-network theoretical view) with its implications, thus urging me to generate more research data and make another analysis. Thus, I have carefully opened up the process of data analysis and interpretation. I have also openly pointed out the difficulties encountered while engaging in this process. I

have discussed the lack of inductive content analysis to consider the nonhumans in the analysis, and how this detected problem was solved – by making a different kind of analysis. Similarly with the application of Callon's (1986) model, I have reported how I classified the identified critical actors, merged two phases of the original model (i.e., the phases of forming the pack and performing various negotiations), separated two (i.e., the phase of filtering the spokesperson was separated into two distinct phases, namely the phases of potential betrayals and filtering the spokesperson), and put the emphasis on demonstrating the contradictory (dialectical) movements within each phase rather than pointing out the actual moments of the locking of actors in the network of the intelligent paper. Related to these, I have also discussed the reasons for using the uncommon words of pack and filtering in the study, and for applying certain means (narrative mode of communication, figures, tables, and network mappings) while providing the analysis of the empirical data.

Secondly, although I initially started from a 'thing' called the intelligent paper and its development in medias res (Latour, 2005, p. 196), the narration of the network formation of the intelligent paper started with the actions of the paper-maker and the initiator in around the mid-1990s and ended with actions of VTT Centre for Printed Intelligence in 2009. Like Miettinen (1999, p. 182) has pointed out, usually the most prominent actors or the loudest ones are given the narrative voice; they are thus selected to depict and explain the processes of (technological) innovation: the managers, the innovators, and the politicians (for a similar viewpoint, see also Whittle & Spicer, 2008, p. 621). In this study, more specifically in the case of the intelligent paper, one could ask why I did not start for instance from the T-NIL method and end with the advancements made with the diffractive gratings as they also operated in the same period of time?

The reasons for my choices stemmed from the decision to give a functional role to the humans – thus to follow 'a weak actor-network theoretical view' (Castree, 2002, p. 135) – but also from the fact that I saw these actors as the most relevant ones at the time. Furthermore, I saw them as being made out of both human and nonhuman entities that can act and influence other entities and being continuously open to change (Callon, 1987, 1991, see also Latour, 2005, pp. 28, 46). I evaluated the actors' relevance at certain time points initially based on the inductive content analysis. Because this analysis treated nonhumans instrumentally, it may have hindered me from continually questioning the roles of the humans and the nonhumans, also when heuristically instilling them into Callon's (1986a) model.

Additionally, while re-categorizing the actors into either interested, reluctant/hostile or neutral actors and further as punctualized if serving a specific function as proposed by Law and Callon (1992), I had continual challenges in identifying those instances that were indicating no approval or opposition to the agendas (neutral actors) but that were still present in the research data and mainly serving a single function. This difficulty can

also be related to the inductive content analysis, in which I focused on analyzing human actors (individuals and companies) that were already acting and/or acted upon, thus showing interest and/or reluctance as well as acting in a specific function over the activities around the intelligent paper. This may have also eroded the empirical analysis, the interpretations as well as the implications to the network studies in business context. I have however carefully opened these silent actors while narrating the network formation of the intelligent paper; I have pointed out that I attributed this actorial role to those serving a single function (although not labelling them as such which derived from the empirical observation that the punctualized actors were found among all the critical actors' sets), thus to public research funding agencies continually providing funding technology development activities around the intelligent paper.

Thirdly, during the empirical part of the study, I have also reported the personal and economic interests of the human actors to join the network of the intelligent paper. This makes it possible to argue that in the case of the intelligent paper (as well as in the other actor-network accounts, see e.g., Harrisson & Laberge, 2002) the human actors rationally pursued their self-interests while trying to build a durable network that would sustain their power bases. It can be argued that this power actually rested in the hands of the human actors and not in the translated heterogeneous networks (Whittle & Spicer, 2008, p. 621; see also McLean & Hassard, 2004, p. 511; Miettinen, 1999, p. 182).

In this study, efforts have been made to explicitly and continually diminish such a portrayal. I have at first theoretically emphasised in this study the ingredients of the packs (heterogeneous networks); they are equipped with entanglements of humans, nonhumans and their interconnected relationships. Then, to sustain this emphasis while conducting the empirical research, in the process of analysis and interpreting the data I have utilised two different types of analysis which complemented each other.

Also, while narrating the network formation of the intelligent paper, I have for instance demonstrated that although the selecting and contacting of human actors was dependent on what nonhumans they 'occupied' – pointing again to the rational promotion of certain actors' self-interests and consequently the power in them – the development activities were, however, often progressed through a friend-to-fried mentality. This means that they did not only have strategic purposes or seemingly clear rationality for ensuring that certain technologies would be developed and disseminated over others. Also, I have demonstrated that some actors were contacted by serendipitous rather than rational actions (e.g., one shareholder of the joint venture firm Alpha).

In reflecting the empirical findings with the network studies in business context, in particular with the networks as processes view (Ahuja et al., 2012; Halinen & Törnroos, 2005; Jack, 2010, p. 131; Knoben et al., 2006, p. 400; Slotte-Kock & Coviello, 2010) and the strong process view to networks (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012), I have continually emphasised the important role of these

packs – the important role of these heterogeneous networks – in deconstructing the dualism between human and natural phenomena, micro and macro, and content and context. Consequently I have provided interpretations of the intelligent paper's case as a process of translation (summarized in Figure 12) and as a sociomaterial network trajectory (three key suggestions). Whereas as the first depicts the formation of continually (dialectically) unfolding packs – heterogeneous networks – equipped with humans, nonhumans, and their interconnected relationships, the latter complements the other three network trajectories identified from the previous literature especially in terms of these packs – heterogeneous networks – and the continual (dialectical) power plays while forming the network (including filtering). Thus, this study joins in line with those actors-network studies that put emphasis on seeing the network formation of technological innovation as an achievement of long sociomaterial struggles during which networks (involving humans, nonhumans and their interconnected relationships) and consequently technological innovations get construed, developed, abandoned, disseminated, and revitalized on a continual (dialectical) basis (Giesler, 2012; Nicolini, 2010; Schneider et al., 2012). What this sociomaterial network trajectory seems to still lack – related to the decisions made while narrating the network formation of the intelligent paper' through the process of translation – is a more systemic orientation onto strategies which enable maintaining produced power relationships in a network and consequently in a technological innovation. Despite this potential pitfall, this sociomaterial network trajectory can be seen as a novel way to depict the overall network formation of technological innovation in the domain of networks in business context. It also includes a few strategies not acknowledged in the previous actor-networks studies, namely the technology developers' personal career development opportunities and the collaborative work.

Finally, the narrative mode of communication utilized in this study while empirically scrutinizing the network formation of technological innovation (the case of the intelligent paper) was seen to provide the possibility to include temporality – a beginning, multiple middles and an end – into the analysis and thus to sustain a somewhat causal dimension in the analysis. This narrative mode together with engaging myself with network studies which have heavily emphasized causal influence of networks on processes (network studies in which a process is not directly observed but a process story or logic is utilized) and the inductive content analysis initially made have however potentially guided me to stay in time of 'Chronos' (Czarniawska, 2004; see also Araujo & Easton, 2012) while narrating the network formation of the intelligent paper. Thus, these choices made during the research process have potentially hindered me from bringing forth a strong process view to networks (Araujo & Easton, 2012; Bizzi & Langley, 2012; see also Halinen et al., 2012); a processual and empirical account which

simultaneously involves past, present and future (subjective time) while describing and analyzing the network formation of technological innovation.

I have also continually tried to diminish this portrayal. I did this by introducing actor-network theory and certain relational and somewhat metaphorical words while narrating the network formation of technological innovation. I have thus adopted concepts and words emphasizing continual flow of events and actions. These include for instance actor-network, translation, actor, and intermediary as well as those not common in actor-network theoretical accounts (or the network studies in business context), namely a pack and filtering. I have also stated how I 'followed the actors' (Callon, 1986a; Latour, 1987, 2005) in the empirical reality of the intelligent paper. I have continually made efforts to let the actors themselves make the connections between them. Additionally, I have reanalyzed the generated research data and focused in the data analysis and interpretation on continual (dialectical) movements rather than exact locking of actors in certain objective points of time while they participated in the network formation of the intelligent paper.

6.5 Directions for future research

I have adopted in this study a holistic and process driven approach to the network formation of technological innovation. I have also explored and adopted the actor-network view, which emphasizes that networks are sociomaterial in nature, involving entanglements of humans, nonhumans and their interconnected relationships. The size of an actor and thus its influence on others is not to be limited beforehand on a dimensional basis but rather it is a question of how it manages to gather animate and inanimate elements around it that are constantly moving. Power relationships are thus continually enacted/produced. As such, this study can be considered as an exploratory opening into the research area of networks as processes generally and into the strong process view to networks specifically. It provides an empirical, longitudinal and qualitative account of network formation of technological innovation, in which networks are considered as sociomaterial processes (packs) equipped with entanglements of humans, nonhumans and their interconnected relationships. These networks are confronted by continuous and contradictory movements as the actors are questing for a character (including filtering). Consequently, these networks do not necessarily form in evolutionary or teleological manner but certainly dialectically. Therefore it provides many interesting paths for future research.

One potential future research direction would be to start with the nonhumans and their relationships to each other and to humans. This would be a means to better understand heterogeneous collectives in general and their changing role in the network

formation of technological innovation in particular. Thus, a more refined categorizing of the critical actors (interested, reluctant/hostile or silent critical actors together with punctualized actors if following that of Law and Callon (1992) could be provided. This could also simultaneously provide a way to problematize further these sets and how/when/why they are seen to emerge – thus further problematizing the quest for an actorial character. Recent developments made within objects in cross-disciplinary collaboration (Nicolini et al., 2012) could provide insights in addressing these questions (especially related to the question of when). Furthermore, the ingredients of these actors as well as the narrative voice given to certain actors could be further problematized so as to thoroughly ponder whether humans have properties that can actually be considered as actors in their own right as suggested by Martin and Schouten (2014) and how nonhumans should and could be given a voice. These issues could also act as potential ways to transcend the criticism proposed about Callon's (1986a) study that it provides essentially a human-centred account (Collins & Yearley, 1992; see also McLean & Hassard, 2004, p. 502).

Secondly and related to the previous, the research data utilised in this study is textual. It was based on the interviews and the documentary data. I had continual difficulties in picturing the many uses of the materials that the research data described may have and consequently their connectedness to the other actors. Thus, to better capture the 'messiness' of (dislocated) actions within the network formation of technological innovation – including the interconnected relationships of heterogeneous collectives as well as their motivations to be part of a network and related actions – a more ethnographic-oriented study might help (for a related remark, see Araujo & Easton, 2012, p. 317). Again, one would have to be wary of becoming blind to the roles of human participants in network formation processes. Also and perhaps more importantly, more narration-oriented research methodologies could be used, to more explicitly study how and why translation processes are equipped with ante-narratives (stories of incidents and events preceding the narratives), narratives (adding the plots, coherence, into the stories) and anti-narratives (situations in which a plot cannot be narrated) (Boje, 2001; see also Law, 2006 pointing shortly to this aspect of translation). These means could also offer insights on how to deconstruct the dualism between humans and nonhumans without actually reinforcing it as well as how to involve a more subjective time orientation to the account.

Thirdly, one interesting future research area could be to more thoroughly explore debates of the inclusion/exclusion within the network formation, thus, when and where to put boundaries for the network. For instance, Strathern (1996, p. 523) argues that "if we take certain kinds of networks as socially expanded hybrids then we can take hybrids as condensed networks. That condensation works as a summation or stop." This study only argued that the imagination of humans intertwined with the allowance of

technologies to be seen as multiple (Latour, 2005, p. 116) can be seen to determine the boundaries of the network being formed in this study (cf. Halinen & Törnroos, 2005).

This study followed the actor-network guideline of 'follow the actors' (Callon, 1986a; Latour, 1987, 2005). Hence, what to consider as part of the network and who is left out was ultimately the researcher's choice. Halinen and Törnroos (2005) have also discussed the determining of network boundaries within people, a viewpoint implicitly present in the studies concerning the processual aspects of networks in the entrepreneurial and business settings (e.g., Ford, 1982; Halinen et al., 1999; Håkansson & Ford, 2002; Larson, 1991, 1992; Maurer & Ebers, 2006). This issue raises problems associated with the maintenance of analytical distance between research constructs and constructs of the world as lived and experienced (McLean & Hassard, 2004, p. 500). Do the actors involved in certain sociomaterial process really perceive themselves as being included in a heterogeneous network in question? More specifically, how and in what ways or not, does the researcher 'know better' and act actually as a spokesperson over the one she/he studies by combining different elements together? Ultimately, are there yet other grounds to be taken into consideration in order to determine if materials perceive their existence in the network?

Additionally, although I have provided strategies of enrolment during the network formation of technological innovation which to some extent differ from earlier research – especially the collaborative work and seduction in terms of the technology developers' personal career development opportunities – one interesting future research path could be to more thoroughly focus on these enrolment strategies and consequently their relation to network formation processes within the sociomaterial network trajectory. This could be a potential way to avoid missing the meaningful character of human and nonhuman action. More specifically, it could offer possibilities for questioning how and why these strategies tend to differ (Whittle & Spicer, 2008, p. 621), and of course when.

Finally, in this study I utilized certain relational and somewhat metaphorical words which have no origin in actor-network theoretical accounts (or the network studies in business context), namely pack and filtering. Regarding the first, this word 'pack' was compared to 'ally' (Callon, 1986a) or 'group' (Latour, 2005) within the process of translation, thus referring to continually unfolding heterogeneous networks equipped with entanglements of humans, nonhumans, and their interconnected relationships (that were beforehand neither given nor fixed but made equivalent during the process of translation as happened in the case of the intelligent paper). As such, it provides future research potential, especially when for instance contested with similar and/or closely related notions derived from either 'nature' (e.g., herds, flocks, and troops) or 'man' (e.g., communities and tribes). These efforts could also further enhance the understanding of how a (stable) social order (e.g., relationships, organizations, and practices) gets construed, thus opening more pathways to bring matter (and materiality in broader

terms) back in and consequently ways to be more sensitive to sociomateriality in organizational landscapes (see Carlile et al., 2013).

With respect to the latter, the word 'filtering' referred to the slow divesting of competing packs. It was compared to the sociomaterial processes occurring during (the final stages of) translation that finally enabled a sole spokesperson – 'the author' – to slowly emerge, to come out, to take care of the interests of others, to speak in their name, and to render them mobile, that is, to say what these entities are, what they want and experience (see Callon, 1986a, 1986b; Callon & Latour, 1981, p. 279; Latour, 2005). Although being rather superficially used in this study (and is debatable as such), the further elaboration of this relational and somewhat metaphorical word is worth considering. Thus, for instance, what are actually the key mechanisms of filtering and how they are different from those already argued within the lens of translation? In the frame of this study the answer to this question remains open.

Furthermore (and related to the previous), this study was directed toward the understanding that the technological innovation actually equals with the network it forms and vice versa. Interpreting the case of the intelligent paper as the sociomaterial network trajectory, I argued that this trajectory can be seen as a continually moving arena in which multiple packs (multiple heterogeneous networks) and consequently multiple technological innovations potentially evolve (Nicolini, 2010; Schneider et al., 2012; for a related remark, see also Nicolini et al., 2012, p. 622). Hence, one interesting research path could be to more thoroughly review the literature on the arenas or 'spaces' in which technological innovation activities are alleged to take place – such as business ecosystems (Battistella et al., 2013; Moore, 1993, 2006), technology communities (Rosenkopf & Tushman, 1994; Van de Ven & Garud, 1994), innovation communities (e.g., Coakes & Smith, 2007; Lynn et al., 1996, 1997; Van Oost et al., 2009), and communities (Owen-Smith & Powell, 2004; Powell et al., 1996) – and to contest them with this sociomaterial network trajectory.

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APPENDICES

Appendix A. Summary of the generated research data

Research material	Informant/Author/Title	Year	Pages
Interview data	The bridge builder	10.3.2004, 31.1.2006	14+18
	The technology developer	15.3.2004, 8.2.2006	23+14
	The initiator	18.3.2004, 7.11.2005	23+14
	The management of Alpha	23.3.2004, 16.1.2006	24+24
	The product design	19.1.2006	21
	The code promoter	23.1.2006	15
	The initiator and the bridge builder (a group interview)	29.5.2009	32
	Interview data in total		**222**
Documents/ Annual reviews and financial statements	One Alpha's shareholder/Annual review 1997	1997	2
	Infotech Oulu (http://www.infotech.oulu.fi/Annual/2000/opme2000.pdf)	1998	4
	One Alpha's shareholder/Annual review 2002	2002	5
	One Alpha's shareholder/Annual review 2003	2003	3
	One Alpha's shareholder/Annual review 2004	2004	1
	Alpha/Financial statements 22.4.–31.12.2004	2004	10
	Alpha/Financial statements 1.1.–31.12.2005	2005	9
	Alpha/Financial statements 1.1.–31.12.2006	2006	10
	Alpha/Financial statements 1.1.–31.12.2007	2007	10
	Alpha/Financial statements 1.1.–31.12.2008	2008	14
	Alpha/Financial statements 1.1.–31.12.2009	2009	13
	VTT Katsaus 2005 [VTT Overview 2005] (http://www.vtt.fi/liitetiedostot/vtt/vk05.pdf)	2005	3
	VTT Katsaus 2006 [VTT Overview 2006] (http://www.vtt.fi/liitetiedostot/vtt/vk06.pdf)	2006	1
	VTT Katsaus 2007 [VTT Overview 2007] (http://www.vtt.fi/liitetiedostot/vtt/vk07.pdf)	2007	1
	VTT Katsaus 2008 [VTT Overview 2008] (http://www.vtt.fi/files/vtt/vk08.pdf)	2008	1
	VTT Katsaus 2009 [VTT Overview 2009] (http://www.vtt.fi/files/vtt/vk09.pdf)	2009	4
	VTT/Research activities in optoelectronics and electronics manufacturing 2001	2002	2
	VTT/Research and development activities in printed intelligence 2006 (http://www.vtt.fi/liitetiedostot/cluster1_tieto-ja_viestintatekniikka_elektroniikka/printed_intelligence_06.pdf)	2006	10
	VTT/Research and development activities 2008 (http://www.vtt.fi/files/download/scientific_reports/cpi_scientific_activities_2008.pdf)	2008	10
	VTT/Research and development activities 2009 (http://www.vtt.fi/files/download/scientific_reports/cpi_09_review.pdf)	2009	6
	Documents/Annual reports and financial statements in total		**119**
Documents/ Research publications	Chou et al., 1996/Nanoimprint lithography (J. Vac. Sci. Technol. B 14 (6), Nov/Dec)	1996	1
	M. Heckele,W. Bacher & K. D. Müller. Hot embossing – The molding technique for plastic microstructures. Microsyste Technologies (4), 1998	1998	3
	Tekes/ETX – Electronics for the Information Society 1997–2001, Technology Programme Report 3/2002	2002	11
	Tekes/ELMO – miniaturising Electronics 2002–2005 (http://www.tekes.fi/julkaisut/elmo.pdf)	2006	4
	Jaakko Lenkkeri, Tero Majamaa, Tuomo Jaakkola, Mikko Karppinen & Terho Kololuoma. Tulevaisuuden elektroniikan pakkaus- ja komponenttitekniikat [Packaging and component technologies of future electronics]. Espoo 2003. VTT tiedotteita – Research notes 2213 (http://www.vtt.fi/inf/pdf/tiedotteet/2003/T2213.pdf)	2003	4
	Tekes/ELMO – Miniaturising Electronics 2002–2005. Final report (Technology Programme Report 3/2006) (www.tekes.fi/fi/document/43145/elmo_pdf)	2006	7
	Mikko Syrjänen, Jussi Nikula, Iivo Vehviläinen, and Tuomas Raivio (Tekes)/Tietoyhteiskunnan uudet toimintatavat mahdollisuutena ja haasteena – FENIX-teknologiaohjelman arviointi [New operation modes of information society as an opportunity and as a challenge], Teknologiaraportti 9/2007 (www.tekes.fi/fi/document/42919/fenix_arviointi_pdf)	2007	2
	Marko Ahvenainen, Olli Hietanen, and Heikki Huhtanen/Tulevaisuuden painopinnat ja materiaalit. Loppuraportti [Future's and materials. Final report.] TUTU-julkaisuja 1/2007	2007	11
	Olli Ventä (Ed.)/Intelligent Products and Systems. Technology theme – Final report (VTT Publications 635) (http://www.vtt.fi/inf/pdf/publications/2007/P635.pdf)	2007	16
	Ulf Lindqvist et al./Technical innovations and business from printed functionality – FUNCTIOBUSINESS (VTT research notes 2436)	2008	16
	Jari Varjus/Painettujen kelojen ominaisuuksien määrittely [Definition of printed inductors characteristics] (https://publications.theseus.fi/bitstream/handle/10024/47820/Jari_Varjus.pdf?sequence=1] (thesis)	2012	16
	Caj Södergård et al./Printed intelligence (http://www.vtt.fi/inf/julkaisut/muut/2007/PulPaper-07-SodergardKuusisto.pdf)	2007	4

	Tekes/Making it Smaller: ELMO – Miniaturising Electronics Technology Programme 2002 – 2005 (short description of the programme in English)	2009	1
	Documents/Research publications in total		**96**
Documents/ Presentations	Caj Södergård/Suomalainen hybridimediatutkimus – VTT:n näkökulma, 20.4.2004	2004	9
	Jani-Mikael Kuusisto/Hybridimedia painetun median näkökulmasta: Onko hybridimedialla tulevaisuutta [Hybrid media from the viewpoint of printed media: Does hybrid media have a future?)] (work shop presentation), 7.6.2005	2005	12
	Raimo Korhonen/Optical solutions as part of printed electronics, ELMO Results Promotion 8.11.2005	2005	6
	Harri Kopola/Printo pojektin tulokset ja vision [Results and visio of the PRINTO project], ELMO-vuosiseminaari 16.3.2005 Innopoli [ELMO annual seminar 16.3.2005 Innopoli]	2005a	10
	Harri Kopola/Painettava elektroniikka ja optiikka mahdollistavat älykkäät pakkaukset jo muutaman vuoden kuluessa [Printed electronics and optics enable intelligent packages in a few years], Lehdistötilaisuus 2.2.2005, VTT Espoo	2005b	7
	Terho Kololuoma/Painettavan optiikan ja elektroniikan teknologioita sekä demonstraattoreita [Technologies and demonstrators of printed optics and electronics], ELMO Results Promotion, 8.11.2005	2005	12
	Harri Kopola/Printed intelligence (Presentation on the printed intelligence)	2006	10
	Harri Kopola et al./Technologies, innovations and new business opportunities in printed intelligence	2007	17
	Jani-Mikael Kuusisto/Printed intelligence (Swbusiness Café, Innopoli), 14.3.2007	2007	14
	Harri Kopola/Finnish activities and clusters (Organic and large area electronics stakeholder meeting in Brussels) (ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/events3-20070530-finnish-activities-and-clusters-kopola_en.pdf), 30.5.2007	2007	9
	Documents/Presentations in total		**89**
Documents/ Brochures	Company brochure of Alpha	2009	4
	VTT/Roll-to-roll pilot facilities for printed intelligence	2009	1
	VTT Center for printed intelligence offering	2009	1
	Printed Electronics for Authentication and Tracking: Our contribution to a safer world	2011	3
	Documents/Brochures in total		**9**
Documents/ Magazines and news	BUSINESS Finland 1996	1996	2
	Tekniikka&Talous 19.6.2002 (http://www.tekniikkatalous.fi/metalli/article36942.ece)	2002	2
	Tekniikka&Talous 3.6.2008 (http://www.tekniikkatalous.fi/tk/article110675.ece)	2008	1
	Tekniikka&Talous 19.9.2008 (http://www.tekniikkatalous.fi/tyo/article131669.ece)	2008	2
	Technology Review February 2003 (http://www.princeton.edu/~chouweb/choubio_papers/MIT_review.pdf)	2003	2
	News about Alpha established (http://www.digitoday.fi/bisnes/2004/06/29/kolmen-kopla-satsaa-alypakkauksiin/200411430/66), 29.6.2004	2004	1
	Kaisa Salminen/Painomaailma, Hologrammit tuovat liikettä pakkauksiin [Holograms bring dynamics to product packages], 5.10.2005	2005	3
	VTT Uutiset 2.2.2005/Painettava elektroniikka ja optiikka mahdollistavat älykkäät pakkaukset jo muutaman vuoden kuluessa (http://www.vtt.fi/newsarchive/2005/uutinen0502001.htm)	2005	2
	Optics & laser Europe, Issue 136	2006/	1
	Tuotanto ja teknologia 1/2007 (http://www.kolumbus.fi/salmicon/Salmicon/jutut/alypaino.pdf)	2007	2
	Science (Vol. 322)/Nanoscale Polymer Processing, 31.10.2008	2008	2
	Documens/Magazines and news in total		**20**
Documents/ Other	Profiles of the "interviewees" (Linkedin)	21.10.2011	7
	Patents related to the technology development (source: Espacenet and) National board of patents and registration of Finland	21.1.–14.2.2011	52
	VTT Information Technology: Information Carriers, Projects	5.1.2011	15
	Lapin yliopisto/Päättyneet tutkimus- ja kehityshankkeet [University of Lappland/Ended R&D projects] (http://www.ulapland.fi/Suomeksi/Yksikot/Taiteiden-tiedekunta/Opiskelu/Teollinen-muotoilu/Tutkimus- ja kehitystoimintaa/Tutkimus- ja kehityshankkeet/Paattyneet-tutkimus- ja-kehityshankkeet/Printo2)	5.1.2011	1
	MIT Technology review/10 Emerging technologies that will change the world (http://www.princeton.edu/~chouweb/choubio_papers/MIT_review.pdf)	26.9.2012	3
	Graphic design history, Tech Advances in Type Making (http://www.designhistory.org/Type_milestones_pages/Panatograph.html)	27.9.2012	1
	Authentication (http://en.wikipedia.org/wiki/Authentication)	15.10.2012	2
	Counterfeit (http://en.wikipedia.org/wiki/Counterfeit)	15.10.2012	2
	Holography (http://en.wikipedia.org/wiki/Holography)	8.10.2012	13
	Die-cutting (web) (http://en.wikipedia.org/wiki/Die_cutting_(web))	2.10.2012	1
	Offset printing (http://en.wikipedia.org/wiki/Offset_printing)	2.10.2012	6
	Foil stamping (http://en.wikipedia.org/wiki/Foil_stamping)	2.10.2012	1
	Hot stamping (http://en.wikipedia.org/wiki/Hot_stamping)	28.9.2012	4
	Printing (http://en.wikipedia.org/wiki/Printing)	2.10.2012	5
	Flexography (http://en.wikipedia.org/wiki/Flexography)	1.10.2012	3
	Calender (http://en.wikipedia.org/wiki/Calender)	1.10.2012	2
	Lithography (http://en.wikipedia.org/wiki/Lithography)	27.9.2012	4
	Nanoimprint lithography (http://en.wikipedia.org/wiki/Nanoimprint_lithography)	27.9.2012	5
	Security printing (http://en.wikipedia.org/wiki/Security_printing)	27.9.2012	4
	Roll-to-roll processing (http://en.wikipedia.org/wiki/Roll-to-roll_processing)	27.9.2012	2
	Company webpages of one spin-off	30.12.2010	8
	VTT Printed intelligence (company webpages)	11.2.2011	12
	Other documents in total		**153**

Appendix B. Findings from the two story-like descriptions

Findings from the 'technology story'

Period	Main actions	Main outcomes	Human actors	Nonhuman actors
Idea generation (mid 1990s–2001)	To invent how patterns of nano-structures can be transferred on a surface at low cost To study how the fabrication of nano-structures can be utilised in future paper-making business To experiment methods to fabricate nano-structured optical effects on paper and plastic	A method of T-NIL; fabricating nanoscale structures smaller than 100 nanometers Experiments on embossing onto paper and plastic (the machines in the pulp and paper company can utilise both substrates); fabricating nanoscale structures which exceed 100 nanometers Patent: Layered structure, sensor and method of producing and use of the same Patent: Method and system for manufacturing optical elements and optical element Patent: Security paper and security package hot embossing a certain lattice structure onto a paper Patent: optoelectronic component and manufacturing method Patent: Method for forming an OLED film Testings in the production plant's machine A failure of embossing nano-diffractive gratings onto a plastic foil	Researchers in the U.S.A and abroad Product development director and a few other developers in one pulp and paper company (having expertise on flexography and calenders) A Few private companies Researchers at VTT Electronics, optoelectronical group from Oulu university, and a few researchers from University of Joensuu One Printing house in Finland A Finnish food industry company	A method of T-NIL (a tool having nanoscale patterned surface, a mould, substrate, heat, pressure and time) A method of hot embossing (embossing tool called shim, substrate: paper or plastic, and heat, pressure and time) Test apparatuses Production technologies (flexo and offset printing) Test samples Consumer packages (plastic and paper) Research publications, presentations Patents Other related technologies (nanoimprint developments and other simple printed passive devices such as light guides and kinegrams)
Technology development part I (2002–2005)	To evaluate continuous roll-to-roll fabrication of active and passive optical electronic and optoelectronic components and circuits on a web (paper or plastic) (To advance another technology toward its concretisation) To advance-diffractive optical gratings to a more concrete form	Printing trials Pilot production trials Realization of several types of diffractive optical elements and microstructures for decorative and informative purposes Development of lacquers and inks Realization of the method of the integrated embossing Several patents Creation of the first customer contact	Participants of the PRINTO programme: Researchers at VTT Electronics and Information Technology; Tekes; Universities of Joensuu, Oulu, Jyväskylä and Lappland; private companies (Asperation, Avantone, Electroplast, Hansaprint, Metso, M-Real, Ciba/former Raisio Chemicals and UPM Kymmene); a few foreign professors Product development director together with a few internal specialists and some researchers participating in the PRINTO programme (a joint venture firm called Alpha); few other private companies contacted abroad	A method of roll-to-roll embossing (two rollers, a mould, a web, and heat, pressure and time) A method of integrated embossing/roll-on-flat embossing (heatset web offset printing, die-cutting, hot foil machines, substrate, shims, heated plates, and pressure) Etching, lacquers and inks Test apparatuses (table-scale printing machines and Pico production facility) Printing technologies (offset, flexo, gravure, and ink-jet) Other related technologies (printed passive devices, namely holograms, light guides and kinegrams, and active printed device, namely optical read-only memory) Test samples Packages (plastic and paper) Patents

				Research publications, presentations
Productization (2005–early 2006)	To productize Diftone™	The creation of the effects library, photography guide, and the design guide Packages illustrating the Diftone™ effect The launch of the first product version	Internal members of Alpha: a designer and developers; one holographic company; a few advertising agencies; a few photographers; customers	The effects library The photography guide The design guide A method of integrated embossing/roll-on-flat embossing (heatset web offset printing, die-cutting, hot foil machines, substrate, shims, heated plates, and pressure) Product packages The first product version (the product D)
Technology development part II (mid 2006–2009)	To advance-diffractive optical gratings To generate new business sector To develop a protective coating	Patent: Anti-Counterfeit Hologram Patent: Embossing member for producing diffractive microstructures Patent: Methods and systems for delivering digital content A spearhead innovation programme called Printed Intelligence; technology transfer projects; a few start-ups Realization of several variations of protective coating which can be used either before or after the embossing	Alpha's specialists Several VTT researchers, private companies, public funding agencies Product development director with a few other researchers in VTT	Test apparatuses Different coatings and inks Patents Research publications and presentations Several technologies that are enabled by the continuously running roll-to-roll printing methods such as optical effects, codes (optical, hidden, reactive and electronic), sensors, indicators, power sources and bioactive applications

Findings from the 'business story'

Technological innovation process	Interests	Network relationships (networking activities)	Challenges	Synthesis
~1997–1999 Individual dream	Parent company is interested and willing to invest in understanding its future role in papermaking business The product development director is interested in fabricating intelligent paper	The product development director has several contacts to different research instances, funding agencies and private companies Contacting overseas parties Research collaboration with a few internal and external parties	Challenges in the technology end (a need to understand technological developments in the area) Overseas parties reluctant to participate in joint technology development	Parent company's investments and the product development directors' personal relations to a few interested internal players enable the creation of the network around the core technology development Internal and external collaborations enable knowledge acquisition and its internalisation Challenges in the technology-end and in contacting overseas parties are overcome utilising personal contacts to a few internal and external specialists
2000–2001 Team Building	Parent company is interested and willing to invest in understanding its future role in papermaking business The product development director is interested in fabricating intelligent paper Internal members have different interests in taking part of the ongoing technology development, mainly related to their personal career development prospects	Planning the dispersed structure of the team Internal recruits; teams members are prompted to either utilise existing contacts or create new ones to boost the core technology development Research collaboration with a few internal and external parties continue	Challenges in the technology end Challenges in the customer-end	Parent company's investments and the ongoing internal and external collaborations strengthen the network around the core technology development Network relationships to external parties rest mainly on personal and local contacts of specialists Different physical places (cities) are occupied by certain expertise needed in core technology development

		Technological innovation activities are processed in many places and in the many hands		Challenges in the technology-end are overcome by the internal recruits Challenges in the customer-end remains unsolved
2002–2003 Incubation	Parent company is interested and willing to invest in understanding its future role in papermaking business but only as one competence area The product development director is interested in fabricating intelligent paper Individual specialists have different interests in taking part of the ongoing technology development, mainly related to their personal career development prospects Future owners have different interests in taking part of the technology development, depending on their competence base and future business scenarios One public research institute and a few public investors interested in the current developments; the launch of a research programme	Research collaboration with several institutional investors, universities and research institutes and private companies Search for potential investors through personal contacts Contacting offshore companies Contacting printing and packaging companies in Finland Search for potential customers Recruits; based yet on personal contacts	Financial challenges; the business unit to which the Alpha was to be located, is sold off Challenges in the technology-end Challenges in the customer-end Overseas parties reluctant to joint technology development	Parent company's investments, research collaborations, and attained public funding enable strengthening the network around the core technology development Collaborations enable to complete the competencies possessed internally The network around core technology mainly involves Finnish players in different locations of Finland Challenges in the technology-end are overcome by acquiring the needed expertise through internal and external contacting Challenges in financial-end and customer-end are overcome by existing personal network relationships
2004–2005 Start-up	Individual specialists' have different interests in taking part of the ongoing technology development, mainly related to their career development prospects The owners have different interests in taking part of the technology development, depending on their competence base and future business scenarios Management is interested in business survival	Research collaboration with several institutional investors, universities and research institutes and private companies Recruited specialists have wide contacts to different players (in the fields of optics, electronics, and printing) and are prompted to utilise them Search for potential customers	Financial challenges Challenges in the technology-end Challenges in the customer-end Challenges in forming external relationships Decentralised operations challenging Management face challenges in controlling the specialists' network relationships	Owners' investments and the ongoing research collaborations (including public funding) enable maintaining the network around the core technology A few new players are involved to the network around core technology development through recruits from the owner companies, the partner organizations near Alpha or by using the specialists' personal contacts The network around Alpha mainly involves local players who know already each other Collaborative activities enable the utilisation of knowledge (including future customer needs), tools and machines possessed by other companies and organizations Core technology development is enabled mainly through specialists' personal contacts Challenges faced are tried to overcome by external recruits (expertise acquisition) and network relations (acquisition of ready-to-use contacts), and through internal rearrangements
2006 Emergency landing	Individual specialists' have different interests in taking part of the ongoing technology development, mainly related to their career development prospects Management is interested in business survival The owners have different interests in taking part of the technology development, depending on their competence	Search for potential financing partners in Finland and abroad Search for potential customers Search for potential buyers for the pending patent applications Informing external collaborative parties about the closing down	Financial challenges Challenges in the technology-end Challenges in the customer-end	Initial owners lack confidence over Alpha's operations Distrust between different funding parties Challenges in the financing-end is tried to overcome first through existing network relations to potential investors and customers then by contacting those unknown but identified by utilising personal relationships

	base and future business scenarios			Challenges in the technology-end remains Challenges in the customer-end remains
2007–2009 New take-offs	VTT is interested in the current developments; the launch of a spearhead innovation programme Two members of Alpha have a deep interest in core technology development; an establishment of a joint venture firm VTT is interested to continue but without the two specialists involved in the joint venture firm in the first place; an establishment of another joint venture firm VTT is interested in expertise occupied in Alpha	The new innovation programme brings several researchers, universities, funding agencies, and private companies together locating in Finland Search for potential financing partners in Finland and abroad Search for customers	Financial challenges Challenges in the technology-end Challenges in the customer-end	The establishment of two spin-offs rest on competencies, expertise, and network relations of parties involved for years in technology development Challenges in the technology-end is overcome by leveraging the extensive body of VTT's and two other companies' expertise in core technology development Network relations yet mainly local Challenges in the customer-end remains VTT overcomes the challenges; during the years VTT has acquired a broad expertise, and a wide contacts to public investors and private companies; VTT's investments together with a few other public investors are utilised to promote innovations from technology development in the printed intelligence area