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Technology Diffusion in Multi-Layered Markets: Networks of Interactions in Telecommunications


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# Technology Diffusion in Multi-Layered Markets: Networks of Interactions in Telecommunications

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# Content

## Abstract

Telecommunications operators function in complex, multi-layered environments of actors, who interdependently co-create value. This study examines telecommunications operators' efforts to diffuse 5G-technology through collaborative engagements with market actors in other layers. By drawing on theoretical contributions on the value creation of telecommunications services and network economics, we build a conceptual model that reflects the layered market-structure and the unique business ecosystems associated with networking services. Since telecommunication operators enable communication among users, including businesses, user ecosystem properties are a potential factor in the value creation of telecommunications operators. We examine the effect of business ecosystem properties and other structural factors on telecommunications operators' engagements with complementary actors, considering actors' ecosystem-affiliation and value creation logic. The findings indicate that the competitive behavior of telecommunications operators significantly influences the collaborative initiatives within business ecosystems. The size of the business ecosystem influences the choice of the engagement partner, whereas time impacts the choice of the number of partners per collaboration. Our results have implications for the management of telecommunications services and future research on network service strategies.


**Keywords:** Telecommunications; Network services; Multi-layered Markets; Technology Diffusion.

## Introduction

*Network service firms* are transaction or communication services that create value by facilitating connections between their users (Stabell & Fjeldstad, 1998). During the recent decades, these firms have seen an unprecedented growth in numbers and have a significant position in today's economy. North and Wallis (1994) argued that innovation in network service firms is a key driver for economic growth and can fundamentally impact how firms in various industries are organized. The adoption of innovation in network services is subject to the concept of network externalities (Schilling, 2009): A user's decision to join the network depends on the existence of other users and services on the network (Katz & Shapiro, 1985). Consequently, researchers have examined the impact of these network effects on network service firms' strategic behavior in respect to the diffusion of novel technologies (Katz & Shapiro, 1986b; Rohlfs, 1974). More recently, this body of literature has explored the multi-sided nature of network service markets (Rochet & Tirole, 2003), where the distinction between user groups has added to the understanding of how network service firms scale and manage interdependence (Parker & Van Alstyne, 2005).

We do not question that distinguishing different types of connected parties, or sides of markets, has been valuable for the examination of how a critical mass of users is generated. Nonetheless, as both scale and composition of networks are of major importance for the value creation in network services (Stabell & Fjeldstad, 1998), we aim to explore an additional perspective. This study highlights two network characteristics that are vital for user composition – layering and local network effects. Network markets have been argued to exhibit a structure of layered complementary actors (Gong & Srinagesh, 1996), which create value in a system (Farrell & Katz, 2000). Network service actors are interdependent and may perform a variety of functions for each other (Eisenmann, Parker, & Van Alstyne, 2011), while serving distinct markets across user groups (Stabell & Fjeldstad, 1998). The value of the service to specific user groups may be subject to local network externalities. Local network effects arise from intra-group considerations of the availability of particular other users and services on the network (Rohlfs, 1974; Stabell & Fjeldstad, 1998). We believe that it is necessary to address these underlying market conditions, as the composition of users is of significant value for technology-diffusing network service firms in their efforts to create sustainable demand (Farrell & Klemperer, 2007; Rohlfs, 1974).

Telecommunications operators create value and compete within a layered value system (Gong & Srinagesh, 1996; Hess & Coe, 2006; Stabell & Fjeldstad, 1998). The purpose of this thesis is to examine collaborative engagements of telecommunications operators with users in a multi-layered environment aimed at generating sustainable demand for the services of the fifth-generation technology standard for telecommunications (5G). The context of our study is the ongoing diffusion of 5G-services. Our study contributes to the network literature by explaining telecommunications operators' diffusion strategies through engagements with actors in a layered business environment with local network effects. Our aim is to provide insight into cross-layer diffusion strategies in telecommunications and their antecedents. We intend to establish insight by answering the research question, how structural and compositional factors influence the diffusion strategy of telecommunications operators across their multi-layered business environments?

The remainder of the thesis is structured as follows. We begin with an overview of literature on the economic and structural characteristics of network markets. Thereafter, we motivate theoretical perspectives on telecommunications operators' multi-layered market structure and what they imply for their diffusion activity. On this basis, we construct our hypotheses about the influencing effects on diffusion strategies and explain our methodology and findings. After discussing the results, the study closes with the limitations of the research. Lastly, we highlight the implications of our findings for management scholars and managers.

## Literature Review

Telecommunications operators are a primary example of firms built around a mediating technology (Thompson, 1967). Such firms have a distinct value creation logic in which scale and user composition are central value drivers (Stabell & Fjeldstad, 1998). The importance of scale is easily exemplified: The more customers possess telephones, the more connections can be facilitated between them. Through compatibility of systems, a variety of actors may be involved in a single connection, leveraging the network's size of a telecommunications operator beyond its immediate boundaries (Katz & Shapiro, 1985). Conversely, the customer benefit increases with network scale, as they can reach additional customers or other actors. When the customers' perception of value from the adoption of a service grows with the number of potential connections, the service is described to exhibit network effects (Farrell & Saloner, 1985). As these network externalities create demand-side economies of scale for the telecommunications operator (Katz & Shapiro, 1985), value-maximizing strategies are directed at the objective to attract as many nodes as possible to its network.

**Network Externalities**

According to Rohlfs (1974), Artle and Averous (1973) pioneered the examination of consumption externalities in communication services. They illustrated the cumulative demand for telephones, as the service's utility grows with the number of consumers (Artle & Averous, 1973). The mechanism that consumers consider the presence of other consumers was later described as direct network externalities (Katz & Shapiro, 1985). There may also be indirect network externalities, where consumers derive a utility from the total number of complementary services and goods available on the network (Farrell & Saloner, 1985; Katz & Shapiro, 1985). Potential users, both consumers and complementors, not only consider the current availability of other users in their adoption decision, but also their expected future availability on the network (Katz & Shapiro, 1985).

The underlying micro-economic dynamics of network markets have occupied the attention of scholars, in particular, the emergence of novel network services (Economides & Himmelberg, 1996; Katz & Shapiro, 1986b, 1992). Investigating network effects in the context of service introduction is of principal relevance, as a self-reinforcing cumulative growth of users only actuates once a critical mass of users has been achieved (Oren & Smith, 1981). Users only join the network if other users are already or expected to be on it. The arising difficulty of the initial attraction of users to obtain a critical mass has been described as the *start-up problem* (Rohlfs, 1974, p. 18). Research has suggested various strategies for network service firms to solve the start-up problem. One approach is to design the technology to be compatible with other systems (Farrell & Saloner, 1985, 1992) or introducing general technical standardization (Katz & Shapiro, 1986a, 1986b). The resulting inter-firm compatibility can leverage the potential size of the network beyond the immediate firm boundaries (Katz & Shapiro, 1994; Shapiro & Varian, 1998, p. 236). Network service firms can also follow different operational strategies aiming to directly influence the market by manipulation of the number of competitors (Katz &

Shapiro, 1985), vertical integration and foreclosure of market actors (Economides, 1996), investment and pricing strategies (Katz & Shapiro, 1992, 1994), or utilization of reputational effects (Katz & Shapiro, 1994). Network service firms may target specific user groups, as users may base their adoption decision on few other users on the network (Rohlfs, 1974).

When the users' decision of technology adoption is influenced by the composition of specific other users on the network, the resulting network effects are described to be local (Farrell & Klemperer, 2007, p. 2007). Here, users derive utility from only a small set of other users, which they deem relevant to their connection behaviour rather than the entire network (Stabell & Fjeldstad, 1998). These disjoint sets of users may be viewed as distinctive populations, each with their own critical mass (Rohlfs, 1974). Thus, as the underlying assumptions about network externalities are similar for local dynamics, so are the strategies to solve the start-up problem. In both cases the population is more specific. Considering the compositional aspects of such specific populations, it is important to note that attracting few but centrally located users to the network can have a substantial positive effect on the adoption of the technology (Rohlfs, 1974; Tucker, 2008).

### Layered Market Structure

Indirect network externalities account for the variety and quality of supplements for a good (Katz & Shapiro, 1985). This implies that users derive a utility from products and services offered as part of a network's system but not necessarily directly by a focal network service firm. The products and services are aligned to be complementing components within a network, where multiple components may be involved in the process to provide a network service to a user (Economides, 1996). In order to jointly deliver a network service, the complementary actors are organized in a vertical structure, which was initially described similarly to classical vertical production chains (Economides, 1996; Katz & Shapiro, 1994). For example, local communication between users is facilitated by a local switch, whereas long distance communication is processed by supra-regional carrier networks between local switches (Economides, 1996). Nonetheless, Stabell and Fjeldstad (1998) argued that the value creation logic of mediation services differs from the classical production chain, as the complementing actors are organized in simultaneously co-performing layers. The layers consist of services that provide the elemental basis for services supplied on higher-level layers (Gong & Srinagesh, 1996). For example, telecommunications operators supply the physical infrastructure for mobile service providers, who supply connectivity for payment service providers to offer services to users (Stabell & Fjeldstad, 1998). Consequently, the demand for a principal layer's offering is positively related to the demand for offerings of adjacent layers, meaning that layers exhibit a particular form of complementarity. As the actors operate interdependently and collectively co-produce value (Farrell & Katz, 2000), the services enable a connection between users to materialize across the layers. Thus, the layered network services may serve the same markets and may also supply users across the boundaries of distinct user-groups (Stabell & Fjeldstad, 1998). This means that they can interact both cooperatively and competitively (Gong & Srinagesh, 1996).

The interdependencies between transacting users are the focus of research on two- or multi-sided markets, i.e. platforms, where these types of network service firms actively enable or mediate an exchange between two or more parties (Rochet & Tirole, 2003; Stabell & Fjeldstad, 1998). The distinction between the role of the parties in the exchange, e.g. supplier and buyer, is crucial to generating sustainable demand, as the parties can be illustrated as complementors (Parker & Van Alstyne, 2005; Rochet & Tirole, 2003). The differentiation between the sides has been valuable in modelling the generation of a critical mass (Rochet & Tirole, 2003). For telecommunications services, the various complementary goods and services exhibit potential indirect network externalities (Katz & Shapiro, 1994). As the complementary actors are themselves structured in interdependent layers, there may also exist inter-layer indirect network externalities. Although the complementors are a side of the market, the telecommunications operators are not necessarily a direct participant of the respective exchange between users, as typically illustrated in multi-sided literature (Parker & Van Alstyne, 2005; Rochet & Tirole, 2003). The technological development and service expansion is interactive across multiple layers (Andersen & Fjeldstad, 2003) and network services can simultaneously perform a variety of functions within a system (Eisenmann et al., 2011), meaning that layers may be sides of other layers and there may be multiple sides within a layer. These layers are acting as a system with various interdependent affiliations (Eisenmann et al., 2011) rather than stringent vertical value chains (Economides, 1996) or direct enablers of an exchange (Rochet & Tirole, 2003). Building on the above, we consider the specific origin of network expectations and subsequent effects to be distributed across the whole layered structure of the business environments.

An essential part of a network service firms' value creation is based on the availability and future emergence of goods and services complementary to the network (Katz & Shapiro, 1985). Although complementors adding value to a particular product may release substantial network effects (McIntyre & Subramaniam, 2009), they are structured in a layered market-architecture, where the value creation by one layer simultaneously increases the overall value of the other layers (Fjeldstad, 1999). Thus, network service firms have an interest in attracting and actively governing their complementing environment (Rochet & Tirole, 2003). The management literature has provided insights into how network service firms may incentivize complementary actors to join the network. Strategies revolving around the actual network service have covered an attractive technology design (Boudreau, 2010; Lerner & Tirole, 2002), the choice of an accurate pricing strategy (Parker & Van Alstyne, 2005; Rochet & Tirole, 2003) and the tying and bundling of the service with complementors' services (Carlton & Waldman, 2002; Eisenmann et al., 2011; Whinston, 1990). Network service firms may also use strategic investments into R&D or supportive tools to foster the complementors' numbers or innovation activities (Evans, 2003; Farrell & Katz, 2000). Additionally, investments can be used as a demonstration of sunk costs, which may incentivize complementors to make such investments themselves (Andersen & Fjeldstad, 2003; Katz & Shapiro, 1994). Lastly, the network service firms can build ties to layered markets through a variety of inter-firm relationships with complementors (Farrell & Weiser, 2003).

## Theory Development

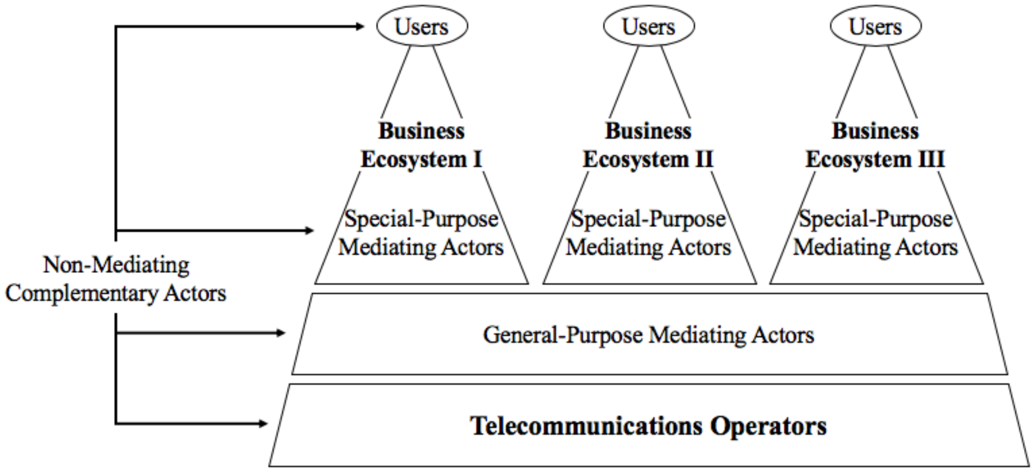
The presence of network externalities poses a challenge for the diffusion of a novel network technology (Katz & Shapiro, 1986b, 1992). We argue that telecommunications operators collaborate with actors in other layers in an effort to create sustainable demand for the 5G-network. There are two particular factors incentivizing collaboration. Firstly, researchers have claimed that collaborations enable the diffusion of new network technology by promoting and enhancing innovation (Farrell & Katz, 2000; Farrell & Weiser, 2003) as well as creating the network infrastructure and increasing the range of layered services offered on the network (Fjeldstad, Becerra, & Narayanan, 2004). Secondly, the interdependent value-creation between layers in telecommunications networks provides a natural logic for collaboration (Stabell & Fjeldstad, 1998). The precondition is a compatibility of systems, where a broad compatibility maximizes the level of output (Katz & Shapiro, 1985) and open systems foster the creation of complementary goods (Boudreau, 2010).

The main value proposition for the telecommunications industry is to enable a connection between its users. We argue that these users predominantly interact within business ecosystems that can be clustered and distinguished from each other. This has important implications for the diffusion activity of telecommunications operators, as the attraction of users is dependent on who the users want to connect with through the network (Stabell & Fjeldstad, 1998). Rohlfs (1974) described this circumstance as “nonuniform calling patterns”, where only few contacts account for a significant part of a user’s communication. Therefore, users cumulate in groups with increased interaction, which are subject to local network effects due to users’ intra-group considerations of other relevant users (Farrell & Klemperer, 2007, p. 2007) and can be recognized as own populations with a critical mass (Rohlfs, 1974). Consequently, network service firms can derive substantial value by considering the composition of their current or potential user-base (Fjeldstad & Sasson, 2010). We describe such groups of affiliated firms exhibiting local network effects (Sasson & Fjeldstad, 2009) as distinct business ecosystems. Business ecosystems are defined as “[…] an economic community supported by a foundation of interacting organizations” (Moore, 1996, p. 26). The economic community consists of interdependent parties “[…] that need to interact in order for a focal value proposition to materialize” (Adner, 2017, p. 42). Interrelated business groups in telecommunications markets can be considered business ecosystems, as the actors interdependently co-create value for a focal demand (Farrell & Katz, 2000). Such business ecosystems are clustered around differing needs for user connection and interaction. The research on platforms lend support to this conceptualization of telecommunications networks by acknowledging the heterogeneity of user groups (Evans, 2003; Parker & Van Alstyne, 2005; Weyl, 2010), in addition to the view that platforms provide services for discrete markets (Eisenmann et al., 2011).

Due to the local network effects present in business ecosystems, telecommunications operators must consider the diffusion of 5G-technology in business ecosystems separately. We have conceptualized the business ecosystem structure in telecommunications networks in Exhibit 1, highlighting the layered architecture and how user affiliations and unique needs reveal distinguishable ecosystems. The multiple actors in each business ecosystem participate to solve the different mediation needs. We have utilized observations made by Gong and Srinagesh (1996), Andersen and Fjeldstad (2003) and Hess and Coe (2006) to distinguish between mediating and non-mediating actors and generalize them into three categories: general-purpose mediating actors, specific-purpose mediating actors, and non-mediating complementary actors. As general-purpose mediating actors solve general mediation needs across business ecosystems, they reside outside the ecosystems' boundaries. Specific-purpose mediating actors provide mediation services tailored to serve the unique needs of a business ecosystem. Mediating actors function as service layers on top of the 5G-infrastructure. Lastly, non-mediating complementary actors provide essential parts, equipment, applications, or services that enable all parties of the network to utilize the range of mediation services offered on the network. Regardless of their characterization, the actors are dependent on each other for value-creation within the whole technological system.

The challenges associated with obtaining a critical mass and the local network effects in distinct business ecosystems provide the strategic context for telecommunications operators with 5G-network ambitions. Typically, they face a trade-off between the reach and range of services provided (Stabell & Fjeldstad, 1998). That means that the service can be diffused to either maximize scope of potential users reached or maximize qualitative range for a particular group of users (Evans & Wurster, 1999). We label the two different strategies as *global* and *local*. Telecommunications operators need not only to consider which distinct user groups to target, but also the optimal intensity of engagement (Rohlfs, 1974). A *global strategy* entails engaging with few actors per business ecosystem but across a multitude of business ecosystems. This enables the telecommunications operator to reach many potential users, but the low diffusion intensity per business ecosystem may not be sufficient enough to overcome users' symmetric inertia (Farrell & Saloner, 1985) and obtain local critical masses. A *local strategy* involves a high intensity of collaboration within one single business ecosystem. This strategy increases the likelihood of reaching a critical mass in distinct user groups but may hinder wide-spread diffusion as the focus is on only a few distinct business ecosystems. Consequently, network service firms are stimulated to follow a mixture of both *global* and *local strategies*, engaging intensively in some business ecosystems but with strategically placed separate engagements in others.

**Exhibit 1 – Conceptualization of the layered business ecosystem structure of telecommunications networks**




## Hypotheses

The accurate assessment of an adequate intensity of engagement in a focal business ecosystem includes the evaluation of local competition with horizontal rivals. Although network service firms have been described to enter into fierce rivalry for the generation of network effects (Katz & Shapiro, 1994), competition among them subsequently causes prices to decrease (Chakravorti & Roson, 2006). The eroding price levels are intensified as the compatibility of the systems increases (Katz & Shapiro, 1986a). As there is general compatibility among systems in the European telecommunications market, the telecommunications operators face significant pressure on price levels. Considering Schumpeter's claim that the perspective of substantial returns is a crucial incentive to innovate (Shapiro, 2011, p. 401), the telecommunications operators may prefer not to enter into fierce competition with their rivals. Accordingly, research has shown that when firms credibly signal or implement large commitments, their competitors will act passively by not showing a direct reaction (Chen & Macmillan, 1992; Chen, Smith, & Grimm, 1992). Large commitments are a measure to build user expectations of the network for firms that are subject to network externalities (Katz & Shapiro, 1994). A commitment may not only be defined as pecuniary sunk costs but also as the existence of liabilities to other actors (Chen & Macmillan, 1992). Therefore, committing to a *local strategy* with multiple collaborative engagements in a business ecosystem may deter rival telecommunications operators from entering due to pay-off considerations in respect to the potential internalization of network effects.

Moreover, telecommunications operators may not have an incentive to actively face direct competition in an early phase. As diffusing network service firms increase their number of engagements to obtain critical mass, their competitors may be able to *free-ride* during a later phase, especially under compatibility (Katz & Shapiro, 1986a). At a free-riding strategy, network service firms expect to benefit from competitors' diffusion activity during a later phase (Gupta, Jain, & Sawhney, 1999; Schilling, 2009, p. 204). Therefore, the telecommunications operators may choose to initially show marginal diffusion activity within business ecosystems targeted by competitors. Thus, we expect telecommunications operators to refrain from aggressive competition due to the prospect of negative returns and the possibility to "free-ride" in the respective business ecosystems during a later phase.

**Hypothesis 1:** The likelihood of a focal network service firm to engage in a business ecosystem decreases with the intensity of the competitors' engagements in the respective business ecosystem.

The network extension of an industry is said to condition the consumer externalities (Katz & Shapiro, 1992). Thus, for our model of business ecosystems, i.e. economic communities, size becomes a considerable determinant as it represents the potential number of complementary layers (Stabell & Fjeldstad, 1998). In this case, it is to be noted, that the ecosystem-size is restricted by geographical boundaries as "5G-licenses" are bound to specific geographical markets. Nonetheless, large industries within their geographical boundaries provide nourishing ground for network service firms to activate a variety of complementary actors and innovators (Gawer, 2014) and subsequently explore a large range of services (Evans & Wurster, 1999). Additionally, network service firms engaging with actors in large business ecosystems can build up reputation, which is valuable to increase intra-industry user expectations (Katz & Shapiro, 1994) and may spill over into adjacent industries (Geroski, 2000), raising inter-industry network expectations. Thus, we expect telecommunications operators to preferably engage in larger business ecosystems due to the prospect of generating potentially larger network effects.

**Hypothesis 2.1:** The likelihood of a focal network service firm to engage in a business ecosystem increases with the size of that business ecosystem.

In order to create positive user expectations to obtain a critical mass, network service firms may have to engage intensively in large business ecosystems as they have to overcome a potentially larger excess inertia amongst the actors (Katz & Shapiro, 1992). Hereby, network service firms rely on the composition of their multi-layered environment. Firms classified as general-purpose and specific-purpose mediating actors are complementary actors whose mediating logic of value-creation across various layers is congruent to that of the technology-diffusing network service firms (Stabell & Fjeldstad, 1998). Acting on similar underlying economic logics, the complementary actors' transactional relations may extend over the boundaries of their own user base (Stabell & Fjeldstad, 1998). Therefore, engaging with these mediating actors may leverage the network service firms' market size by generating cross-layer network effects (Eisenmann et al., 2011). These effects may be more extensive than the direct effects (Gawer & Cusumano, 2014), which accrue from engaging with non-mediating complementary actors, which typically provide products qualifying as direct nodes on the network. Thus, in large business ecosystems we expect that telecommunications operators will choose to diffuse their technology through engaging with general-purpose or specific-purpose mediating actors to increase reach, rather than with non-mediating complementary actors.

**Hypothesis 2.2:** The likelihood of a focal network service firm to engage with general-purpose or specific-purpose mediating actors rather than with non-mediating complementary actors increases with the size of that business ecosystem.

Open approaches to technology diffusion may fuel a broader and faster adoption of the technology while enhancing product quality and variation, which drives indirect network effects through increased participation by complementary actors and innovators (Boudreau, 2008, 2010; Shapiro, 1999, p. 153). Accordingly, Lerner and Tirole (2002) argued for positive effects of open innovation approaches on platform demand and Farrell and Weiser (2003) established that openness in interfirm relations can maximise the creativity and variety of inputs complementors are adding to a platform. Once the technology has gained traction, controlled diffusion becomes increasingly more relevant (Shapiro, 1999, p. 151). This is because over time, the network service firms' focus will shift towards the appropriability of returns and internalization of network effects, as well as the development of stringent guidelines encouraging continuous commitments and innovative efforts by complementary actors (Boudreau, 2010).

These targeted diffusion activities have further value when network service firms are aiming to trigger *bandwagon-effects*, where companies adopt a technology by assessment of previous adopters (Farrell & Saloner, 1985). Network service firms may attempt to trigger such behaviour by controlling the diffusion to seperate actors, thereby contributing to overcome symmetric excess inertia towards adoption (Farrell & Saloner, 1985). Thus, we expect network service firms to engage in more targeted collaborations with fewer participants as time progresses.

> **Hypothesis 3:** The likelihood of a network service firm to engage in a dyadic collaborative relationship within a business ecosystem increases over time.

## Methodology

To contribute to this specific stream of research, we focus our study on the economic environment of the telecommunications networks. With the contemporary introduction of the innovative 5G-technology, telecommunications operators face the challenge of large-scale technology diffusion through the layered market structure of complementary actors. The introduction of 5G-technology represents a natural experiment for the strategizing of telecommunications operators in their efforts to obtain a critical mass of users.

### Sample

To investigate collaborative engagements for technology diffusion in the 5G-context of the telecommunications industry, we focused on firms that have acquired a license to operate in the spectrum of 5G-frequencies. The acquisition of a "5G-license" is associated with a considerable financial commitment and as such, it represents a definitive commitment aimed at creating a profitable 5G-network. For reasons of validity and to concentrate the data collection, we excluded telecommunications operators in markets that have not yet auctioned off "5G-licenses". The data collection was focused on ten Western European markets in the European Economic Area: Austria, Denmark, Finland, Germany, Ireland, Italy, Norway, Spain, Sweden, and the United Kingdom. These telecommunications markets are congruent to the markets investigated by Fjeldstad et al. (2004), who examined telecommunications operators strategizing, reduced by the countries of Belgium, France and the Netherlands, which have not yet held 5G-spectrum auctions. The ten geographical markets vary in size and characteristics but share similar legal frameworks through agreements of the European Union and the European Economic Area. This makes the strategizing of the respective telecommunications operators comparable across geographical boundaries. A total of 36 telecommunications operators which have acquired “5G-licenses” through national auctions in the ten geographical markets of interest serve as the focus of our study.

**Data collection**

The activity of technological diffusion was observed in the “business-to-business”-segment, as the diffusion of a technology and creation of network expectations are fostered by network service firms’ investments in complementary layers (Bresnahan, 2001; Katz & Shapiro, 1994) and subsequent investments of complementary actors in the technology (Andersen & Fjeldstad, 2003). To collect data on engagements in complementary layers we conducted content analysis of press releases published by the 36 “5G-license”-holders. Structured content analysis has previously been used to investigate strategizing of firms with a mediating value creation logic (most notably in Chen and Macmillan (1992) and Chen et al. (1992)) and in the telecommunications industry in particular (Fjeldstad et al., 2004). A basic premise for using structured content analysis is that the phenomenon in question is observable through the detailed and structured analysis of text material. As argued above, engagement with complementary actors is an effort with the potential of diffusing a new technology. Thus, it can be expected that any significant engagements will be communicated to the market as network service firms attempt to positively influence expectations of future network size (Katz & Shapiro, 1994). Press releases have been shown to be a valuable source of data for understanding inter-firm relationships (Dahlin, Fors, & Öberg, 2006). The risk that press releases on complementary engagements are simply used for promotional purpose is reduced as they entail liabilities towards the engagement partners, signifying a commitment

(Chen & Macmillan, 1992) and can be used to hold the reputation of the network service firm hostage (Katz & Shapiro, 1994). Consequently, engagements with complementary actors will be observable through press releases published by the telecommunications operators.

In addition to the information collected from press releases, we used publicly available data sources to collect data on industry size and the market shares of the telecommunications operators. Information on industry size was obtained from *Eurostat* while data on market shares was obtained from *Statista* and *Bundesnetzagentur*. The data on market shares was obtained per geographical market on a yearly basis. The market shares were then used to compute the Herfindahl-Hirschmann Index to assess market concentration per geographical market.

**Identifying engagements**

Semantic structured content analysis was applied to identify engagements with complementary actors, a method which is specifically useful for uncovering the underlying meaning of a text (Neuman, 2014). In this thesis, the aim of the structured content analysis was to uncover which business ecosystem the engagement was directed at, what type of firm it was with (mediating or non-mediating) and if the engagement was dyadic or involved multiple partners. We developed a coding schedule through the collection of a pilot sample to ensure consistency among coders and to test the reliability of the collection method (Duriau, Reger, & Pfarrer, 2007). The initial identification of relevant press releases was done by searching for the key-phrase “5G” in the archives of the 36 telecommunications operators included in the sample. In cases where the telecommunications operators did not have a searchable archive for press releases, every press release since 2016 was screened for the key-phrase “5G”.

As the aim of this study is to investigate technology diffusion in distinct business ecosystems, only data on vertical complementary engagements was collected. Although joint horizontal efforts may be advantageous for generating a critical mass considering total user expectations (Katz & Shapiro, 1994), our model of deliberately targeted engagements within business ecosystems highlights commitments in complementary layers as the central diffusion strategy. Consequently, horizontal engagements between telecommunications operators were not included in the dataset. Furthermore, only engagements that identified the complementary actor by name and that clearly identified a joint effort of a given purpose were included in the dataset. Cases where the telecommunications operators implied collaboration or cooperation with industrial players without mentioning a specific company or the purpose of the engagement were consequently excluded. Words such as "partnership", "collaboration" and "cooperation" would typically indicate a joint project with a common purpose. Cases with limited common purpose or strictly commercial intentions were excluded as they imply no measurable significant commitment in terms of liability towards other actors (Chen & Macmillan, 1992) or sunk costs (Katz & Shapiro, 1986a). Per example, this includes an observation of *Three UK* showcasing an augmented reality solution at its flagship store.

The business ecosystems were classified using the Thomson Reuters Business Classification (TRBC) and coded according to the ten economic sectors included in it. The economic sectors are at the top of the hierarchy of TRBC (Phillips & Ormsby, 2016, p. 8) and were chosen as the basis for coding to ensure consistency among observations. TRBC is an empirically validated marked-based classification scheme (Horrell & Meraz, 2009). The classification scheme was applied to the business ecosystem that the engagement was directed at rather than the industry which the engaged complementary actor was part of. In most cases the two overlap, but in several observations the two differ. For instance, *Vodafone Germany*'s separate engagements with the two automobile manufacturers *Ford* and *e.GO Mobile* were classified differently. The engagement with *Ford* was for the purpose of using 5G-technology to develop autonomous vehicles while the purpose of the engagement with *e.GO Mobile* was to enable smart factories. In this case, the purposes of the engagements are directed at two different business ecosystem contexts with unique mediation needs, even though the vertical actors are both automotive firms. Therefore, the two observations were classified as "consumer cyclicals" (automotive) and "industrials" (smart factories), respectively. Furthermore, each engagement was classified as either "dyadic" or "multiple" depending on how many complementary actors the focal telecommunications operator collaborated with in each engagement. Lastly, the function of the engaged firm was classified as being either "mediating" or "non-mediating" according to the firm's underlying value-creation logic. Exhibit 2 shows an excerpt of the output of the structured content analysis on five engagement observations.

In accordance with the recommendations of the structured content analysis literature (Duriau et al., 2007) multiple coders executed the data collection, and the consistency of the coding was evaluated through inter-coder reliability. The two coders re-coded 20 of the other coder's observations, obtaining an inter-coder reliability of 97.5%. The high inter-coder reliability indicates that the sample was reliably collected (Neuendorf, 2002, p. 143).

**Exhibit 2 - Classification of engagements**

| Date | Geographical Market | Industry-Ecosystem | Type of engagment | Firm type | Description |
|---|---|---|---|---|---|
| 12.09.2018 | Finland | Basic Materials | Dyadic | Non-mediating | Telia Company together with Stora Enso tested the augmented reality and 5G technology use cases in the forest industry. The solutions were tested at Stora Enso's Oulu mill in Finland where real-time information is being used in mill maintenance |
| 04.12.2019 | United Kingdom | Industrials | Dyadic | Mediating | Vodafone Business is collaborating with Amazon Web Services (AWS) to make AWS Wavelength available in Europe. AWS Wavelength provides developers with the ability to build applications that serve end users with single-digit millisecond latencies over the 5G network |
| 10.01.2018 | Germany | Consumer Cyclicals | Dyadic | Mediating | Vodafone Germany and HERE Technologies are developing the 5G Atlas for autnomous driving. |
| 14.06.2019 | Spain | Financials | Dyadic | Mediating | Banco Santander and Telefónica have reached an agreement to launch a joint innovation project on 5G technology applied to the banking business |
| 20.12.2019 | United Kingdom | Utilities | Multiple | Non-mediating | O2 and Ericsson build private 5G network with Northumbrian Water to explore the potential of 5G |

## Measures

Based on 297 observations of engagements in the ten Western European markets, the following measures were used to test the four hypotheses:

- *Competitors' engagement intensity*: The number of engagements that the competitors of a focal telecommunications operator have within a business ecosystem at the time of the focal telecommunications operator's engagement. Hereby, competitors are specified as every telecommunications operator with a "5G-license" within the same geographical market. Exemplified, if *Vodafone Germany* and *Deutsche Telekom* each engaged with one complementary actor in the economic sector "industrials" at time t-1, then the competitors' engagement intensity in "industrials" for an observation on *Telefonica Germany* at time t would be 2.

- *Time*: Date of publication of the press release that announced the complementary engagement.
- *Relative Industry Size*: Each economic sector is ranked according to its relative size within the geographical market that the observation pertains to. Industry sizes were ranked according to their relative importance within the economy of each geographical market. While transforming a continuous variable to ordinal rank risks weakening some of the data, the rank addresses the issues arising from the differences in the sizes of the economies. As telecommunications operators' "5G-licenses" are restricted to a given geographical market, the absolute size of industries in other economies are irrelevant to strategic decisions on which industries to engage with. Ranking the industry size to measure relative economic magnitude of industries within geographical markets is consequently merited as it reflects the choices faced by a telecommunications operator more appropriately than absolute industry size which would indirectly factor in economy size.
- *Market Concentration:* Herfindahl-Hirschmann-Index of market shares computed yearly for each geographical market: $\sum S_i^2 \times 10\ 000$, where $S_i$ is the market share of firm i.
- *Firm Type:* Each complementary actor who was engaged by a telecommunications operator was classified as being mediating or non-mediating according to the actor's value creation logic (Stabell & Fjeldstad, 1998). Mediating firms were classified as 1, non-mediating firms were classified as 0.
- *Type of engagement:* Each engagement was classified according to how many actors were part of the engagement. It was classified as 1 if the engagement was dyadic and 0 if the engagement involved multiple actors.
- *Business Ecosystem:* Each engagement was classified as being within one of ten different economic sectors according to the TRBC scheme.

**Exhibit 3 - Independent Variables**

*Descriptive statistics and corrrelation matrix of independent variables based on 297 observations*

| | Mean | Max | Min | StDev | Correlations | | |
|---|---|---|---|---|---|---|---|
| Competitors' engagement intensity | 3.03 | 17 | 0 | 3.96 | | | |
| Time | 29.10.2018 | 07.05.2020 | 01.12.2015 | 393 | 0.38*** | | |
| Market Concentration | 2960 | 4224 | 2214 | 467 | 0.072 | -0.0087 | |
| Relative Industry Size | 5.24 | 8 | 1 | 1.99 | 0.038 | 0.26*** | 0.13* |

* Represents signifiance on the 0.05, 0.01 and 0.001 levels

Exhibit 3 outlines descriptive statistics and a correlation matrix for the independent variables. Competitors' engagement intensity varies between 0 and 17 and the average engagement by telecommunications operators is done when their competitors already have roughly 3 engagements within that business ecosystem. Furthermore, the market concentration variable shows that the ten geographical markets are on average considered to be highly concentrated (US Department of Justice, 2018)[1].

The correlation matrix indicates that there is little correlation among the independent variables. The correlation of 0.38 between competitors' engagement intensity and time is relatively high compared to the other variables. The higher correlation is not surprising as the number of engagements will accumulate over time. Irrespective of the relatively high correlation, the variables of time and competitors' engagement intensity are not used in the same regression models and as such will not give rise to multicollinearity issues.

Exhibit 4, 5 and 6 show descriptive statistics for the three dependent variables. Both firm type and type of engagement are evenly distributed. Of the 297 engagement observations, 159 were with multiple actors and the remaining 138 engagements were dyadic. Furthermore, 160 of the engagements were with non-mediating firms while the remaining 137 were with mediating firms. The most popular business ecosystem to engage with among telecommunications operators was "industrials" with 30.6% of the observations, followed by "consumer cyclicals" (29%) and "telecommunications" (20.2%). Exhibit 7 and 8 present an overview of the observations collated by telecommunications operator, geographical market, and year.

**Exhibit 4 - Type of Engagement**

*Descriptive statistics of type of engagement based on 297 observations*

| Multiple | Dyadic | n | Min | Max | Mean | StDev |
|---|---|---|---|---|---|---|
| 159 | 138 | 297 | 0 | 1 | 0.465 | 0.4996 |
| 0.535 | 0.465 | | | | | |

The categories are categorized 0-1 based on the order above

**Exhibit 5 - Firm Type**

*Descriptive statistics of firm type based on 297 observations*

| Non-Mediating | Mediating | n | Min | Max | Mean | StDev |
|---|---|---|---|---|---|---|
| 160 | 137 | 297 | 0 | 1 | 0.461 | 0.4993 |
| 0.539 | 0.461 | | | | | |

The categories are categorized 0-1 based on the order above

[1] For the market concentration levels, we used the classification given by the US Department of Justice as an orientation. The reason is, that the measurement guidelines by the European Union (specified under EU-Law '2004/C 31/03', within the scope of '(EC) No 139/2004') apply to situations around mergers and acquisitions, thus not to the context of this thesis.

**Exhibit 6 - Engagements**

*Descriptive statistics of vertical engagements based on 297 observations*

| Type | Max | Min | Mean | StDev |
|---|---|---|---|---|
| Categorical Variable | 9 | 0 | 5.189 | 3.072 |

| | Basic Materials | Consumer Cyclicals | Consumer Non-Cyclicals | Energy | Financials | Healthcare | Industrials | Technology | Telecommunications Services | Utilities | n |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | 2 | 86 | 3 | 1 | 4 | 16 | 91 | 21 | 60 | 13 | 297 |
| | 0.007 | 0.290 | 0.010 | 0.003 | 0.013 | 0.054 | 0.306 | 0.071 | 0.202 | 0.044 | |
| Austria | | 3 | | | | | 3 | | | | 6 |
| Denmark | | 1 | | | | | 1 | | 5 | | 7 |
| Finland | 1 | 5 | 1 | | 2 | 3 | 18 | 2 | 3 | | 35 |
| Germany | | 23 | | | | | 19 | 1 | 14 | 3 | 60 |
| Ireland | | 1 | | | | 2 | | | 2 | | 5 |
| Italy | | 11 | 1 | | | 2 | 23 | 8 | 17 | 3 | 65 |
| Norway | | 4 | 1 | 1 | | | 4 | | 3 | | 13 |
| Spain | | 21 | | | 2 | 6 | 8 | 3 | 9 | 1 | 50 |
| Sweden | 1 | 2 | | | | | 9 | | 4 | 4 | 20 |
| United Kingdom | | 15 | | | | 3 | 6 | 7 | 3 | 2 | 36 |

The categories are categorized 0-9 based on the order above

**Exhibit 7 - Telecommunications Providers**

*Observations per network service provider*

| Network Service Provider | Geographical market | Observations |
|---|---|---|
| Drei | Austria | 1 |
| T-Mobile | Austria | 5 |
| 3 | Denmark | 2 |
| TDC | Denmark | 1 |
| Telenor | Denmark | 4 |
| DNA | Finland | 5 |
| Elisa | Finland | 13 |
| Telia | Finland | 17 |
| Telefonica | Germany | 12 |
| Telekom | Germany | 31 |
| Vodafone | Germany | 17 |
| Dense Air | Ireland | 3 |
| Vodafone | Ireland | 2 |
| Illiad | Italy | 1 |
| Fastweb | Italy | 14 |
| Telecom Italia (TIM) | Italy | 46 |
| Wind Tre | Italy | 4 |
| Telenor | Norway | 5 |
| Telia | Norway | 8 |
| Orange | Spain | 9 |
| Telefonica | Spain | 28 |
| Vodafone | Spain | 13 |
| Telenor | Sweden | 2 |
| Telia | Sweden | 18 |
| O2 | United Kingdom | 16 |
| Three | United Kingdom | 3 |
| EE (British Telecom) | United Kingdom | 4 |
| Vodafone | United Kingdom | 13 |
| | | 297 |

**Exhibit 8**

*Observations per year*

| Year | Observations |
|---|---|
| 2015 | 4 |
| 2016 | 16 |
| 2017 | 39 |
| 2018 | 79 |
| 2019 | 134 |
| 2020 | 25 |
| | 297 |

## Results

Due to the categorical nature of the dependent variables, the hypotheses were evaluated using logistic regressions. The use of logistic regression analysis has become a crucial part of the methodology in strategic management (Glenn, 2007). Specifically, logistic regression models have merit in the investigation of firms with a mediating value creation logic (Chen & Macmillan, 1992; Chen et al., 1992; Fjeldstad et al., 2004). We performed three different logistic regressions to test the four hypotheses.

*Hypothesis 1* and *2.1* were tested using a conditional multinomial logistic regression model as the dependent variable consists of ten different alternatives. The conditional multinomial logistic regression is suitable when the choices are dependent on characteristics of the choices itself (i.e. one of ten economic sectors) rather than characteristics of the entity making the choice (i.e. telecommunications operators with “5G-licenses”) (Hoffman & Duncan, 1988, p. 415). The log of the probability of a telecommunications operator engaging in one of the business ecosystems over the log of the probability of the telecommunications operator engaging in any of the other nine business ecosystems was regressed over competitors' engagement intensity and relative industry size (see Exhibit 9). The interpretation of the coefficients is such that if the exponential of the coefficient is larger than one, the independent variable is associated with an increase in likelihood, while an exponential below one is associated with a decrease in likelihood. The market shares were only publicly available on a yearly basis for most geographical markets, and as such the market concentration variable was only computed yearly. The consequence is that the market concentration variable has too little variation to be included in the wide format required by a multinomial logistic regression. The reason is that the statistical tools applied to perform the regression are unable to compute the necessary matrix calculations when most of the observations have the same market concentration data input. Market concentration was consequently dropped as a control variable to test the likelihood of engaging within different business ecosystems.

*Hypothesis 2.2* and *3* were tested using a binomial logistic regression as the dependent variables are binary (i.e. mediating versus non-mediating firms and dyadic engagement versus multiple engagement partners). Firstly, to test *hypothesis 2.2* the log of the probability of an engagement being with a mediating firm over the log of the probability of an engagement being with a non-mediating firm was regressed over the variables time, relative industry size and market concentration (see Exhibit 10). Secondly, the log of the probability of an engagement being dyadic over the log of the probability of an engagement being with multiple engagement partners was regressed over the same variables to test *hypothesis 3* (see Exhibit 11).

The fit of the models was evaluated using McFadden's $R^2$, considered by Menard (2000) as the most appropriate measure of fit for logistic regressions. McFadden's $R^2$ is "[…] close conceptually as well as mathematically" (Menard, 2000, p. 20) to the ordinary least squares $R^2$, but yields lower estimates and should be interpreted less stringently (Smith & McKenna, 2013). For all three models McFadden's $R^2$ indicates that the independent variables have explanatory power over the dependent variables. To evaluate the robustness of the models, we gradually inserted variables. In all three models McFadden's $R^2$ increased with added variables, indicating that the explanatory power of the models grew in the process.

*Hypothesis 1*, that the likelihood of telecommunications operators to engage with a given business ecosystem decreases with the competitors' engagement intensity in that business ecosystem, received strong support at the 0.001 confidence level (see Exhibit 10). However, contrary to our expectations, that the likelihood of a telecommunications operator to engage in a business ecosystem will increase with business ecosystem size, did not receive support. Consequently, *hypothesis 2* was rejected. Furthermore, *hypothesis 2.2* received support at the 0.05 confidence level, indicating that telecommunications operators are indeed more likely to engage with other mediating firms in larger business ecosystems (see Exhibit 10). Lastly, *hypothesis 3* was supported on the 0.001 confidence level (see Exhibit 11). This supports the hypothesis that telecommunications operators are more likely to engage dyadically as time progresses.

**Exhibit 9 - Likelihood of engaging with business ecosystems**

Conditional Multinomial Logsitic Regression Model

| | *Dependent variable (log odds):* Prob(Vertical Industry/Alternatives) | |
|---|---|---|
| | Model 1 | Model 2 |
| *Independent variables* | | |
| Competitors' engagement intensity | -0.10272** | -0.10741*** |
| Relative Industry Size | | -19.845 |
| McFadden's $R^2$ | 0.13465 | 0.14448 |
| Chi-square | 134.64 | 144.46 |
| P-value | <0.001 | <0.001 |

*N = 297 observations (vertical engagements)*

Insignificant intercepts and country dummy variables not shown

* Represents signifiance on the 0.05, 0.01 and 0.001 levels

**Exhibit 10- Likelihood of engaging with mediating or non-mediating firms**

*Binomial Logistic Regression Model*

| | *Dependent variable (log odds):* Prob(Mediating/Non-mediating) | | |
|---|---|---|---|
| | Model 1 | Model 2 | Model 3 |
| Intercept | 0.6471 | -1.1539*** | -3.816 |
| *Independent variables* | | | |
| Time | | 0.0001 | 0 |
| Relative Industry Size | 0.1574* | 0.1527* | 0.1590* |
| Market Concentration | | | 0.00147 |
| McFadden's $R^2$ | 0.06303 | 0.06323 | 0.0672 |

*N = 297 observations (collaborative engagements)*

Results control for 10 country dummy variables (coefficients not shown)

* Represents signifiance on the 0.05, 0.01 and 0.001 levels

**Exhibit 11 - Likelihood of engaging dyadically or with multiple partners**

*Binomial Logistic Regression Model*

| | *Dependent variable (log odds):* Prob(Dyadic/Multiple) | | |
|---|---|---|---|
| | Model 1 | Model 2 | Model 3 |
| Intercept | -28.03*** | -29.92*** | -32.17*** |
| *Independent variables* | | | |
| Time | 0.001586*** | 0.001727*** | 0.001691*** |
| Relative Industry Size | | -0.1079 | -0.106 |
| Market Concentration | | | 0.00096 |
| McFadden's $R^2$ | 0.07795 | 0.08406 | 0.08507 |

*N = 297 observations (collaborative engagements)*

Results control for 10 country dummy variables (coefficients not shown)

* Represents signifiance on the 0.05, 0.01 and 0.001 levels

# Discussion

In this thesis, we aimed to explore influences on diffusion behaviour of telecommunications operators in regard to the composition of network users by taking into account the layered architecture of networks and local network effects in user-groups. We illustrated the telecommunications operators' layered market-structure as a basis, accounting for distinct business ecosystems. The introduction of 5G-technology served as a context to investigate how telecommunications operators engaged in business ecosystems to obtain critical mass. We proposed four hypotheses, arguing that the engagement behaviour of competitors, the business ecosystem size, and time evolution moderate telecommunications operators' engagement behaviour. As expected, the findings show that telecommunications operators are less likely to engage with business ecosystems where their competitors exhibit a high degree of engagement intensity. Our findings also indicate that the likelihood of engaging with mediating firms increases with the size of a business ecosystem and that engagements in dyadic collaborations increase as time progresses. Contrary to our expectations, we did not find statistical support for our hypothesis that larger business ecosystems increase the likelihood of a telecommunications operator to engage. In the following, we will discuss these results and elaborate on their implications for research and management practice.

The finding that telecommunications operators choose which business ecosystem to engage with based on where their competitors engage indicates that intra-industry rivalries have an adverse effect on the preference to follow a *local strategy* in that business ecosystem. As we anticipated, telecommunications operators refrain from aggressive competitive activity due to the prospect of negative returns and the possibility to free-ride in the respective business ecosystems during a later phase. Our finding is in line with earlier findings of Chen and Macmillan (1992) and Chen et al. (1992). Their research, grounded on a game-theoretic approach, investigates the competitive behavior of the firm and the ability "play tough" by making credible commitments. Nonetheless, substantial commitments are not only a signal to the competitors, but also to the users, who interpret high commitments as dedication to network development, which subsequently creates positive network effects (Katz & Shapiro, 1994).

A telecommunications operator who can internalize a majority of the accruing network effects may ultimately become the dominant business ecosystem operator due to user expectations of market dominance (Katz & Shapiro, 1985). The dominant mover can initially exert influence over the design of the technological system (Bresnahan, 2001) and may prefer technological incompatibility (Katz & Shapiro, 1992) which is possible even under the general European compatibility regulations (Fjeldstad et al., 2004, p. 178). This gives rise to lock-in effects for the early users in the market (Farrell & Klemperer, 2007), which may be advantageous for the respective telecommunications operator due to the extension and preservation of a direct user base (Witt, 1997). Nonetheless, the creation of lock-in effects seems counter-intuitive as the concentrated enclosure of user groups hinders the expansion of transactions across markets, limiting the extension of network effects to the locked-in user groups (Parker & Van Alstyne, 2005). Further, unattractive lock-ins and expectations of low future competition may deter user adaptation and place the dominant mover in a disadvantage (Katz & Shapiro, 1986a). Thus, strong signals of future market dominance and the creation of functional incompatibilities may not be initially preferred by network service firms as it threatens the generation of a critical mass. Albeit, the choice to follow a lock-in strategy may exhibit a future advantage for the respective network service firm, as closed systems bear switching costs for users, thus raising entry barriers for later competitors (Eisenmann et al., 2011; Farrell & Klemperer, 2007).

The fact that telecommunications operators prefer to engage less intensely where their competitors exhibit dominance suggests that they tend to follow a free-riding strategy. In a free-riding strategy the telecommunications operator enters late into a business ecosystem and appropriates some of the externalities generated by the dominant early mover. Although entry barriers may have risen at this point, the follower has sunk fewer investments into obtaining a critical mass. Furthermore, followers have been argued to surpass the dominant mover if they can achieve a superiority in complementary assets (Tucker, 2008), provide a better technological functionality (Henderson & Clark, 1990) or follow a combined product strategy of tying or bundling (Eisenmann et al., 2011). Thus, as long as the free-riding telecommunications operators are somewhat present in the market and closely follow structural as well as technological developments within the business ecosystem, they might be able to attack the dominant mover and gain market shares (Eisenmann et al., 2011; Farrell & Klemperer, 2007).

Our results show that the size of the business ecosystem has no effect on the network service firms' choice of engagement intensity. This is an intriguing finding as it implies that the decision to strategically engage with business ecosystems is based on other rationales than their economic importance. Telecommunications operators are attracted to large business ecosystems due to their higher number of layers (Stabell & Fjeldstad, 1998) and service development potential (Evans & Wurster, 1999). The considerable ecosystem size requires substantial investments to obtain the intended critical mass by user expectations (Katz & Shapiro, 1992). Our analysis has shown that such large commitments by one telecommunications operator deter the competitors from entering. Thus, the high investment requirements in large business ecosystems alongside the finding that competitors' engagement intensity deters entry may explain the insignificance of relative business ecosystem size. Additionally, earlier research has indicated that network service firms have ample reasons to favor smaller business ecosystems. Platforms have been observed to follow "trial and error"-approaches, where they build footholds in smaller markets first to establish suitable technological and operational standards (Evans, 2003, p. 200). The complexity of actors is generally lower in these markets, and the network service firms may also be aiming at targeting self-sufficient groups of users, generating critical mass for small but distinct populations (Rohlfs, 1974), before moving to larger ones.

Another interpretation of this result is that the availability of complementary actors (McIntyre & Subramaniam, 2009) may not be an increasing function of the business ecosystems' size. Teece (2007) argues that a business ecosystem contains a community of actors such as complementors, suppliers and institutions that influence the dynamics of firm behaviour. As the composition of such communities is unique to some extent, the proportion of complementary actors may not be identical across all business ecosystems. Thus, since scale and composition of user groups play a crucial role in the service development for the network service firms, the whole structure of the business ecosystem may be considered independently from overall ecosystem size. This implies that telecommunications operators will consider the composition of an business ecosystem rather than its size when determining where to engage.

The engagement choice of network service firms may be contingent on the abilities and social conditions residing in the ecosystems rather than their size. Assuming a "probit model" of technology adoption, where firms have different preferences when to adopt a technology, telecommunications operators may have identified which actors in which business ecosystems will be more receptive to technological change (Geroski, 2000, p. 610). Some business ecosystems may display better adaptive capabilities or business cases (Schilling & Esmundo, 2009). Other business ecosystems may open a playground to define various use cases for the technology with the users, which in turn impacts its design (Abernathy & Utterback, 1978) and the overall orientation of the telecommunications operator. To identify such opportunities, the respective telecommunications operators may have an ecosystem-specific "absorptive capacity" (Cohen & Levinthal, 1990). It may also be the case that they are embedded in the business ecosystem by some form of organizational or transactional tie, thus having more accurate information about the respective structure (Fjeldstad & Sasson, 2010). Additionally, industry embeddedness can potentially provide a beneficial basis for collaborative engagements through resource compatibility (Mitsuhashi & Greve, 2008) and therefore ease inter-firm relations regardless of the business ecosystem's characteristics.

Our findings show that the larger the relative business ecosystem size, the higher the likelihood to engage with a mediating actor rather than a non-mediating actor. The higher number of complementary layers in larger industries should not only naturally increase the excess inertia observed to be residing amongst actors (Katz & Shapiro, 1992) but also the complexity of the ecosystem, making it more difficult for telecommunications operators to accurately address and incentivize complementary actors (Gawer & Cusumano, 2014). Thus, technology diffusion by means of collaborating with complementary mediating firms is relevant in large business ecosystems, as it entails some advantages. Firstly, the users of complementary mediating firms stretch across firm-boundaries (Stabell & Fjeldstad, 1998) giving a larger starting base for the generation of a critical mass. Secondly, platforms occupy various affiliations to other platforms within their network structure (Eisenmann et al., 2011) giving the potential to diffuse the technology both vertically and horizontally from the perspective of the complementary platform. Consequently, faced with a large business ecosystem requiring substantial investments to obtain a critical mass, a telecommunications operator is incentivized to engage with other mediating firms as they provide access to already existing user-bases, both horizontally and vertically.

Telecommunications operators are also incentivized to engage with other mediating firms in large business ecosystems as the mediating complementors are confronted with similar network externalities and competitive assumptions. One of them is that once a platform starts losing users, the network effects will result in an opposite force dragging users from the platform (Evans, 2009). Thus, in order to not get pushed out of the market and quickly fall into irrelevance, much like the broadly discussed “Netscape”-case (e.g. Farrell and Weiser (2003), Shapiro (1999, p. 2)), platforms need to stay competitive. This circumstance may fuel the diffusion of a technology through complementary platforms since these actors have a self-interest to remain innovative and may promote the technology to their own users. Consequentially, telecommunications operators may be held hostage by their own reputation through the promotion of the technology by complementary platforms, raising user expectations but putting pressure on the reliability and functionality of the technological system (Katz & Shapiro, 1994).

The findings also show that dyadic engagements become more likely over time, as opposed to engagements with multiple collaborators. The need for controlled, dyadic diffusion over time can stem from multiple origins, such as an increasing need to appropriate value from the service (Shapiro, 1999, p. 153), create bandwagon-effects for a more widespread diffusion (Farrell & Saloner, 1985) or to close gaps in the network (Tucker, 2008). Further, collaborative engagements can be used to accelerate a technology into a specific group of users (Powell, Koput, & Smith-Doerr, 1996), potentially through a centrally-located actor. These key actors, who foster the diffusion of a technology by their location within a specific network

(Afuah, 2013; Tucker, 2008), may only become identifiable for a focal telecommunications operator over time or with increasing experience in the industry (Fjeldstad & Sasson, 2010). Considering the compositional aspects of local industry contexts (Teece, 2007), diffusion through a few central players may not only be more economically efficient but also increase the likelihood to obtain a critical mass within the respective user group. Closing “structural holes” (Burt, 1992), i.e. gaps within the network, can contribute to a successful diffusion of the technology, if the central network actors are targeted (Tucker, 2008), and ultimately increase the network service firms’ performance (Zaheer & Bell, 2005).

There are additional reasons for the finding that collaborative engagements become more targeted over time. Hagedoorn (1993, p. 372) argued that firms pursue cooperation on technologies i.a. to “[…] assess technological synergies [and] near-future results of […] relevant complementarities of technologies”. The basis for this is the accumulation and improvement of knowledge specific to business ecosystems through early engagements with a maximum of actors. If the ongoing evaluation of synergetic potential in technological collaborations is multilateral between the parties, time may be a necessary contingency to the self-assignment of complementary innovators to network service firms (Gawer, 2014). The active operation of complementary actors towards telecommunications operators may also be initiated as reputation is built over time (Katz & Shapiro, 1994). Further, the conversion from multi-actor to dyadic collaborations is consistent with the argument that there is a general path-dependence of relationsips in network markets, where knowledge-sharing reinforces inter-firm relations (Jacobides, Cennamo, & Gawer, 2018). The knowledge specific to a business ecosystem may also enable the respective telecommunications operator to assess the relevance of technological use cases or particular complementary actors as well as organizational capabilities and assets. The latter two have crucial importance for a profitable introduction of a novel technology (Teece, 1986).

## Limitations

Although this study enhances the understanding of network service firm behaviour, it is limited by several aspects. For one thing, the number of observations is neither evenly nor proportionally distributed across the ten geographical markets included in the data collection. It is not surprising that there are more observations in the larger economies, but this nevertheless creates a bias in the dataset in favour of large economies. Likewise, there are notable differences in the number of observations per telecommunications operator. Additionally, of the 36 telecommunications operators who obtained a “5G-license”, only 27 are present in our dataset. Generally, it is the dominant actors in the ten geographical markets who are actively engaging with complementary actors. The nine telecommunications operators who do not engage at all are unobservable in the dataset. In sum, the bias towards larger economies and more active telecommunications operators potentially reduces the generalizability of the results and findings.

As only engagements are included as observations, the collected data does not account for telecommunications operators who deliberately chose not to engage. This methodological limitation is parallel to limitations faced by Chen et al. (1992) when they investigated actions and response lag. The mathematical models applied in the analysis of the data assume that a focal telecommunications operator will make a deliberate choice between ten defined business ecosystems when engaging with a complementary actor. For every observation, the option *not* to act is not accounted for, even though the choice of not engaging may be strategically reasoned by the focal telecommunications operator. Consequently, one should be careful to extrapolate the findings presented here to situations where a network service firm chooses *not* to engage with complementary actors.

Lastly, engagements with business ecosystems were classified by economic sectors, the top of the hierarchy of the TRBC (Phillips & Ormsby, 2016, p. 8). This was done to ensure reliability and consistency in categorization as the level of detail in the press releases regularly made it impossible to classify the engagement more specifically than economic sector. Had a more fine-grained classification of business ecosystems been possible, it may have provided additional insights into differences that exists within the economic sectors. As such the use of TRBC’s economic sector tier of classification represents a limitation of this study.

## Further areas of research

This study draws on perspectives of network externalities and multi-layered complementarity with technology diffusion and can serve as a foundation for a variety of further research areas. Firstly, we want to address a limitation of our research that does not account for the deliberate choice of telecommunications operators not to engage. Although the results of the analysis show that network service firms may rely on their competitors to obtain a critical mass within a business ecosystem, there is an opportunity to examine a variety of characteristics of layered ecosystems that may cause purposeful inactivity. This echoes a call for further research on platform strategies by Jacobides et al. (2018, p. 2268) for an elaboration on when network service firms decide to “rely on markets”. For example, potential spill-overs of information raising network expectations across industry boundaries (Geroski, 2000; Katz & Shapiro, 1994) or the deliberate targeting of actors, who centrally connect various other actors and may diffuse a technology (Afuah, 2013; Tucker, 2008) across ecosystem boundaries could improve the understanding of why a focal network service firm could have incentives to deliberately choose to avoid a given business ecosystem.

Although it was argued that collaborative engagements represent a beneficial diffusion strategy, it is certainly not the sole mode of interaction with complementary actors in that context. Thus, an examination contrasting the interaction strategies of network service firms could illuminate their differentiated efforts to create network expectations. Hereby, the range of inter-firm relationships could orientate itself towards the list introduced by Farrell and Weiser (2003, p. 13), which includes joint ventures and alliances, “tie-ins, partial equity investments, long-term contracts, and affiliate relationships”. This investigation could be enhanced by the addition of less “classical” but recently prominent modes of inter-firm relations in network markets, like programs for open innovation (Boudreau, 2010; Schilling, 2009) or platform envelopment, where common user bases are leveraged by combination of platform services across market boundaries (Eisenmann et al., 2011).

Future research should further consider the implications of how horizontal relationships between network service firms influence the choice of their diffusion strategy. Although horizontal engagements become more likely during a later phase (Fjeldstad et al., 2004), in the absence of distinct consumer groups and presence of potentially global network effects, users recognize the adoption of the entire population (Farrell & Klemperer, 2007). Considering the generally compatible systems in the European markets, network service firms may prefer to cooperate on a diffusion strategy to jointly raise network expectations. Additional to horizontal inter-firm relations, an interesting area of research are the effects of cross-border intra-firm relations of telecommunications operators. Prior research has described the extension of knowledge flows and differences between regional subsidiaries of multi-national corporations (Gupta & Govindarajan, 1991). Identifying the path, medium and magnitude of influence, regional subsidiaries have on each other's diffusion-decision regarding business ecosystems, may offer a valuable perspective on the matter at hand.

Lastly, it may be beneficial to diverge from the view that business ecosystems are homogenous in their characteristics other than size. As specified in the discussion of the results for *hypothesis 2.1,* business ecosystems may be fairly heterogenous from a telecommunications operator's perspective in their ability to adopt a novel technology (Schilling & Esmundo, 2009), in the existence of collaboration-easing assets (Mitsuhashi & Greve, 2008) and predominantly in their composition (Teece, 2007), especially in the composition of complementary actors. Accounting for more fine-grained structural differences between the business ecosystems could be an explanation for varying intensities of engagements in the technology diffusion strategy of network service firms and thus constitute a useful extension of this thesis.

## Implications for managers

Stabell and Fjeldstad (1998) established that the management of service contracts is a primary activity for network service firms. The findings presented in this study emphasize the importance of such an activity for telecommunications operators to diffuse a technology and create positive expectations. Thus, managers should pay close attention and put significant efforts into it, particularly by assessing the management of contracts in the context of their layered environment. Our study specifically highlights two aspects.

Firstly, managers should note that investments and commitments towards a given business ecosystem are observed by competitors and act as a deterrent to engagement. While this represents an opportunity for managers to establish a dominant position, it also implies that the dominantly moving telecommunications operator should expect to carry "most of the weight" for obtaining a critical mass in business ecosystems where they engage intensely. At the same time, managers should not interpret the results to assume that dominant positions, established through a high engagement intensity, imply that the respective telecommunications operator is able to internalize most network effects without competition ad infinitum. Free-riding strategies allow telecommunications operators to keep presence in business ecosystems on low engagement intensity with the likely opportunity to enter during a later phase. As argued before, previous research has shown that late entry actors may outcompete incumbents in various situations (e.g. Tucker (2008), Henderson and Clark (1990) or Eisenmann et al. (2011)).

Secondly, managers should pay close attention to their surrounding layered market structure. This is predominantly, because the complementary actors are not only co-producing value in services but may also be useful partners in the diffusion of a technology. As the results show, telecommunications operators adapt their collaboration-choice with complementary actors based on the business ecosystems characteristics. This may improve the diffusion efforts in context to the respective economic environment. Nonetheless, managers should carefully plan the extension of their collaborative efforts ahead, as the appropriation of value gains an increasing relevance with investment activity and the control over profit streams remains. The benefits of a balance between more open diffusion and controlled collaborations should be evaluated as time progresses.

## Conclusions

In this thesis we aimed to investigate how structural and compositional factors influence the diffusion strategy of telecommunications operators across multi-layered market structures. The results show that telecommunications operators are less likely to engage with a complementary actor in a business ecosystem if their competitors are already demonstrating a high degree of engagement intensity in the same area. Furthermore, the findings highlight important aspects of the composition of an ecosystem in the diffusion of a novel technology. Specifically, telecommunications operators are more likely to engage with mediating complementary actors in larger business ecosystems and more likely to engage dyadically as time progresses. These findings have important implications both for strategy scholars and managers alike. Firstly, this study gives novel insights into the orientation of telecommunications operators' diffusion strategies in their endeavor to obtain critical mass and subsequent network effects. It expands the understanding of how telecommunications operators diffuse technology by recognizing the multi-layered structure of mediating business environments. The analysis shows that telecommunications operators make clear strategic choices in the governance of complementary actors by considering the diffusion activity of their competitors and the composition of the ecosystem. Accordingly, there is further opportunity to investigate the related network firm behavior, specifically by contrasting the inter-firm affiliations for diffusion, including horizontal ones, and by developing a more fine-grained understanding on activity conditioned by ecosystem heterogeneity. Lastly, this study highlights the importance of value networks' primary activity of managing contracts and relationships. Managers should balance their diffusion activity in relation to their competitors' activity and pay close attention to favorable compositional structures in their multi-layered environment.

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