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Is network sharing changing the role of mobile network operators?

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1 Introduction

1.1 Operators reducing the cost base

The combination of maturing mobile markets with lower revenue growth, less influx of new subscribers, intense competition has placed the issue of consolidation and network sharing on top of operators' agenda.

The EU Commission's arm for competition issues, DG-Comp is analyzing Telefonica's EUR 8.6 bn acquisition of E-Plus in Germany, scrutinizing the remedies that Telefonica has proposed, which aim to offset the competition concern that DG-Comp has expressed. The outcome of the regulatory approval is expected to have a significant impact on the formation of the future European operator landscape. Moreover, Hutchison's acquisition of Telefonica's mobile operation in Ireland is also being analyzed by DG-Comp. A major concern for the Commission is that these two mergers would reduce the number of mobile network operators from 4 to 3 in both Germany and Ireland, potentially leading to higher retail prices. This worry has been confirmed by the outcome of the consolidation in Austria where Hutchison acquired Orange Austria in December 2012, reducing the number of mobile network operators from 4 to 3, and resulting in higher prices, although from a comparable low level.

The transition to mobile data challenge established business models and the profitable voice operation, illustrated by the fact that mobile voice generates over EUR 200 per GB while mobile broadband generates around EUR 4 per GB.[2] The ubiquitous availability of smartphones has not only facilitated an app market driven by over the top players (OTT), it has also blurred the distinction between mobile and fixed networks as the majority of data consumed in smartphones are offloaded to WiFi using fixed broadband networks as backbone, and lead to increased competition for mobile network operators from OTT-players, and required continued network investments. Consequently, average capex-to-sales for European operators' remain stable around 15 percent as the following figure illustrates.

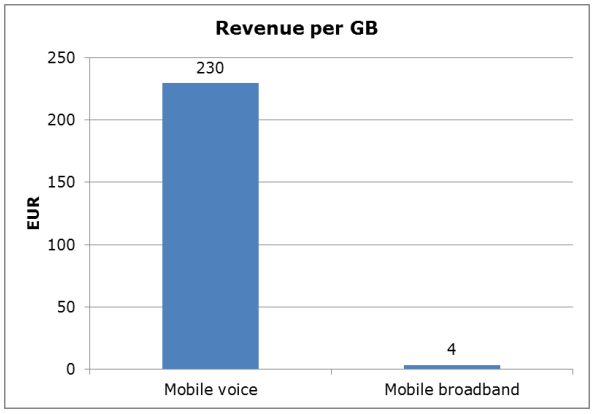
This development has diluted revenue growth, as the following figure illustrate, and forced operators to launch efficiency programs, and pursue network sharing. Network sharing is nowadays used by most operators, primarily sharing of passive infrastructure, and it could broadly be grouped into three categories: 1) agreements between operators that share parts or even entire networks, 2) separate network companies that operate on the behalf of their owners, and 3) independent infrastructure companies, which provide tower, passive and active infrastructure, and potential outsourcing services.

Passive network sharing is used in all countries in the EU, and active network sharing is used by operators in several countries, such as the UK, Sweden (BEREC (2011)). In the US, Africa and Asia (India, Indonesia) network sharing primarily consists of site sharing where mobile operators lease antenna space from tower companies.

Network sharing is raising fundamental questions about competition. It is for example, the tradeoff between infrastructure and service competition, and whether service competition is sufficient to provide end-customers with a broad range of price worthy services, and how it influence the willingness for operators to invest.

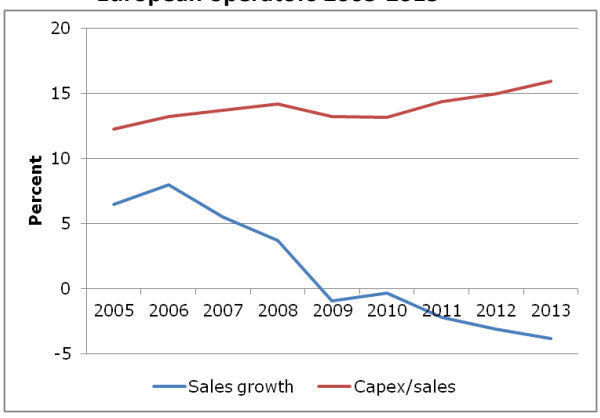
[2] The calculation is based on data for mobile communications in Sweden 2013 with million mobile voice minutes *(47*60/8), 47= kbps, 60 seconds per min, 8 = kilobits per byte), source: PTS, link www.PTS.se/statistics

Figure 1 Revenue per GB for mobile in Sweden 2013



Source: PTS statistics and authors calculation

Average capex-to-sales and sales growth for European operators 2005-2013[3]



Source: Bloomberg

Mobile operators predominately build their macro networks with sites deployed outdoor while a growing share of the usage is taking place indoors, implying an inefficient use of energy and spectrum. Given that facility owners are reluctant to allow parallel networks in buildings, and shopping centers the development of indoor systems require some sort of network sharing. All in all, network sharing has become an inevitable part of the telecom industry.

1.2 Objective, research questions and contribution

Given that network sharing is a wide concept and used throughout the industry it raises a number of interesting questions and issues. The mindset in the mobile industry is based on the deployment of macro networks, making small cell networks and indoor networks to a potentially disruptive issue for mobile operators as facility owners seems to be reluctant to have parallel networks.[4]

As network sharing means that competitiors collaborates it entails risks to competition if sensitive information, like for example about retail offers are leaked. This requires that network sharing agreements stipulates a usage of "Chinese walls" and strictly limits the sharing to the wholesale operation and thereby minimize the risk for tacit collusion between mobile network operators.

Network sharing leads to the formation of so called "network clubs" which could make it difficult for other players and new entrants to be competitive on the market. What advantages do the parties to a network sharing agreement have compared to competition? Moreover, the question is what impact network sharing has on the wholesale markets as the reduction of parallel network decrease possible providers for Mobile Virtual Network Operators (MVNO).

Furthermore, the question is how network sharing influences the involved operators' ability to differentiate from competition on coverage, capacity and speed? Is network sharing undermining the idea of parallel infrastructures, which is the cornerstone of the competition regime? Altogether, network sharing has been driven by the potential to lower cost, but it could also be a way to meet future challenges. This paper focus on two research questions:

RQ 1: How is network sharing influencing the competition on the downstream market and what is the impact of network sharing has on profitability and competition?

[3] Based on an average on company ratios for: BT, DT, FT, KPN, Swisscom, Telefonica, and TeliaSonera

[4] See Markendahl and Ghanbari (2013)

RQ 2: What is the role of network sharing in developing the operator business and transforming the operator business?

1.3 Paper outline

This paper builds on previous research conducted by the authors and analyzes network sharing from a number of different perspectives. The following chapter gives a definition of network sharing, and an overview of the literature that cover issues about network sharing. Given that the competition regulatory framework regards network sharing as horizontal agreements it is relevant to incorporate the concept of co-opetition, which combines co-operation and competition. A section of the regulatory framework is followed by a section of the research approach and data collection. Given that network sharing is a global phenomenon, the paper gives a brief description of network sharing in Sweden, examples of network sharing in Europe and a short overview of network sharing in the US, which is dominated by tower companies. The mindset among mobile network operators revolves around macro networks which make the growing demand for indoor networks to a potential disruptive force motivating a section of indoor sharing. In order to quantify the possible economic gains of network sharing, the paper explores two scenarios, urban and rural, for implications on the cost structure with network sharing. The analysis in chapter 5 address the question of competition on the downstream market by comparing retail baskets provided by the OECD, and the financial impact of network sharing is analyzed in the following section. The impact of network sharing on market structure and competition is addressed in the following section. The last section in chapter 5 discusses the potential transformation of the operator business that network sharing could contribute with. Chapter 6 highlights the main points in paper and in the final chapter do we outline issues for further research.

2 Definition, related work and methodology

2.1 Introduction

This chapter presents a definition of network sharing, and gives an overview of related works about relevant reports, papers and books that cover the subject of network sharing. The subject of co-operation between competitors is labeled as co-opetition and is the focus on the following section. Given that network sharing has a potential consequence of competition the paper describes the regulatory framework. The chapter is concluded with a section of the research approach and data collection.

2.2 Definition of network sharing

Network sharing agreements range from passive network sharing, e.g. sharing of sites, mast, base station, over active network sharing, such as Radio Access Network sharing sometimes combined with spectrum sharing, to full sharing with core networks. It could also be national roaming and MVNOs, which enables usage of other operators' networks. Network sharing could also be cases where operators share networks in different geographical areas. Outsourcing is also a form of network sharing. The following table defines different types of network sharing.

Table 1 Definition of network sharing

Type of network sharing	Characteristics
Passive network sharing	Sharing of passive elements of network like towers, mast, sites, cabinet, power, conditioning.
Active RAN network sharing	Sharing of active equipment in the access network, like antenna, node, radio network controller elements, sharing of the radio access network (RAN), backhaul segment to the RNC (radio network controller).
Core network sharing	Sharing of core networks relate to active equipment with switches (SGSN, MSC, HLR, and GGSN).
Spectrum sharing	Sharing of spectrum could be in the form of pooling of spectrum
National roaming and MVNO	Such agreements are a sort of network sharing as network operators open their network for other operators

Network sharing is not only relevant for mobile networks as it is also used in fixed networks, such as co-investments of fiber networks, geographical split of fiber networks, sharing of access networks through unbundling, sharing of transmission networks in the core and backhaul, or leased from other operators.[5]

2.3 Network sharing – a way to lower cost and improve coverage

The interest for network sharing has gradually increased as it is on the agenda for operators, equipment manufacturers, regulators, and competition authorities around the world. This has generated a large number of reports, white papers and academic papers.

GSMA (2012) present a view on different types of network sharing, the strategic rationale for infrastructure sharing, the economic and regulatory considerations as well as technical and environmental issues. The report underscores that it is commercial considerations rather than regulatory mandates that drive the trend for mobile operators to adopt a variety of infrastructure

[5] Two report that focus on network sharing on fixed networks: 1) Berec published a report in May 2012: Co-investment and significant market power (SMP) in Next Generation Access Networks (NGA), BoR 12(41), and 2) Oxera prepared a report for Vodafone in November 2011, How a co-investment model could boost investments in NGA networks, Feasibility and implementation of a co-investment model.

models through infrastructure and network sharing. Based on interviews with mobile operators GSMA (2012) conclude that for mobile operators in mature markets infrastructure sharing offers a way to reduce capital and operating expenditures as well as it get access to sites. Infrastructure sharing for operators' in developing market primarily represents a way to cost efficiently increase coverage. Infrastructure sharing is increasingly being used in congested urban centers where acquisition of new sites is difficult. GSMA (2012) pinpoint that infrastructure funds are showing more interest in acquiring or establishing third party masts or radio network businesses.

Frisanco et al. (2008) address the issue of network sharing and managed services, and argue that operators has to focus on critical success factors and key assets due to lower growth, and competitive pressure in combination with technology migration. Frisanco et al. (2008) demonstrate that depending upon the extent of the network sharing could facilitate up to 40 percent lower operational and capital expenditures. Losada (2009) examine whether infrastructure sharing agreements among network operators affects networks qualities, operators' profits and social welfare. Losada (2009) underscores that allowing operators to build facilities jointly facilitate increased qualities of the networks given that either firm determines the infrastructure for their networks prior to the signing of the agreement, alternatively the regulator determine the amount of facilities that could be built jointly. Losada's finds that there is a risk for decreased network quality in case the involved operators first decide about the amount of facilities that they should build jointly.

Markendahl (2011) underscores that network sharing leads to cost reduction for both network deployment and operation, and emphasize that network sharing has a large impact on green field investments, as well as having a very positive effect on new entrants or smaller operators. Moreover, Markendahl (2011) address the question of spectrum sharing and that joint utilization of spectrum leads to a number of benefits. Beckman and Smith (2005) underscores that sharing of passive Radio Access Network (RAN) will significantly extend the reach of coverage into office spaces and other indoor areas, allow outdoor coverage to be economically extended. Beckman and Smith (2005) argue that regulators must convince industry of its commitment to spur restructuring and ensuring equal, cost based, and nondiscriminatory access to the network for all existing, and potential new market entrants. Meddour et al. (2011) pinpoint that the traditional model with all the physical network elements and network layers provided by mobile network operators is beginning to be challenged. Network sharing is driven by technology migration, regulatory requirements (coverage), increased capital expenditures in combination with increased competition, commodization of telecommunication equipment, separation of network and service provisioning. Network sharing facilities, according to Meddour et al. (2011), affordable access to mobile and broadband services in developing and emerging economies. The authors' present figures that show that sharing of sites and antennas can reduce capex with 20-30 percent and with Radio Access Network sharing network operators are able to save between 25-45 percent of capex. But Meddour et al. (2011) underscores that the magnitude of the economic impact of network sharing is difficult to assess as it depends on the particular level of sharing and geographical deployment strategy. However, Meddour et al (2011) recommend that both fixed and mobile operators should consider network sharing as a medium to cut operational and capital costs, and to focus on innovation and differentiation in customer-facing activities. In the longer run, Meddour et al (2011), suggest that incumbent operators could leverage network sharing as a means for continued growth by structurally separating all or part of their network assets or spinning out network provider companies in competitive markets.

Cambini and Silvestri (2013) develops a model of competition between an incumbent firm and an Other Licenced Operator (OLO) in the broadband market where the alternative for the incumbent either to build a Next Generation Network (NGN) alone or together with the OLO. The paper shows

that basic investment sharing is the preferable option in most cases, and the policy recommendation is that investment sharing can potentially be beneficial in terms of competition and investments, but the concerns shown by the authorities relates to the inherent form of such agreements are not void. The authors underscore that the number of firms involved matters and so does the choice of the NGN access price for insiders and outsiders of the sharing agreement.

OECD (2014) in a recent report examines how many facilities based networks are optimal in providing competitive services in the same geographical location. The report underscores that there are at least three mobile network operators in all of the OECD countries, which broadly compete on a national basis, with some countries having four or five facilities based networks operating nationally or in the same region. The report emphasize that in countries where there are a larger number of MNOs there is a higher likelihood of more competitive and innovative services being introduced and maintained. Particularly, the fourth and fifth operators are often the source for innovative offers and making the market more competitive. The policy recommendation the report make is that network sharing should be allowed and encouraged if it leads to more players at both the wholesale and retail levels as well as nationally or in specific regions.

2.4 Co-opetition – co-operation and competition at the same time

Co-operation between competing firms is usually denoted "co-opetition". Different types of co-opetitive relationships between competitors are described in (Bengtsson and Kock, 2000). The analysis deals with markets with few large actors, the dairy industry in Finland and the brewery industry in Sweden. The relationships are characterized as being co-operation dominated, equal or completion-dominated. In (Luo, 2007) co-opetition is characterized in terms of intensity and diversity. In (Gnyawli, et al., 2008) a framework is described where co-opetition occurs with high or lower intensity between the partners.

Another co-opetition dynamics framework for analysis of patterns of co-operation and competition is proposed by (Bengtsson et al. (2010)). The dimensions of co-operation are degree of complementarity, degree of trust and the tie strength (i.e. the characteristics of interaction between parties in terms of duration, frequency of contracts. The dimensions of competition are degree of symmetry, degree to which parties perceive each other as competitors, intensity in competition, and degree of hostility existing between parties. Both co-operation and competition can be weak or strong and the different combinations are used for the analysis

The literature on co-opetition covers many co-operation aspects, types of actors, industries and markets. Hence it is illustrative to highlight the key characteristics of the mobile operator business and markets in the developed world. Mobile operators compete on a national telecom market with a few other actors, i.e. an oligopoly. Operators make long term investments in networks and customers and provide mobile services, usually with very low or even zero marginal cost. Hence, it is not without risk to "directly" apply different models and frameworks that are developed to analyze co-petition for R&D and manufacturing of physical products. Co-opetition between very large global companies developing and manufacturing electronics e.g. (Lou, 2007), (Gnyawali and Park, 2011) can be different from mobile operators offering services at a national market.

However, there are many other examples where the analysis models, analysis aspects and type of market are relevant "as is" even if the conditions are different. When it comes to drivers and obstacles for co-opetition strategic alliances are discussed in (Perks and Easton, 2000). One motivation for a strategic alliance with a competitor can be to "allow them to compete better against third party competitors", this is highly applicable for network sharing. Tensions due to unstable or changing

market conditions are discussed in (Luo 2007) and (Park and Russo, 1996). For network sharing a number of tensions can be identified although this type of co-operation is long-term characterized by stability. One potential cause of tension is if one partner wants to improve its own market position by getting a greater share of the jointly created value resulting from the co-operation (Ritala and Hurmelinna-Laukkanen, 2009). These findings are also related to the value network configuration for mobile operators that are used in (Andersen and Fjeldstad, 2003). Three main groups of parallel activities: marketing and contract management, service provisioning and infrastructure operation. The network sharing cases to be described in this paper include close co-operation in the infrastructure operation part and very fierce competition in the two other areas.

2.5 Network sharing and regulation

Network sharing agreements are commonly examined by both National Regulatory Authorities (NRA) and Competition Authorities, with respectively regulatory framework. The assessments made by the NRA's regarding the effect on competition, and particularly if transfer of spectrum is involved, are based on competition law methods and examines the need for *ex ante* regulation. The NRA:s in Europe are subject to the regulatory framework for electronic communication which builds on a number of directives made by the EU Commission which have been transposed into national law, like the Electronic Communications Act in Sweden.

At the EU level, the Commission's Guidelines on Horizontal Co-operation Agreements provide an analytical framework for the most common types of horizontal co-operation agreements and therefore constitute a basis to assess network sharing agreements.

The Competition Authorities base their analysis on national Competition Act and articles 101 and 102 in the Treaty of the Functioning of the European Union (TFEU). According to the regulatory framework network sharing is a form of horizontal co-operation (EU Commission (2011), as competitors make production agreements on a wholesale level, where the appropriate regulatory focus is on the commonality of cost in order not violate competition regulation (EU Commission (2011), and Viscusi (2005)). The underpinning is that the share of commonality of cost should not be too high in order to facilitate a differentiation in pricing and market offers. Moreover, the Competition Authority as well as DG Comp at the EU Commission closely monitors to what extent synergies or lower production costs are translated into lower prices for the end-customers.

2.6 Research approach and data collection

The research question on the role of network sharing in transforming the operator business and the impact on competition and profitability are answered by analyzing network sharing in a number of countries and data on operators and infrastructure companies, so called tower companies. Data about the cases have been collected through a number of meetings and interviews as well as through desk research.

The business analysis is focused on the co-operation aspects and the relations between network operators. Based on Markendahl (2011) and Frisanco et al. (2008) the analysis provide insights about what activities are included in network sharing, and the interaction patterns between actors. For description and analysis of patterns of co-operation and competition we use the co-opetition dynamics framework proposed by Bengtsson et al (2010). Both co-operation and competition can be weak or strong and the different combinations are used for the analysis.

The underlying data and insights about network sharing has been described by the authors in previous work, see Markendahl (2011), Mölleryd and Markendahl (2013). Moreover, the issue of network

sharing has been analyzed by PTS in 2012 and carried out by the author as part of applications for transfer of spectrum from Tele2 and Telenor to Net4Mobility.[6] The issue of network sharing has also been part of a number of exchanges between PTS and the EU Commission. The financial and market analysis has been carried out through desk research by analyzing company reports, and financial data retrieved from the Bloomberg system.

2.7 Concluding remark on the research framework

Although network sharing is a wide concept, the definitions are widely accepted within the industry making it possible to discuss network sharing in a wider context. Given that network sharing is a global phenomenon it generates a steady stream of reports, research, and literature, and the general view is that network sharing facilitates lower cost for operators which could translate into lower prices for end customers, assuming that the retail market is competitive. But the long term effect of network sharing is yet to be seen and depending upon the outcome of the consolidation within the sector network sharing could be a way to maintain competition on the retail market while competitors are collaborating on the wholesale market.

[6] PTS decision 2012-02-07 on transfer of license to use radio transceivers in 900 MHz and 2.6 GHz band (in Swedish), link www.pts.se

3 The diffusion of network sharing

3.1 Established practice in most countries

Network sharing is a global phenomenon, which primarily consists of sharing passive infrastructure, and there is a lot of activity within this area and network sharing agreements are constantly being made. There are agreements for passive network sharing in all member states in the EU, and the whole practice of passive sharing has come a long way and it is now considered commonplace (BEREC (2011)). Active network sharing is also used by operators in some countries, such as the UK.

Network sharing in the US primarily consists of site sharing where mobile network operators make agreements with tower companies to lease antenna space. India has also seen the emergence of a number of tower companies that provide tower space to the operators, and a similar development has taken place in Indonesia and Africa, where a growing number of operators are using external tower companies in the network deployment.

The increased usage of network sharing has generated a growing number of companies dedicated to provide access to towers, sites and networks. A growing number of operators transfer their tower assets to separate tower companies, which could be in the form of joint ventures or separate infrastructure companies. The tower companies upgrade existing towers, build new towers and broaden the geographical footprint. Tower sharing in Africa has become a way for mobile operators to reduce operating costs by locating antennas on the same towers enabling operators to benefit from shared costs of power, maintenance and security. Network build and operating costs are significantly higher in Africa, yet revenues per customer are falling and regulators are seeking additional rural coverage and improvements in quality of service. Tower sharing is growing in Africa. For example France Telecom made an agreement to outsource more than 2000 mobile towers in Cote d'Ivoire and Cameron to HIS, which is a Nigerian company, specialized in operating mobile infrastructure.[7]

3.2 Network sharing in Sweden

There are three mobile network sharing companies in Sweden, which are described below. The 3G licenses issued in the year 2000 facilitated for the licensees to fulfill 70 percent of the coverage requirement through network sharing of the radio access network, including Node Bs and RNCs, which paved the way for Svenska UMTS nät AB (SUNAB) and 3GIS. Tele2 and Telenor formed a joint venture called Net4Mobility in 2009 in order to deploy a nationwide 2G and 4G network.

Figure 2 Network sharing agreements in Sweden

Sunab is owned by Svenska UMTS-nät Holding AB which is jointly owned with 50 percent each held by Tele2 and TeliaSonera, and it has a national 3G network. Through Sunab's network do Tele2 and

[7] Source Financial Times April 1, 2013

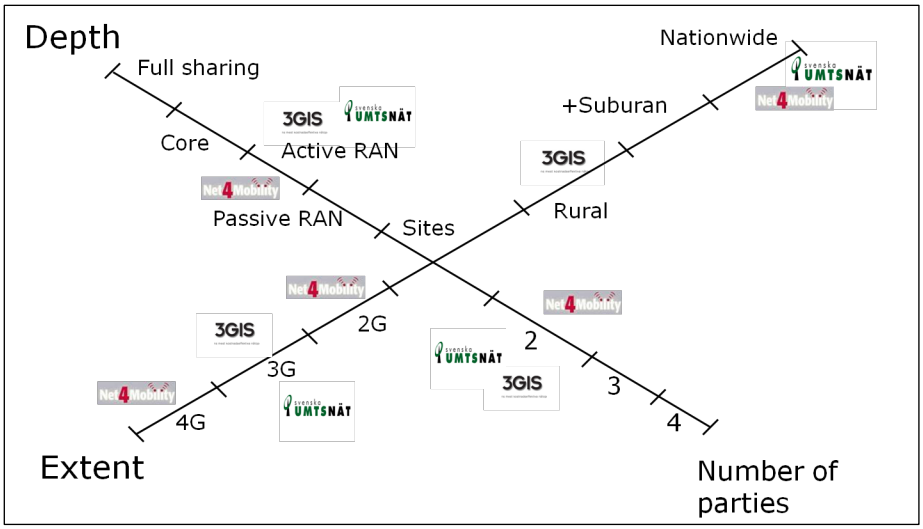
TeliaSonera share sites and mast as well as the Radio Access Network (RAN), including backhaul, but the two owners have separate core networks.

3GIS is jointly owned by Telenor and Hi3G each holding 50 percent and has a 3G network outside the major cities in Sweden. Through the 3GIS network does Telenor and Hi3G share sites and mast as well as the Radio Access Network (RAN), including backhaul. The network covers around 70 percent of the Swedish population. The two owners have their own core networks.

Net4Mobility is jointly owned with 50 percent each held by Tele2 and Telenor, and the company has a national GSM and LTE-network with associated transmission network and sell network capacity to the owners, with population coverage over 90 percent. Net4Mobility's network enables Telenor and Tele2 to share sites and mast as well as the Radio Access Network (RAN), including backhaul. The two owners have their own core network. Net4Mobility is also holding spectrum in 800 MHz, 900 MHz, a1800 MHz and 2600 MHz.

We apply the taxonomy presented in Frisanco et al. (2008) which on one axis distinguish between the depth of the network sharing arrangement, on a scale from passive network sharing regarding sites to full network sharing including core networks, and the number of involved parties in the network sharing agreement. The other axis show the extent of the collaboration regarding technology, from 2G to 4G, and the geographical coverage of the network sharing agreement, from rural areas to suburban or nationwide. The Swedish network sharing consists of active Radio Access Network sharing, besides that the operators share leases antenna space in each other base stations. Each JV consists of two parties. The collaboration is on 3G for two of the network sharing companies and 2G/4G in the Net4Mobility case. Two out of the three network sharing arrangements has a nation-wide coverage, while 3GIS only cover areas outside of the major three cities in Sweden.

Figure 3 Different network sharing agreements in Sweden



Source: Based on Frisanco et al. (2008)

3.3 Examples of network sharing in Europe

TeliaSonera and Telenor has over the years had difficulties to make a reasonable return on investments in **Denmark** which motivated them to form a nationwide network sharing company TT-Network, which covers site and mast sharing as well as RAN sharing. TT-Network is obliged to provide mobile radio access on a non-discriminatory market conditions to interested wholesale customers. The two owners pay the commonly owned JV for its supply of radio access capacity according to a cost-based

tariff structure. The JV owns spectrum in the 800 MHz band. Besides TT Networks all mobile network operators are doing site and mast sharing.[8]

In **Austria** are all mobile operators involved in site and mast sharing, antennae and repeaters are shared in tunnels and metro.[9]

In **France** the regulator, Arcep, is supportive towards network sharing on 3G, and with Radio Access Network sharing in rural areas. All French operators have signed an agreement to share infrastructure. Moreover, Free mobile (Ilidad) has a national roaming agreement with Orange.[10] SFR and Bouygues Telecom have formed a joint venture which plan to operate 11 500 sites, sharing sites, antennas but not spectrum or core networks. The agreement has been scrutinized by Arcep which require that the joint venture is a strict wholesale business for the radio access in order to avoid any spillover effect on business strategy and retail operation, and it only covers sparsely populated areas.[11]

In **Italy** is passive network sharing allowed but sharing of Radio Access Network and core networks is not permitted. Vodafone and Wind have an agreement for site sharing, Vodafone and Telecom Italia have an agreement on site sharing, and Telecom Italia and Hi3G have an agreement on site sharing besides a national roaming agreement.[12] Italy has the only listed tower company in Europe, EI Towers with 2700 sites under management of which 400 are mobile sites that are leased by mobile operators in Italy.[13]

In **Spain** are all mobile operators involved in site sharing, Vodafone and Orange entered a network sharing agreement in 2006 for a nationwide 3G Radio Access Network sharing covering areas with less than 25 000 inhabitants.[14] Moreover, Yoigo has a national roaming agreement and network sharing agreement with Telefonica.[15]

In the **UK** T-Mobile and Orange merged their networks and formed Everything Everywhere in 2010. The European Commission approved the JV after the companies offered to divest 25 percent of their combined spectrum. Orange and T-Mobile are remained as autonomous brands in the market with separate shops, marketing campaigns, propositions and service centers. Moreover, Everything Everywhere is marketing its own brand EE4G.[16] 3 UK had a network sharing agreement with T-Mobile from 2007, which subsequently was taken over by EE enabling 3UK to be part of the wider EE network through active RAN-sharing, but maintaining its own spectrum. Vodafone and O2 (Telefonica) has established JV (Towerco) that operate a national networks of 18 500 masts previously held by Vodafone and O2, labeled Cornerstone.[17]

[8] Source: Cullen-International, Infrastructure and network sharing by mobile operators, last update June 2014

[9] ibid

[10] ibid

[11] Ibid, and OECD (2014)

[12] ibid

[13] Source: EI Towers, Roadshow presentation March 2014, availble at www.eitowers.it

[14] Source: Cullen-International, Infrastructure and network sharing by mobile operators, last update June 2014

[15] Source: TeliaSonera

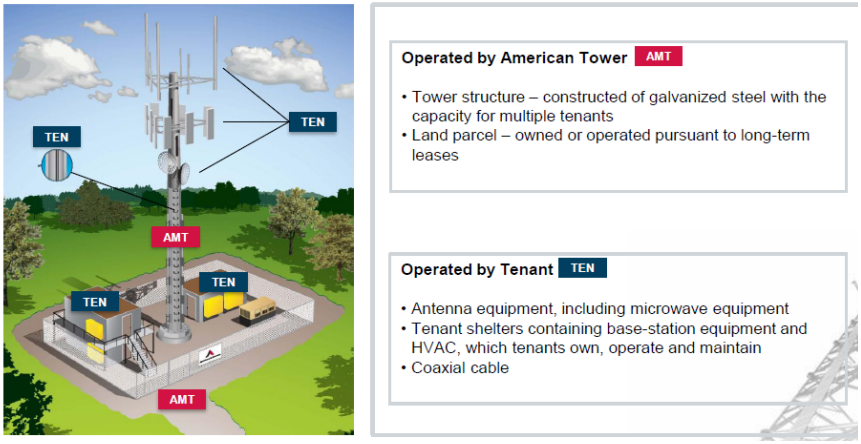
[16] Source: Cullen-International, Infrastructure and network sharing by mobile operators, last update June 2014

[17] Source: OECD, Wireless Market Structures and Network Sharing, DSTI/ICCP/CISP(2014)2

3.4 Network sharing and tower companies in the US

The emergence of separate tower companies has been part of the development of the mobile market in the US since the 1990s. The tower companies lease antenna space on multi-tenant towers to mobile operators with long-term contracts, and the target is to have at least two tenants per site and if the tower company reaches three the profitability increase considerable.[18] An important factor behind the emergence of dedicated tower companies is that they could be classified as Real Estate Investment Trust (REIT). A REIT is a corporation or business trust which owns, manages, and/or leases commercial real estate properties, and/or invests in real estate securities. REITs are exempt from federal and usually state corporate income taxation, given that they fulfil certain IRS requirements, such as that they pay out at least 90 percent of taxable income as a dividend. REITs must invest at least 75 percent of total assets in real estate and derive at least 75 percent of gross income from rental or management of real estate or interest from mortage activities.[19] Of the US tower companies are American Tower and Crown Castle classified as REITs.

Figure 4 Site sharing



Source: American Tower

The four major tower companies have around 25 percent of the installed base of over 300K sites in the US.[20] The other 75 percent are held by a large number of regional independent tower companies, mobile operators that own and operate their own towers, and alternative facilities such as rooftops, outdoor and indoor distributed antenna system (DAS) networks, billboards and electric transmission towers.

3.5 Indoor sharing will contribute to a change of the business landscape for operators

For sharing of macro cell networks there is a wide range of options ranging from passive sharing to sharing of active elements and also spectrum. Hence, the co-operation can be more or less tight. When it comes to future indoor network sharing we claim that the situation will be different.

- The main driver for indoor sharing is that the mobile operators *have to* share the indoor infrastructure since multiple networks will not be feasible

[18] Financial reports from the tower companies American Tower, Crown Castle

[19] Source: Bloomberg

[20] The number of totals sites are presented by CTIA, http://www.ctia.org/advocacy/research/index.cfm/aid/10323

- With one single physical infrastructure it will be apparent to also share spectrum resources, which applies regardless of what spectrum bands and spectrum access strategies that are used.
- The sharing of both infrastructure and spectrum will lead to a very close co-operation between competing operators, with facility owners and actors providing the common network.

Is should be noted that indoor network sharing that use distributed antenna systems (DAS) offer a solution where the physical distribution network is shared but operators control their own traffic and users by use of own spectrum resources. However, for future indoor network deployment small cells networks offer higher capacity in a more cost and spectrum efficient way (Markendahl, 2011). Hence, our discussion will consider small cell multi-operator LTE networks. Multiple options exist for how operators can access the indoor radio access network; small cell gateway or roaming solutions or small cell version of the Multi-operator Core network (MOCN) solution e.g. proposed by Alcatel-Lucent (Markendahl, Ghanbari, 2013)

For these solutions it is too early to present any comparison of performance, capacity or cost. As mentioned, the main drivers are not performance or cost advantages but more a need to use a common indoor infrastructure in order to be able to offer service at all. In this paper we would like to highlight some research challenges that we have identified in the technical, business and regulation domains.

1. How to combine spectrum resources into a common pool, i.e. both aggregating licensed spectrum of different operators and combination of licensed and unlicensed spectrum bands.
2. To look into new types of spectrum allocation and management that allows and enables use of local spectrum licenses, e.g. for buildings of blocks
3. How operators can control the traffic of own customers in the shared network
4. How to resolve conflicts when it comes to prioritizations of traffic and sharing of costs
5. How will competition change if there will be just one common indoor infrastructure? Will there be a risk of closed clubs? Is there a need for new legislation or policies?

To contribute to answers to the research questions we believe that the indoor sharing will have a big impact on the mobile operator business. Sharing will be more common and operators will most likely be forced to form sharing agreements or to connect to existing infrastructure if there is one. But we can also foresee many new business opportunities for operators who want to be in the front seat:

- To be pro-active in getting agreements with facility owners
- To acquire new spectrum or make use of unlicensed spectrum for indoor use
- To invite other operators and partners to join ventures and to organize the co-operation
- The deploy and operate indoor infrastructure

All this means an increased focus on B2B services, i.e. the customers would be enterprises, facility owners and other operators.

3.6 Concluding on diffusion of network sharing

Although network sharing in Sweden has been in operation since 2001 it is not yet obvious, or rather not in the public domain, how the life cycle of network sharing agreements develop over time and what happens when agreements have been completed. Overall network sharing is still in a buildup phase with a global diffusion. The emergence of tower companies and separate network sharing companies on developing markets have been driven by the possibility to release capital from the

network investments to make market investments. The emergence and demand for indoor networks is growing and it has a potential disruptive impact on mobile network operators, which so far has been unable to capitalize on this development.

4 Modeling network sharing in two scenarios

4.1 Introduction

This chapter quantifies the monetary gains of network sharing through the use of a common radio network in two deployment cases: 1) rural, and 2) dense urban. In order to make the calculations manageable they are simplified in comparison to real-world radio planning and network design. Examples of the involved complexities are:

- Complex cost structures for suppliers of hardware, software and services.
- Large operator organization providing a range of different services like radio planning, construction, O&M, support services.
- National variations of cost levels for man power, electricity, site acquisition process.
- Operator openness and price confidentiality
- Geographical variations, population density and market situation

4.2 Model and basic assumptions

In order to quantify the relationship between network sharing and monetary gain in different capacity scenarios we use a simplified model. The system technology used is LTE, however, we do not go into details in terms of frequency bands, 3GPP release, throughput capacity or network nodes. Two different traffic areas are used: rural and dense urban.

The capex is split into passive and active equipment. The passive equipment includes towers, antennas, feeders, sites and civil work and presented as total values for an average site. Capex for active equipment includes radio network equipment, backhaul transport and related implementation services. The price model is reduced to two items - a base configuration including 10 Mbps throughput capacity and 10 Mbps expansion steps. The peak capacity is – as usual – several times larger than the average throughput.

An important parameter is the average throughput per user in the busy hour. To our knowledge, the current world average is around 10 Kbps per user in LTE networks, but as the number is increasing, we apply 15 Kbps in our model.[21]

Opex is assumed to be a fixed yearly price per radio network node. Costs for site visits and power consumption are typically higher for rural sites, but site rental can be considerable higher for urban sites. The annual opex per site is assumed to be EUR 8000 for dense urban and EUR 12000 for rural, although this figure varies significantly between countries depending on man hour cost, leased line transmission cost and operator organizational efficiency.

For the network sharing case, we also introduce a factor for “co-operation/administration cost per shared site”, in order to cater for the increased administration, which is required for system upgrades, capacity expansions and fault handling, necessary when operators need to co-operate and formally take decisions. The basic assumptions are presented in the table below.

[21] This is implies an average monthly data consumption of 1.5 GB per user spread out over 8 hours per day.

Table 1 Assumptions

Subscribers and site sizes	
Rural site max site radius	6,0 km
Max rural area	113 km^2
Urban site max site radius	1,0 km
Max urban area:	3,1 km^2
Capacity per subscriber / BH /	15 kb/s/BH
Subscribers/km2 in Scenario 1 rural area	2 subs/km^2
Subscribers/km2 in Scenario 2 dense urban area	600 subs/km^2
Capex passive equipment	
Passive equipment cost for rural site	400 000 EUR
Passive equipment cost for urban site	80 000 EUR
Depreciation passive equipment	20 years
Cost of capital	7,80%
Annuity cost rural site	40 136 EUR/year
Annuity cost urban site	8 027 EUR/year
Capex active equipment	
Capacity expansion step	10 Mbit/s
Basic equipment cost including first expansion step	10 000 EUR
Cost additional expansion step	2 000 EUR
Depreciation active equipment	4 years
Cost of capital	7,80%
Depreciated cost active equipment base configuration	3 006 EUR/year
Ditto expansion step	601 EUR/year
Opex assumptions	
Opex per year per rural site	12 000 EUR/year
Opex per year per urban site	8 000 EUR/year
Co-operation/administration cost per shared site(per operator)	500 EUR/year

4.3 Calculations

The aim with the calculation is to get an estimate of the monetary gain for an operator sharing the radio network, and the exercise is conducted in three steps:

1. Calculation of the cost for a single operator to cover an area with either of the two scenarios is calculated. The target is to get a yearly cost per km^2 covering both capex, which is calculated with an annuity, and opex.

2. Calculation of the cost for a joint network with two identical operators. The capacity requirement per area is twice as much compared to a single operator network. Note that new sites are not needed to be added in this model. Since the two operators both have the same amount of spectrum, it is possible to add spectrum and just upgrade the active radio equipment.

3. The final step is to calculate the gain for each operator when they are sharing networks. The result is an estimate of the level of cost reduction for the two scenarios.

Table 2 Scenario one: Rural area

Input	
Subscribers per km^2 in the dense urban scenario:	2 subs/km^2
Data traffic per subscriber/BH	15 kbit/s/sub
Single operator	
Resulting data load per area	30 kbit/s/km
A rural site with base configuration supports	10 Mbit/s
The covered area is	113 km^2
Average supported load is	88 kbit/s/km
Cost per year per operator per site	55 142 EUR
Cost per per km2	488 EUR
Shared network	
Assume that the two operators have the same traffic load.	
A site with minimum capacity can handle the traffic from both networks without capacity expansion	
Cost for two operators sharing the same equipment:	56 142 EUR
Cost per operator for shared network:	28 071 EUR
Benchmark	
The saving per operator is therefore:	**49%**

Table 3 Scenario two: Dense Urban Area

Input	
Subscribers per km^2	600 subs/km^2
Data traffic per subscriber/BH	15 kbit/s/sub
Single operator	
Resulting average data load per km2	9 000 kbit/s/km^2
Assuming a site using the throughput:	30 Mbit/s
The site coverage area	3,33 km^2
The annual site cost	20 235 EUR/site
The cost per km^2 for a single operator running its network	6 071 EUR/km^2/year
Shared network	
Assume that the two operators have the same traffic load.	
The capacity increased is achieved by doubling the capacity of each cell. The combined shared network use twice the number of frequencies.	
The cost of a shared network site	23 039 EUR
The cost per km^2 for a shared network	6 912 EUR/km^2/year
Benchmark	
The saving per operator is therefore:	**43%**

There are many factors that make the real world more complicated than the model above, with some of the most important factors being:

- Cost for phased out sites
    - When two similar-size operators merge their radio networks, the primarily gain is to reduce the number of sites. However, it takes a long time to achieve the cost decrease as existing towers and sites has a long life-time and is far from easy to sell to third party.
    - In case many of the sites are also used by other networks through leasing or are leased from tower companies the cost for phased-out sites is lower.
- Trunking efficiency in the radio network
    - An additional advantage in network sharing is the increased trunking efficiency, as a doubling of the capacity for a site makes the probability higher to handle a capacity

peak. With the introduction of LTE carrier aggregation it becomes even more advantageous for mobile operators that pursue network sharing.

4.4 Conclusion on the two scenarios

It is apparent that network sharing has a great savings potential for MNOs, both in the rural and dense urban areas. In the rural scenario, the traffic is so limited, that the equipment used by one operator can support both operators' capacity needs without upgrades. The only reason why the gain is 49 percent and not 50 percent is the factor for co-operation/administration cost per shared site. For the densely urban case, the saving is estimated to be 43 percent. The cost of the capacity expansion of a shared site is considerable lower than the cost of a site.

5 Analysis of network sharing

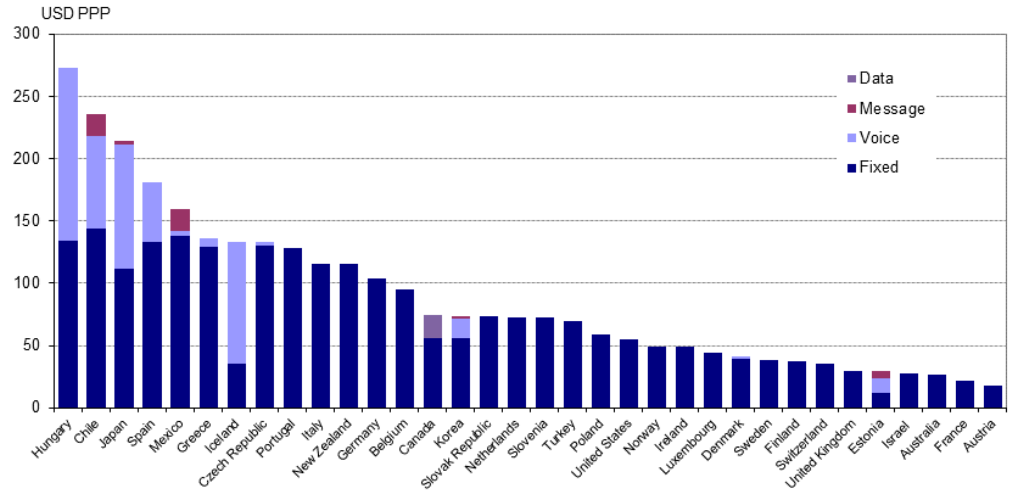
5.1 Input to the research questions

This chapter examines the impact of network sharing on the level of competition on the wholesale and retail market, cost structure and profitability, industry structure and transformation. First, the issue of competition on the downstream market is addressed, followed by an analysis of the financial impact of network sharing, the impact on the market structure and competition, and the chapter is concluded with a section on broader industry implications of network sharing.

5.2 Competition on the downstream market

Price baskets provided by the OECD in Communications Outlook makes it possible to compare retail prices between different countries. Regarding a mobile basket with 900 calls and 2 GB of data Austria, France, Australia, Israel, Estonia and United Kingdom offer the lowest prices indicating competitive retail markets, presumably providing price worthy services to the end customers. Network sharing is used in all of these countries indicating that the combination of sufficient level of competition and adjusted cost structures facilitated by network sharing makes it feasible to provide competitive prices. Although prices in Austria have risen since the consolidation in 2013, they are increasing from a comparatively low level.

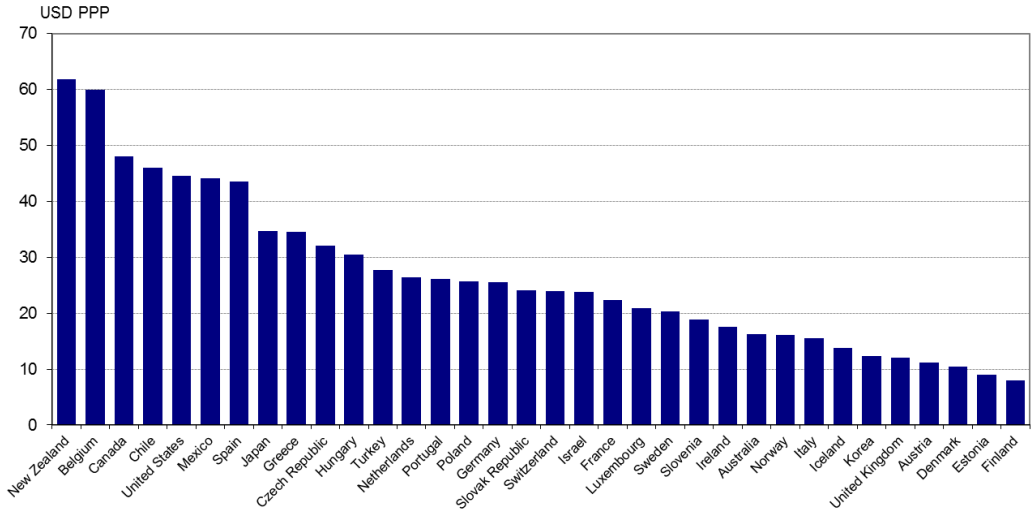
Figure 5 OECD 900 calls + 2 GB mobile basket, August 2012, VAT included



Source: OECD Communications Outlook 2013

On the market for mobile broadband and measured with a basket consisting of 5 GB data it is a similar view with competitive prices in a number of European countries. The countries with the lowest prices are Finland, Estonia, Denmark, Austria, and United Kingdom. Operators in all of these countries use network sharing potentially lowering the cost levels. Price levels are probably more a function of how many operators that are competing, how fierce they compete, and the level of innovative offers that operators provides to the market. Given that network sharing reduces the number of parallel networks it would be a risk for lower level of competition and thereby potentially higher prices. But this would imply tacit collusion between the operators and that the network sharing agreements, which are limited to supply of wholesale, have a spillover effect on the downstream market. The availble data does not indicate that has occurred, so far.

Figure 6 OECD Wireless Broadband basket, OECD Laptop 5 GB, September 2012



Source: OECD Communications Outlook 2013

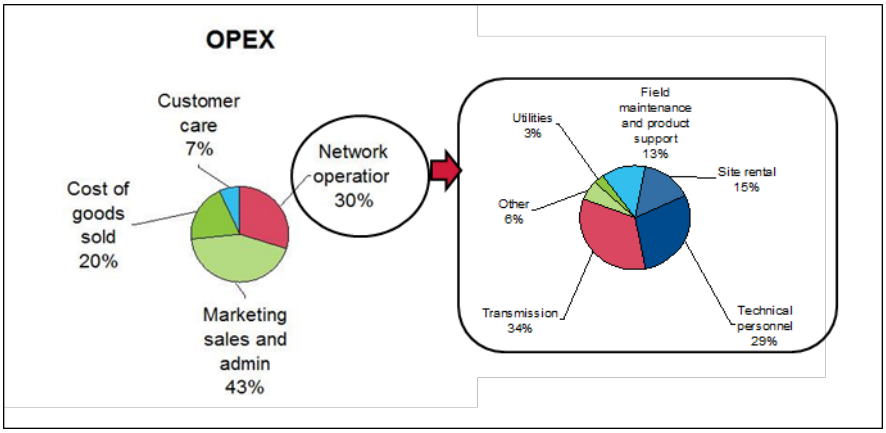
There are four large operators in Sweden that compete on the end customer market with network sharing in various combinations, and there is no ground to claim that the network sharing agreements have had a spillover effect on the downstream market. By taking the aspect of a sparsely populated country with a land mass of 450K km^2, and with a geographical coverage up to 90 percent it is fair to claim that Sweden has competitive prices.

OECD (2014) underscore that sufficient competition can be maintained with network sharing frameworks, even if they cover all geographical areas and share spectrum bandwidth that have been originally allocated to individual operators.

5.3 The financial impact of network sharing

The cost for network operation makes up 30 percent of total operational expenditures (opex), according to Nokia Siemens Network (2009). Network opex consists of transmission, technical personnel and site rental, illustrated in the following figure.

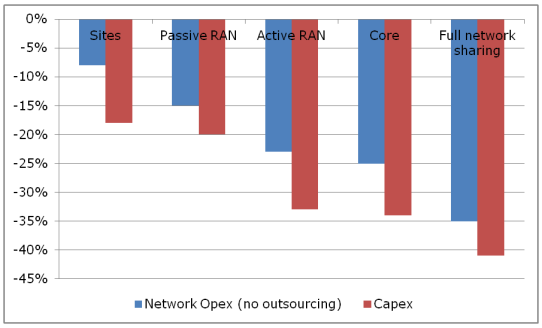
Figure 7 Cost categories for total opex and network opex consist of a number of cost categories



Source: Nokia Siemens Networks (2009)

Frisanco et al. (2008) state that network sharing can reduce network opex up to 35 percent, depending upon the extent and depth of the network sharing. The basis for the estimates is simulations on different alternatives of network sharing that the researchers have conducted.

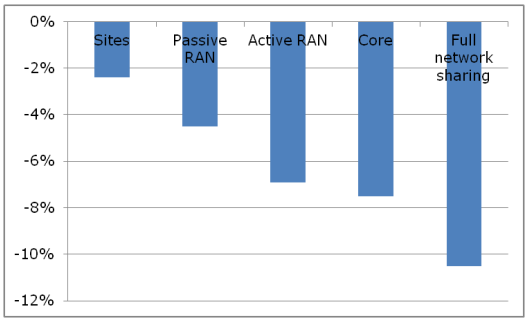
Figure 8 Cost reductions with network sharing



Source: T. Frisanco et al. (2008)

The aim with network sharing is to achieve synergies in capital and operating expenditures. RAN sharing has the potential to alter the cost structure of mobile network operators as it is the costliest part of mobile networks comprising of cell sites, towers, base station equipment and transmission networks. By combining NokiaSiemens' assumption that network opex makes up 30 percent of total opex with Frisanco's cost reduction estimates it indicates a potential impact to reduce total opex up to 10 percent. The potential cost reduction is 7 percent with RAN-sharing and 2 percent with site sharing, as the following figure illustrates.

Figure 9 Reduction of total opex by network sharing



Source: Authors' calculation based on Nokia (2009) and Frisanco (2008)

What impact does a 7 percent reduction of opex have on the profit margin? In order to examine this we use a fictitious operator in a country with 50 million inhabitants and a 25 percent market share for the operator. Assuming that the EBITDA margin (Earnings before interest, taxation, depreciations and amortizations) without network sharing is 30 percent, which is in line with European operators, and with a RAN-sharing would the EBITDA margin raise to 34.8 percent. Site sharing would give a boost of the EBITDA margin just below 2 percentage points. The reduction of opex could potentially result in a higher valuation of the company, as a consequence of that the profit level would be pushed up. By applying the valuation metric of 7x EV/EBITDA could the RAN sharing boost the value of the company with 16 percent, in line with the revision of the profit, underscoring that network sharing could give a financial boost.[22] But the dynamics on the mobile communications market certainly have other forces working in the other direction offsetting company's ability to utilize all the positive effects, depending upon the market sentiment.

[22] Based on current valuation of the peer group of European operators with a 7x EV/EBITDA

Table 4 Impact on EBITDA margin on lower opex

	Site sharing	RAN-sharing
Population million	50,0	50,0
Penetration	90%	90%
Operator		
ARPU EUR	20	20
Market share	25%	25%
Subs million	12,5	12,5
Revenues MEUR	3 000	3 000
EBITDA margin	**30,0%**	**30,0%**
EBITDA MEUR	900	900
Opex MEUR	2 100	2 100
Reduction of opex	2,4%	6,9%
Lower opex MEUR	50	145
Revised opex MEUR	2 050	1 955
Modified EBITDA MEUR	950	1 045
Modified EBITDA margin	**31,7%**	**34,8%**

The Swedish mobile operators have reported growth during the last five years and the profit margin, measured as earnings before interest, taxes, depreciation and amortization (EBITDA) has been going both up and down. This implies that, for Tele2, where the margin has decreased from 37 percent 2007 to 29 percent 2012, despite extensive usage of network sharing. However, Telenor has reported flat margins, while 3 and TeliaSonera has improved profit margins. This means that other costs have influenced the profit margin, and a contrafactual argument would be to state that if, for example, Tele2 had not been involved in network sharing the profit margin would have been lower.

The level of capex in relation to revenues varies considerable between tower and network sharing companies, with a median of 20 percent for the tower companies compared to an average of 14 percent for European operators. Moreover, the level of gearing, measured as net debt[23] in relation to EBITDA, show a spread from negative up to 12x, with an average of 6x for tower companies compared to an average of 2x for European operators. Tower companies are able to raise more capital compared to operators, and thereby operate with a lower share of equity. Operators that offload their networks to tower companies are able to raise substantial amount of capital, all depending on if it is a divestment, leaseback or other form of agreement.

Network sharing facilitates increased coverage as sharing costs makes it more cost effective to extend coverage further. The total costs of providing additional coverage are largely independent of the number of sharing parties, so the costs for each sharing MNO will be lower than those of non-sharing MNOs. Faster rollout of new technology as pooling of existing sites and resources reduces the need to acquire new sites and increase resources to meet the workload of a rollout program. Significant cost savings would be generated from RAN sharing and transmission sharing in particular and consumers would benefit if competition causes these savings to be passed on to consumers.

5.3.1 Impact on market structure and competition

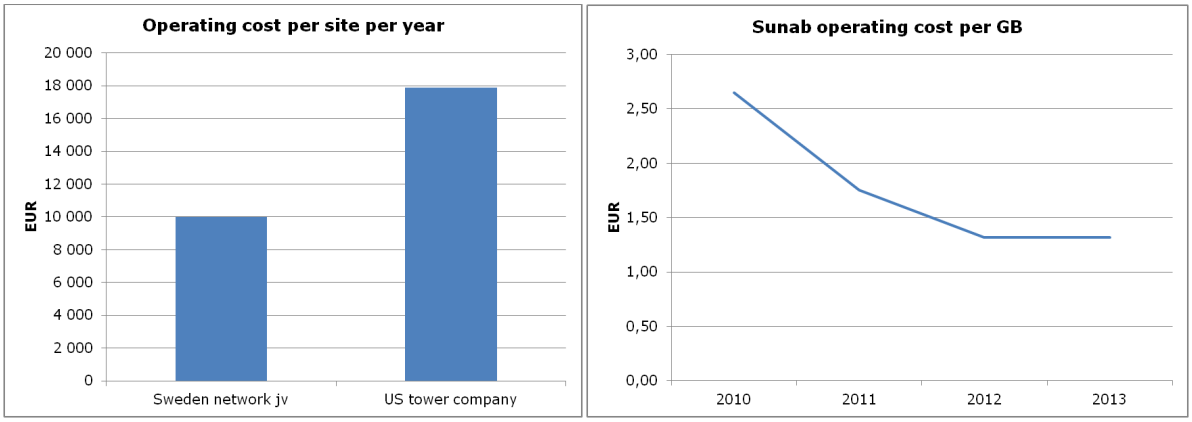
The incentive to enter network sharing agreements seems to be depending upon the operators' market position and scale. Some operators, like TeliaSonera, choose not to enter network sharing agreements on markets where they are market leaders, while pursuing network sharing on markets where they are

[23] Net debt shows a company's overall debt situation by netting the value of a company's liabilities and debts with its cash and other similar liquid assets. Calculated as: Net debt = short term debt + long term debt – cash & cash equivalents. Source: http://www.investopedia.com

number two, three or four. This has been the case for TeliaSonera in Denmark, where it is number three with long term profitability problems.[24]

An analysis of the operating cost to run the radio access network show that the annual operating cost per site for the Swedish network sharing companies in average is EUR 10000 per site which could be compared with EUR 18000 for an average of the US tower companies. It is an average which means that given that the Swedish network sharing companies have a combination of roof top antennas, which are cheaper to run, and towers, which are more expensive to run, compared to the US tower companies which primarily have towers. Nevertheless, it gives a figure for operating a site which means that with network sharing two or more partners could share that cost compared to an individual owner. Given that presumably 80 percent of mobile base stations are underutilized in mobile networks the incentive to do network sharing is strong. Moreover, given the increased data volumes but a stable operating cost per site one of the Swedish network sharing companies operating cost to produce a GB has consistently been declining. The operating cost per GB is around EUR 1.3. The average revenue per GB on the Swedish mobile broadband market was EUR 3.6 during 2013, implying a significant gross margin.

Figure 10 Operating cost



Moreover, there is also an environmental aspect for network sharing. Regulators promote passive network sharing as it reduces the duplication of passive networks and thereby reduce the impact on the environment. The deployment of mobile base stations across towns, cities and the countryside has led to a negative visual impact on the environment.[25]

5.4 Transformation of the operator business

Given that the mobile communications industry has undergone a tremendous development during the last 30 years propelled by a continuously growing demand for mobile communication services facilitated by the deployment of competing mobile networks that have established coverage and capacity. Mobile network operators have benefitted from a steep price deflation on network equipment and mobile terminals.

The breakthrough for smart phones has fundamentally altered the balance in the mobile eco system as operators have lost influence over handsets, which has been further emphasized by the dominance of mobile platforms, such as Android and Apple's iOS, and the emergence of a global app market. This

[24] Source: TeliaSonera

25 The regulatory authority of Botswana, http://www.bta.org.bw/infrastructure-sharing

has been facilitated by the ip-fication, through the separation of the application layer and transport layer, in principal reducing operators to bit byte providers with voice as the main service besides data.

The overall trend in the telecommunication industry is a process towards a vertical disintegration, where operators divest non-core operations in order to concentrate on the core business. But it is far from obvious what the core competence of an operator is, whether it is to provide customer experiences through a combination of technology and marketing, or if it is just a vehicle for return on financial assets. An operator that has been innovative in this respect is 3UK that outsourced its network management in 2005, made a network sharing agreement with T-Mobile in the UK in 2008, and has stopped to market its services through independent mobile phone retailer in order to focus on direct channels, like over the web.[26]

The technological development makes it possible to transfer processing to the cloud and software defined radio makes the mobile networks more flexible, but it requires that fiber is used for backhaul.

Although network sharing unquestionable result in lower cost to run mobile networks it could deteriorate the competence to run mobile networks, and whether network capabilities is a core competence and a strategic asset (OECD, 2014). Moreover, network sharing means that operators lose some control over network strategy, which historically have been regarded as a strategic asset.

The mindset in the mobile industry is based on the deployment of macro networks, while the majority of the usage takes place indoor making small cell networks and indoor networks to a potentially disruptive issue for mobile operators as facility owners seems to be reluctant to have parallel networks.

Co-opetition with network sharing is that what has previously been handled internally is now handled between companies meaning that they have co-ordinate network strategies, coverage areas, cost mechanism, governing structure of the operation, and maintenance. It is also driving to have a balanced spectrum holding. Communality of cost for one operator compared to competition. Co-opetition on the wholesale market while competing on the retail market.

The base station design means that all greenfield base stations are designed and built to ensure they are capable of supporting at least two further MNOs' equipment, include site space for housing arrangements such as cabinets, as well as providing access to power.

ACCC reports and an improved understanding of how people make use of smart phones show that over 70 percent of average usage in many OECD countries is on fixed networks. In other words, authorities making decisions on market structures need to be cautious in using the demand for mobile broadband and traffic increases as the basis for considering the number of players in the MNO market. If, for example, players share mobile facilities and backhaul they reduce costs even at a time of overall increasing demand for investment and the services its supports but there has been a reduction in wholesale and retail competition.

5.5 Summing up the analysis

Network sharing could be regarded as a "light" form of consolidation as competitors are collaborating on part of their network and thereby achieve synergies. The potential to reduce the operating cost for the radio access network with over 40 percent is compelling, and it could translate into a mid-single digit boost to the profit margin, assuming that other factors is not offsetting this cost saving. Moreover, there are potentially significant consumer benefits from active network (RAN) sharing

[26] Source: OECD 2014

from increased coverage, faster rollout and lower prices. The analysis has addressed a number of relevant aspects for the issue of network sharing. Although risks for weakened competition are a threat this has so far not materialized. Neither has Mobile Network Operators driven a transformation of the industry but there is rather a number of challenges that could have a severe impact on the future development of the mobile communications industry.

6 Conclusions

This paper examines the concept of network sharing and has strived to analyze the role of network sharing on the operator business, and the impact on profitability and competition. Altogether, we would like to highlight five aspects that the paper has covered.

Network sharing is used throughout the world, and in the longer run move the focus from infrastructure based to service based competition, as competitors are collaborating. Network sharing could be seen as a form of light consolidation although reducing the infrastructure competition on the wholesale market facilitating a competitive retail market.

Network sharing enables operators to lower network operation cost which could push up profitability levels, but competitive dynamics as well as industry development is going in the other direction. This implies that network sharing has offset a part of a profitability tap, and without network sharing profits would have been lower.

Network sharing and outsourcing have propelled a development of dedicated tower and infrastructure companies which have released capital for operators as it is able to manage higher debt ratios than operators meaning that it has a transformative impact on the operator business.

Despite an extensive usage of network sharing – which means that competitors collaborate - competition on the retail market prevails. A potential spillover from network collaboration on the downstream market is a risk, and a factor that competition authorities are monitoring very closely.

The social benefit with larger coverage and improved capacity has so far given extensive support for network sharing which has become an established practice within the market for electronic communications.

The growing interest for machine-to-machine (M2M) means that mobile networks are a critical infrastructure. Roaming is commonly used as network operators commonly use SIM cards issued by the operators operations in other countries enabling national roaming.

Operators' inability to balance the focus on macro networks with small cell and indoor networks creates an opportunity for other players to challenge the MNOs with indoor solutions, which could be combined with WiFi and thereby further undermining profitable segments for mobile network operators.

7 Further research

This paper addresses an interesting field for research that can be extended into a number of areas:

- Network sharing could be a step in the direction towards an industrial change and generate a development where operators go in the direction towards vertical disintegration and thereby forming a new industry structure.
- For indoor networks a common approach for network sharing including network deployment and operation can be expected since facility owners do not allow multiple indoor single-operator networks.
- The combination of spectrum and network sharing should be investigated more both from a system performance as well as a competition perspective. Pooling of licensed spectrum is currently used by some operators in Sweden. Spectrum sharing with multiple license holders, so called co-primary spectrum sharing is discussed as a way to increase the use of available spectrum resources. Co-primary sharing would be especially interesting to analyze for indoor and local networks.
- Spectrum aggregation is an interesting topic as the current regime of dividing the spectrum into slots would not make it possible to utilize the benefit of spectrum aggregation and the possibility to achieve high capacity services.

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