NTNU – Trondheim
Norwegian University of
Science and Technology

A Case Study of a National Open Access Network in Norway

Ørjan Bøe Thygesen

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Supervisor: Harald Øverby, ITEM

Norwegian University of Science and Technology
Department of Telematics

Title: A Case Study of a National Open Access Network in Norway
Student: Ørjan Bøe Thygesen

Problem description:

Per the second quarter of 2014 8 out of 10 households in Norway have fixed broadband according to a report from Statistics Norway. Further, the same report says the median download speed for these households are 17.8 Mbit/s, while the average is 23.1 Mbit/s. A report from Vista Analyse from 2013 shows that 94 % of all households have at least a download speed between 4 Mbit/s (mobile and fixed broadband), which according to them should be sufficient for daily chores. All in all, Norway is, despite its challenging landscape and scattered households, a well-developed country in terms of Internet connection. But most households suffers from limited choices when it comes to service providers (providers of the Internet service), network providers (providers of the physical connection) and content providers (cable or IP TV). Most households are bound to choose between one to two. In most cases households are victims of vertical integration and a monopolistic situation.

However there are examples of international markets which practice open access networks. [FLM13] defines open access networks as "... the roles of the service provider and the network owner are separated, and the service providers get access to network and the end customers on fair and non-discriminatory conditions”. Examples of this kind of broadband networks can be seen in Singapore, Sweden and Australia.

This master thesis conduct a case study of a national open access network in Norway. It will look at its:

- positive and negative socioeconomic aspects;
- business models and value chains;
- obstacles for realization and benefits of implementation.

This master thesis will also explore if an open access network in Norway exists, has been attempted and if there exists plans for it. At last it should compare Norway’s broadband market to international open access networks and classify it after the access network business models from [FLM13].

[FLM13] Marco Forzati and Claus Popp Larsen and Crister Mattsson, Open Access Networks and Swedish market in 2013, 2013

Responsible professor: Harald Øverby, ITEM
Supervisor: Harald Øverby, ITEM

Abstract

Due to changes in the problem description during the work on this thesis, a more precise title to this thesis would be: "A Comparative Study of The Internet Access Markets in Norway and Sweden - Open Access Networks versus Vertical Closed Networks. This thesis conducts a comparative study on the Norwegian and Swedish Internet access market. Access fiber networks in Norway are vertical closed networks, while the majority of Swedish fiber networks are open access networks. Somewhat simplified, a vertical closed network is a network where a single provider has a monopoly on service delivery to end users. An open access network is a network where the network owner opens up for service delivery from other providers. Further, Norway and Sweden are well suited to compare because of their many similarities. The national price level, geography and population density is relatively equal.

This thesis has gathered data on coverage, penetration, prices and government support for development of fixed broadband access in Norway and Sweden. By using these figures this thesis is attempting to explain the effects the different business models have on coverage, penetration and prices in Norway and Sweden. Furthermore the goal of the thesis is also to say something about what these two very different models brings compared with each other on a general basis.

In summary this thesis' findings are the following:

1. The overlap of HFC and fiber networks, and the high new entry cost in Sweden are significant factors in terms of the lower penetration of the aforementioned access technologies in Sweden compared to Norway;
2. OAN business models causes lower subscription prices and existing entry costs compared with vertical closed network business models;
3. Vertical closed network business models causes a lower new entry cost compared to OAN business models;
4. Vertical closed network business models and limited government intervention secures demand driven fiber rollout;
5. In the fiber market a Swedish end user will, with its far lower monthly subscription price than a Norwegian, quickly equalize the benefit the Norwegian end users achieves with its low new entry cost.

Sammendrag

På grunn av endringer i problembeskrivelsen under arbeidet med denne masteroppgaven, vil en mer presis tittel til denne masteroppgaven være: "En komparativ studie av Internettaksessmarkedet i Norge og Sverige - Åpne aksessnettverk versus Vertikalt lukkede nettverk. Denne masteroppgaven gjennomfører en komparativ studie på det norske og svenske Internettaksessmarkedet. Aksessfibernettverk i Norge er vertikal lukkede nettverk, mens majoriteten av svenske fibernettverk er åpne aksessnettverk. Sverige og Norge egner seg godt til å sammenligne på grunn av deres likheter. Det nasjonale prisnivået, geografien og befolkningstettheten er relativ lik.

Denne masteroppgaven har samlet sammen data om dekning, penetrasjon, priser og statlig støtte for utbygging av faste bredbåndsaksesser i Norge og Sverige. Ved å bruke disse tallene forsøker denne masteroppgaven å forklare hvilke innvirkninger forskjellige foretningsmodeller har på dekning, penetrasjon og priser i Norge og Sverige. Videre er også målet med oppgaven og si noe om hva disse forskjellige modellene bringer med seg på generell basis.

Oppsummert er oppgavens funn er følgende:

1. Overlapping av HFC- og fibernett, og den høye førstegangsetableringskostnaden i Sverige er signifikante faktorer som fører til av lavere penetrasjon av nevnte aksessteknologier i Sverige sammenlignet med Norge;
2. OAN-forretningsmodeller fører til lavere abonnementspriser og andregangsetableringskostnad sammenlignet med vertikale lukkede nettverk;
3. Forretningsmodeller som innebærer vertikale lukkede nettverk fører til lavere førstegangsetableringskostnad sammenlignet med OAN-forretningsmodeller;
4. Forretningsmodeller som innebærer vertikale lukkede nettverk og begrenset statlig inngrep sikrer etterspørseldrevet fiberutbygging;
5. I fibermarkedet vil en svensk sluttbruker, med sin langt lavere månedlige abonnementspris enn en norsk, raskt utjevne fordelen de norske sluttbrukere oppnår med sin lave førstegangsetableringskostnaden .

Preface

This thesis represent the end of five and a half years in Trondheim, my final and last semester at NTNU and the completion of my masters degree in Communication Technology.

I want to give thanks to two people for help for this thesis: Harald Øverby and Harald Wium Lie. All input, guidance and feedback received from you were invaluable. This thesis had not been the same without any help from you two.

Siljan, January 2015

Ørjan Bøe Thygesen

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List of Acronyms

ADSL Asymmetric Digital Subscriber Line.

AON Optical Active Network.

BA Bit-stream Access.

BEREC Body of European Regulators of Electronic Communication.

BRAS Broadband Remote Access Server.

BW Bandwidth.

DLS Digital Subscriber Line.

DOCSIS Data Over Cable Service Interface Specification.

DSLAM Digital Subscriber Line Access Multiplexer.

EEC Existing Entry Cost.

EP2P Ethernet Point-to-point.

FTTB Fiber to the building.

FTTC Fiber to the curb.

FTTH Fiber to the home.

FTTN Fiber to the node.

FTTX Fiber to the x.

FU Full Unbundling.

GPON Gigabit Passive Optical Network.

HFC Hybrid Fiber Coax.

IDA Infocomm Development Authority of Singapore.

IPTV Internet Protocol Television.

ISP Internet Service Provider.

IXP Internet Exchange Point.

LLU Local Loop Unbundling.

MDF Main Distribution Frame.

NBN National Broadband Network.

NEC New Entry Cost.

Next Gen NBN Next Generation Nationwide Broadband Network.

NGA Next-Generation Access.

NGAN Next Generation Access Network.

.

NP Network Provider.

NPT The Norwegian Post and Telecommunication Authorties.

NTNU Norwegian University of Science and Technology.

OAN Open Access Network.

Ofcom Office of Communications.

OLT Optical Line Terminal.

ONT Optical Network Terminal.

ONU Optical Network Unit.

P2P Point-to-point.

PIP Physical Infrastructure Provider.

PMP Point-to-multipoint.

PON Passive Optical Network.

PPP Purchasing power Parity.

PSTN Public Switched Telephone Network.

PTS The Swedish Post and Telecom Authority.

RSP Retail Service Providers.

SDSL Symmetric Digital Subscriber Line.

SMP Strong Marked Position.

SP Service Provider.

VDSL Very-high-bit-rate Digital Subscriber line.

VoIP Voice over IP.

VULA Virtual Unbundled Local Access.

Glossary

Bandwidth	The maximum data transfer rate of a network or Internet connection. It measures how much data can be sent over a specific connection in a given amount of time. Given in bits per second, i.e. 100 Mbit/s.
Brownfield	An area were a given Internet access technology does exist.
CAPEX	Capital Expenditure. The one time investment needed to deploy physical Internet infrastructure.
Coverage	Percentage of the total households/population in a geographical area which have access to a given access technology or bandwidth.
Greenfield	An area were a given Internet access technology does not exist.
Network Provider	The provider of active equipment (transponders, routers and switches, control and management servers) in a physical network.
OPEX	Operating Expense. The cost needed to operate the physical Internet infrastructure after deployment.

Penetration	Percentage of total households/population in a geographical area which have access to a given access technology or bandwidth and who have chosen to connect to such a service.
Physical Infrastructure Provider	The provider of passive infrastructure (implying right-of-way acquisition, trenching, cable duct laying, local-office premises).
Service Provider	The provider of Internet services in a physical network.

Chapter 1
Introduction

1.1 Background and Motivation

Norway and Sweden are both despite its challenging landscape and scarce distribution of population countries that are at the forefront in the coverage of Next-Generation Access (NGA) networks. Fibre and HFC networks are widely adopted in both countries and high bandwidth is available for large parts of the country. However, the two countries takes a different approach to how the development of NGA networks will take place. Where Norway has allowed the market take control of the development and take action where there are bottlenecks, Sweden does the opposite. Government and local authorities have taken and still takes intervention to create a completely different market model.

The Norwegian NGA market consists of, with few exceptions, vertical closed networks where the provider of Internet services and physical infrastructure alone have control over the whole value chain. The vertical closed network model entails little to no competition at the service level. Thus, the Norwegian model creates a monopolistic situation for the end users. The end users can only chose the NGA provider which it chose to connect. The opposite is true for Sweden. Here there is a clear separation of who is providing Internet services and who is providing the physical infrastructure. Sweden's market fiber market structure is an Open Access Network (OAN). The Swedish end user may, after its connection to a fiber network, may often chose between several Internet service providers.

1.2 Problem Description

The original problem description is no longer valid for this thesis. The original problem description involved a case study of a nationwide national NGA OAN. However, it did not take long with preliminary studies before I realized how unlikely it would be with a national NGA OAN and how much guesswork that would entail. Luckily, during the first months of work and discussions with Harald Wium Lie, the goal of the task changed into something more concrete. A more precise title to this thesis would be: "A Comparative Study of The Internet Access Markets in Norway and Sweden - Open Access Networks versus Vertical Closed Networks.

Norway and Sweden are similar countries on many levels. The relative equal geography, culture and price levels makes the Norwegian and Swedish Internet access markets well fitted for a comparative study. As governments all over the world face the challenge to find the right balance between creating competition at the service level in NGA networks, while still providing viable incentives to continue the rollout, this thesis will explore the repercussions of the two access market models. More specifically, this thesis will:

- Compare the two markets to Forzati et al.'s [FML13] business models;
- Explore how these market models impact prices, coverage and penetration;
- Explore how government intervention impacts, coverage and penetration;
- Find the pros and cons of these market models.

Forzati et al.'s "Open Access Networks and Swedish market in 2013" [FML13] introduces 6 different access network business models. The different access markets in Norway and Sweden will be categorized in these models in order to provide an understanding of how different business models affect prices, coverage and penetration.

This thesis will have its main focus on the fiber market, however it will also describe the DSL and HFC markets in each country and how all these 3 markets affect each other.

1.3 Limitations

It is not in the scope of this thesis to evaluate the socioeconomic effects of these two market models. Also, the goal is not to say whether one model is better than the other, but rather to explain the differences in them and what kind of impacts they entail.

1.4 Contributions

This thesis conducts a quantitative comparison between markets that implement NGA open access networks towards markets with NGA closed vertical access networks with respect to price, coverage and penetration. It is as far as I can find not done previously. Furthermore, there is no equally comprehensive comparative study of the Norwegian and Swedish Internet access market.

1.5 Structure

The structure of this thesis is as follows: Chapter 2 introduces theory in order to understand the technical aspects of the different market models and how it is possible to implement competition and wholesale in physical networks. Chapter 2 also defines NGA, OAN, vertical closed networks. At last it introduces Forzati et al.'s access network business models. Chapter 3 introduces relevant literature for this thesis. The focus is to provide an international picture of rollout, open access, business models, prices, and government participation regarding NGA. Chapter 4 gives two examples of two national open access NGA networks. Chapter 5 explains how the Norwegian and Swedish DSL, HFC and fiber access markets looks like.

Chapter 6 is about the methodology used to collect data about the Norwegian and Swedish coverage, penetration, prices and government spending. In chapter 7 the results are shown and are in chapter 8 discussed. Chapter 9 contains this thesis' conclusions.

Chapter 2 Theory: Internet Access Technologies and Market Structures

First this chapter will in a short manner introduce the fixed access technologies which are relevant for this thesis. Then, it will explain how wholesale is used and how it works in the access market to increase competition. Third, the terms OAN, vertical closed network and NGA will be defined, and at last 6 different business models for the access market will be explained.

There are three distinct roles a company wishing to participate in the access market may take:

- Service Provider (SP): The provider of Internet services in a physical network;
- Network Provider (NP): The provider of active equipment (transponders, routers and switches, control and management servers) in a physical network;
- Physical Infrastructure Provider (PIP): The provider of passive infrastructure (trenching, cable duct laying, local-office premises).

For the time being, it is sufficient to know what each actor does and that one actor might take 1, 2 or all 3 roles.

2.1 Access Technologies

The next three sections are aimed to give a quick introduction to the fixed access technologies which are used in the Internet access networks. It is important to understand the technical aspects surrounding these technologies in order to answer and understand the issues provided by this thesis. The introductions may leave out some details, however, they should be sufficient to obtain an adequate understanding of the fixed Internet access networks. The access networks that will be explained briefly here is seen in table 2.1. As [OEC14c] points out, there is essentially two ways of delivering Internet access: copper and fiber. Where copper again is divided in two categories: the twisted pair (originally used for telephone services) and the coax cables (original used for cable tv access) which offers higher capacity. In table 2.1

PSTN is equivalent with DSL. The "Core" cables are the cables connecting Internet Exchange Point (IXP)[1] to the PIP. The "Distribution" cables connects the PIP to the local street cabinet closer to the end user. The "Last Mile" (aslo known as the "local loop") is the cable connection the street cabinet to the end user. This thesis will from this point on use "local loop" rather than "last mile".

Table 2.1: Categories of Fixed Networks [OEC14c]

Technology	Core	Distribution	Last Mile
PSTN	Fibre	Twisted Pair	Twisted Pair
Cable TV	Fibre	Coax	Coax
HFC	Fibre	Fibre	Coax
FTTN	Fibre	Fibre	Twisted Pair
FTTH	Fibre	Fibre	Fibre

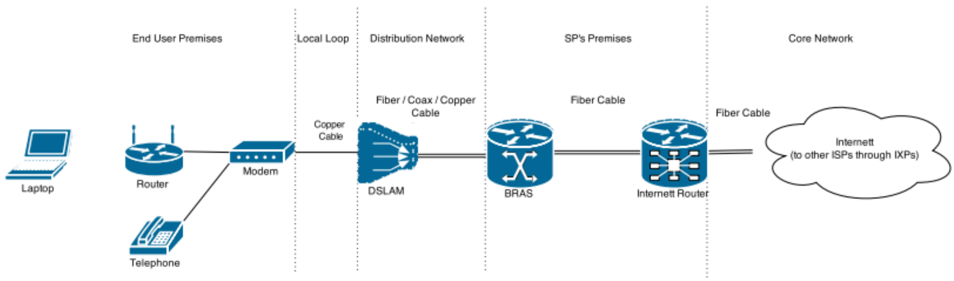
2.1.1 Digital Subscriber Line

Digital Subscriber Line (DLS) is a collective term for several technologies [Lek13] used to deliver Internet services over the Public Switched Telephone Network (PSTN), which is made of copper. The copper cable is known as twisted pair. xDSL is also used as an abbreviation for technologies. The DLS technologies can be divided in two groups: Symmetric Digital Subscriber Line (SDSL) and Asymmetric Digital Subscriber Line (ADSL). The SDSL provides, as the name implies, symmetrical download and upload bandwidth, while ADSL provides greater speed in one direction over the other. ADSL is the dominant technology when it comes to providing Internet access over the copper network. The structure for a DSL network is depicted in figure 2.1.

Here the DSl specific components are the modem, Digital Subscriber Line Access Multiplexer (DSLAM), and Broadband Remote Access Server (BRAS). The modem is used to transfer the DSL service on the telephone line to a router or computer for Internet connection. The DSLAM delivers high speed data transmission from fiber or other high capacity cables to copper wires, which the telephone network is made of. It is the interface between the end user and the service provider [Con07]. The bandwidth which the end user experiences depend highly on the distance from the DSLAM to the modem. The bandwidth capacity rapidly decreases with the distance between the two components. There are multiple ways to cope with this, but this is outside the scope of this introduction. However, one way to assure a

[1] "An Internet Exchange Point (IXP) is a place where networks exchange traffic. It allows SP to peer with one another at a shared facility. The European Internet Exchange Association (Euro-IX) has defined an IXP as a “physical network infrastructure operated by a single entity with the purpose to facilitate the exchange of Internet traffic between Autonomous Systems." [RG12]

Figure 2.1: DSL Structure



higher bandwidth is moving the DSLAM closer to the end user. The last component, the BRAS, is not important for this thesis.

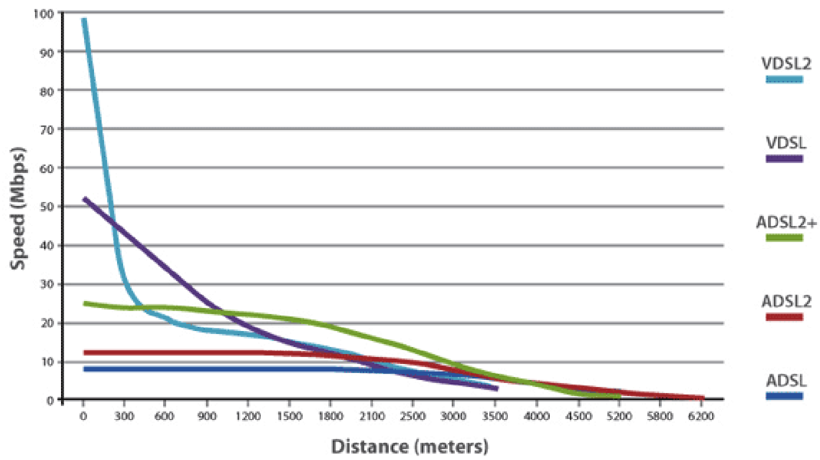
It exist several types of ADSL technologies: ADSL, ADSL2, ADSL2+, VDSL, VDSL2, and VDSL2+. Very-high-bit-rate Digital Subscriber line (VDSL) is the technology which is able to deliver the throughput with theoretical 100 Mbit/s download and upload speeds [Wik14] [Lek13]. However, to achieve this capacity, the end user must be no longer than 300 meters from the street cabinet (where the twisted pair starts) to the end user (more on this in section 2.1.3). For ADSL, ADSL2, and ADSL2+ the distribution cable is also made of fiber, however here the speed also greatly depends on the distance to the street cabinet. Although there is a big difference in theoretical speed, in Norway, most SPs advertise with a maximum download and upload speed in the range of 20/5 to 50/20 Mbit/s [pow14] [Nex14] with the use of DSL technologies.

Figure 2.2 shows how the download speed decreases as the distance to the street cabinet increases. As seen, the theoretical received download bandwidth quickly decreases with the distance to the DSLAM/street cabinet.

2.1.2 Hybrid Fibre Coax

Introduced over 50 years ago, the Hybrid Fiber Coax (HFC) was originally a cable TV network supporting analog video channels, as depicted in figure 2.3. With the introduction of the DSL technology and the broadcast satellite, the cable TV companies faced competition which needed to be addressed. In 1997 this resulted the first Data Over Cable Service Interface Specification (DOCSIS) standard, the DOCSIS 1.0. [Cis12] [Cis09]. The DOCSIS standard enables data transfer over the cable TV network, along with TV signals. By replacing the distribution cables from coax to fibre, transforming the cable TV network into a HFC network makes it possible to offer greater bandwidth. A typical HFC network can be seen in figure 2.4. The most recent DOCSIS standard, the DOCSIS 3.1, provides high bandwidth both

Figure 2.2: DSL Download Speed Graph [Hol11]



down and upstream. According to [Cab13] the DOCSIS 3.1 specification provides 10 Gbit/s downstream and 1 Gbit/s upstream bandwidth. The most widespread and used DOCSIS standard today is the DOCSIS 3.0, which provides a theoretical bandwidth of 160 to 240 Mbit/s downstream and 120 Mbit/s upstream [Cis09] [OEC11].

Figure 2.3: Cable TV Structure [Cis12]

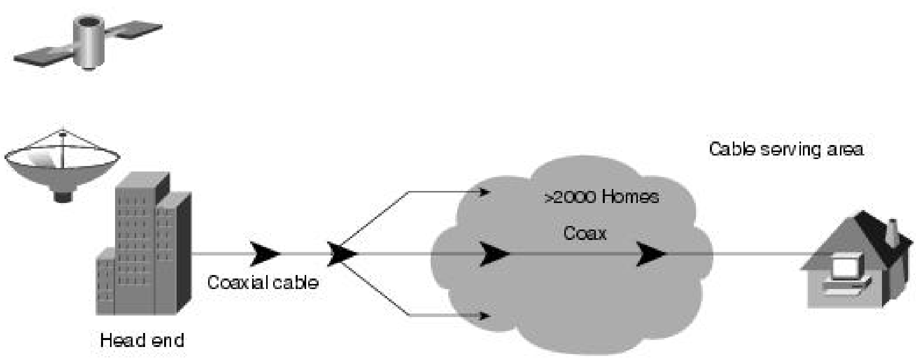
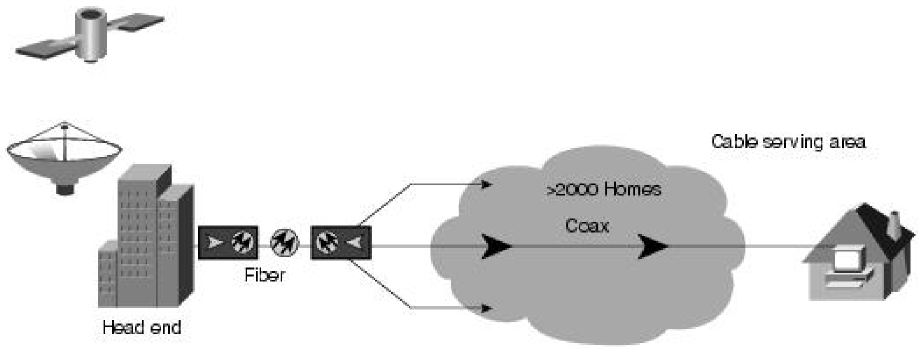


Figure 2.4: HFC Structure [Cis12]



2.1.3 Fiber to the X

Fiber to the x (FTTX) is a term for different fiber network architectures, indicating how close the fiber is to the end user. This thesis will describe and explain the following FTTX architectures: Fiber to the node (FTTN)Fiber to the curb (FTTC); Fiber to the building (FTTB); and Fiber to the home (FTTH). The FTTH Councils from Asia Pacific, North America, and Europe have agreed upon common definitions of FTTH and FTTB [FTT11]. There also seems to be a general consensus of the definition of FTTC [Tec14a] and FTTN [Tec14b] [Gro14]. The different FTTX architectures can be depicted in figure 2.5 and explained in the next four sections.

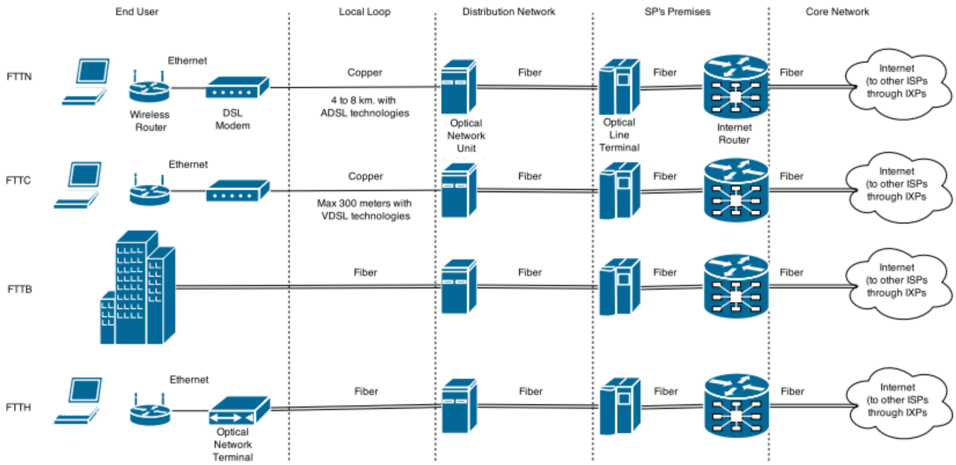
FTTN

FTTN is also known as "Fiber to the neighborhood". This is due to the placement of the street cabinet (in figure 2.5 referred to as the Optical Network Unit (ONU)) beeing close to a neighborhood. The local loop in the FTTN network is made of twisted pair. ADSL technologies is used to deliver Internet access over the twisted pair. The twisted cables are between 4 to 8 km. long.

FTTC

As the name implies, FTTC architecture delivers fiber cables all the way from the SPs premises to the street cabinet (ONU) placed on a curb, approximately 300 meters from the end user. The local loop is, similar to FTTN, also made of twisted pair. The VDSL technologies are used to deliver Internet access. Therefore, the FTTC is also known as VDSL [Lin06] [Gar12]. HFC (DOCSIS 3.0 and higher) is also by some considered to be a FTTC architecture [OEC11].

Figure 2.5: FTTX Architectures



FTTB

As mentioned The FTTH Councils from Asia Pacific, North America, and Europe have agreed upon common definitions of FTTH and FTTB [FTT11]. Their definition of FTTB is as follows: "... an access network architecture in which the final connection to the subscriber's premises is a physical medium other than Optical Fiber". Further the definition states that the purpose of FTTB is offer Internet access to a building with potentially multiple subscribers. The final cables, from the entry of fiber in the building to the end user, is made of any other cable except fiber.

FTTH

[FTT11] defines FTTH as "... an access network architecture in which the final connection to the subscriber's premises is Optical Fiber". This means that all cables, from the SP to the end user (to the Optical Network Terminal (ONT)) is made of fiber. This enables high bandwidth in both directions. As elaborated in section 2.1.4 there are different FTTH architectures.

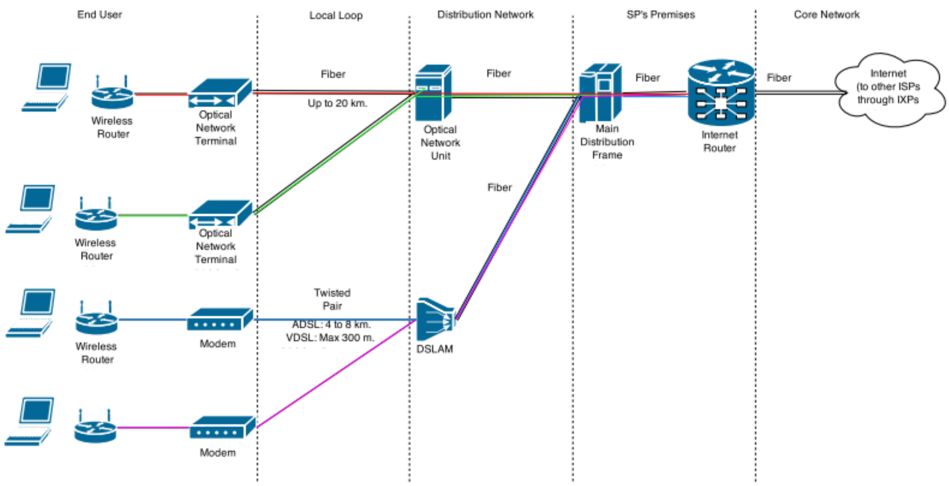
2.1.4 Implementing FTTX Architectures

There are three ways of implementing FTTX architectures [JAP+07]: Optical Active Network (AON); Passive Optical Network (PON); and Point-to-point (P2P).

AON

An example of an FTTX AON architecture is depicted in figure 2.6. The main characteristic for an AON is the active component placed between the end user and the SP's Main Distribution Frame (MDF). In the case of a FTTN or FTTC architecture this active component is a DSLAM. If the network is a FTTH or FTTB this component is a ONU (as seen in figure 2.5). This active component routes the traffic from the MDF to the relevant end user. The end users shares the bandwidth between the ONU and MDF.

Figure 2.6: FTTX AON Architecture



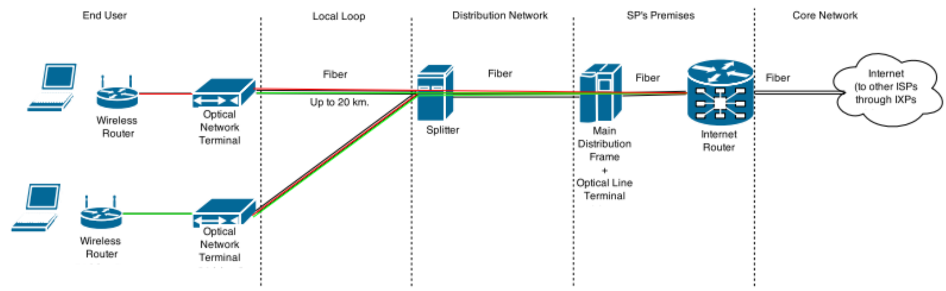
PON

An example of an FTTX PON architecture is depicted in figure 2.7. For PON there is no active component between the end user and MDF. Between the MDF and end user there is now two components: the splitter and the Optical Line Terminal (OLT). The OLT is placed together with the MDF, while the splitter is closer to the end user. The splitter simply splits the traffic from the MDF/OLT to all connected end users. The traffic intended for the end user is filtered out at the ONT. As for AON the end users shares the bandwidth between the splitter and MDF/OLT. PON networks is either FTTB or FTTH networks.

P2P

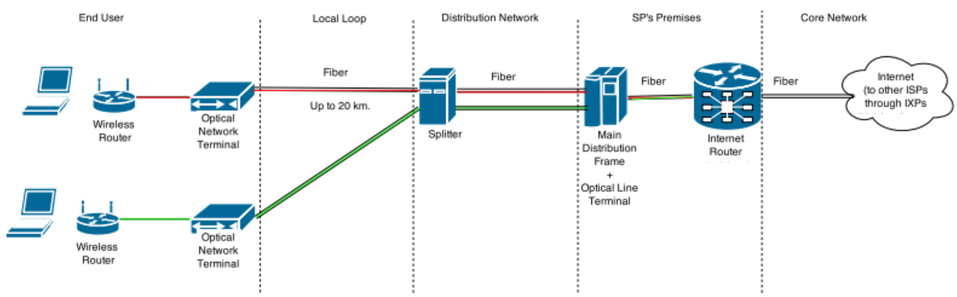
An example of an FTTX P2P architecture is depicted in figure 2.8. The P2P network is, as a PON network, either a FTTB or FTTH network. In the P2P architecture, every end user has one dedicated fiber cable all the way from the MDF to the ONT

Figure 2.7: FTTX PON Architecture



(see figure 2.8). In the case of a FTTH P2P network, the available bandwidth to the end users is 10 Gbit/s downstream and 1 Gbit/s upstream [Aq14]. This is also the highest possible bandwidth provided through any FTTX architecture to this date.

Figure 2.8: FTTX P2P Architecture



For all three architectures comes economic and practical consequences. The aforementioned maximum possible bandwidth for FTTH P2P is why this architecture is considered to be the most future proof architecture. However, throughout Europe, the PON architecture is the far most used [JNP+10]. Further, the PON architecture is also the cheapest to implement. It requires less fiber, due the sharing of the fiber cable between the ONU and MDF, and is easier to maintain. There are also other consequences regarding wholesale, which will be elaborated further in section 2.2.

2.1.5 Deployment of NGA-Networks

Building new Internet infrastructure is characterised by high CAPEX. The Swedish Urban Network Association (Se. Svenska Stadsnätföreningen) [Sve14] estimates that to connect one household to a fiber network cost between 573 to 3440 USD (Adjusted for 5000 to 30000 SEK). A study for the French government in 2006 estimates the CAPEX to between 476 to 2451 USD [Mar07]. Adjusted for inflation up to 2013, the numbers would be approximate 550 and 2800 USD. The same study also estimates that 70% of the cost is civil engineering costs.

The CAPEX vary depending on which type of FTTX architecture is chosen and if the household is in a metropolitan, suburban or rural area. I.e. the cost of installing a PON network in a metropolitan area costs approximate 550 USD. The same technology in an suburban area cost approximate 2200 USD.

In a 2011 report from OECD [OEC11], PIP which favors passive FTTX networks, such as the PON network, states that they compared to active architectures have both lower CAPEX and OPEX. As stated in the previous sections, the PON architecture provides lower bandwidth compared to the P2P architecture. However, proponents of the passive architecture states that this architecture is a far more economically sustainable model for developing FTTX networks to rural areas and that his architecture will be sufficient for future use.

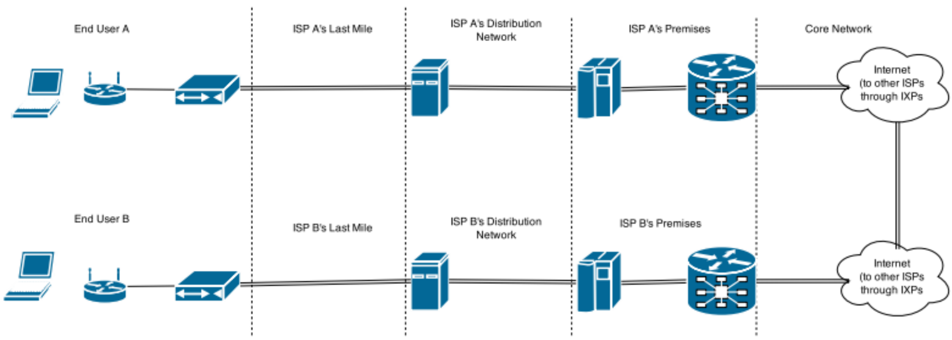
Proponents of the active architecture, the P2P and AON, claims that these architectures provides a far more future proof solution due to their higher bandwidth and flexible wholesale possibilities. PON architecture demands more logic and encryption to separate customer streams if a wholesale solution is to be implemented.

2.2 Wholesale Access

As stated in the previous section deploying physical infrastructure is very expensive. Therefore, when one SP connects one household to its network (either DSL, HFC or fiber) there is little to no incentives for another SP to connect the same household to its similar network. The competition would be to high for an entry cost that big. I.e. if SP A connects a household to its DSL network, SP B would not try to connect the same household to its DSL network, but instead try to connect that household to a NGA network, or focus on connecting households which lack Internet access. This often leads to a monopolistic situation for households, since one household might only have connection to a network with one SP (an example of this is depicted in figure 2.9). Wholesale access is a way to increase competition when it comes to delivering Internet access services. Wholesale access entails that an PIP (which also can be a SP as well) provides access to the customers connected to their physical network to additional SPs.

Local Loop Unbundling (LLU), Bit-stream Access (BA), and Full Unbundling (FU) are three ways for one incumbent SP to share its infrastructure with SPs which may not own infrastructure.

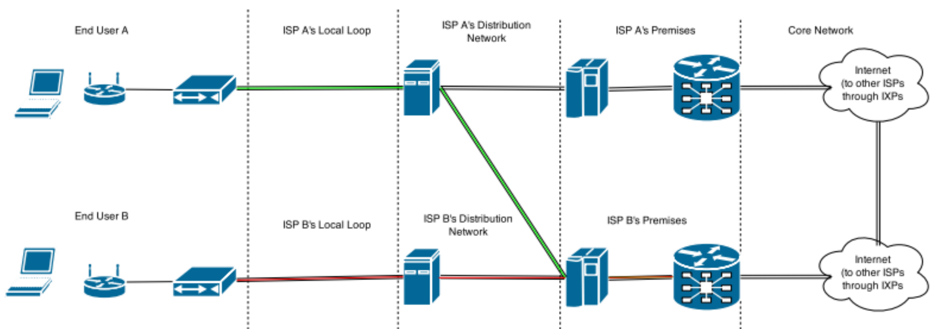
Figure 2.9: SP Monopol



2.2.1 Local Loop Unbundling

LLU involves giving another SP physical access to the local loop. An example of this is depicted in figure 2.10. In the example SP B receives access to SP A's local loop (SP A is also the PIP) through a street cabinet connected to End User A. Here both End User A and B subscribes to Internet services from SP B (indicated by the green and red lines). In most cases SP B pays SP A to compensate for the loss in income for SP A losing a potential subscriber.

Figure 2.10: Local Loop Unbundling

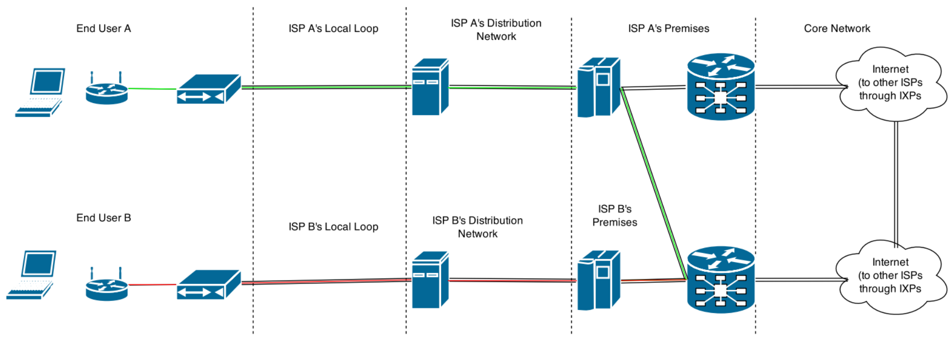


2.2.2 Bit-stream Access

Instead of SP A giving SP B physical access to a street cabinet, SP A can give SP B physical access to their premises. Figure 2.11 depicts an example where SP B is given bit-stream access to SP A's network. Here SP B connects to SP A's premises and End User A subscribes to Internet access from SP B through SP A's network.

For Fiber networks, there is a additional way to provide BA called Virtual Unbundled Local Access (VULA). Because of the technological differences between DSL which supports BA and Fiber which supports BA and VULA, VULA gives more control for the additional SP over the connection to an end user than BA does. I.e. VULA supports traffic prioritizing, which BA does not [Tel14].

Figure 2.11: Bit-stream Access



2.2.3 Full Unbundling

FU [OEC11] entails giving (from the previous examples) SP B 100% control over the physical cable all the way from SP A's premises to the End User. This is only possible with a FTTH P2P architecture, due to its dedicated fiber all the way from the end user's ONT to the SP's premises.

2.2.4 LLU, BA, and FU in DSL, HFC and Fiber Networks

The technical architecture in DSL, HFC and fiber networks have major implications on the possibility whether or not local loop unbundling, bit-stream access or unbundled access is possible at all.

DSL

For DSL networks LLU and BA are possible, but not UA.

HFC

Due to the shared infrastructure for up to 2000 households, bit stream is the only way to enable wholesale access in the HFC network [Gar09].

Fiber

As mentioned, full unbundling is only possible in FTTH P2P networks [JAP$^+$07].

Table 2.2: BA Possibilities in FTTX Architectures [JAP+07]

FTTX Architecture	Access at PIP's premises	Access at Street Cabinet
FTTX AON	possible	possible (low incentive)
FTTX PON	possible	impossible
FTTX P2P	possible	impossible

As table 2.2 shows, there most practical way to provide wholesale access to additional SPs for an incumbent PIP is at the PIP's premises.

2.3 Next Generation Access

The term NGA is tossed around in numerous articles, reports, and papers all having a different definition in them. OECD defines it in a paper from 2011 [OEC11] as the following: "The term next generation access (NGA) is commonly used to describe the requirement of fibre coming closer to the end-user, or providing the direct connection". The European Union [Com10] defines NGA as: "wired access networks which consist wholly or in part of optical elements and which are capable of delivering broadband access services with enhanced characteristics (such as higher throughput) as compared to those provided over already existing copper networks". Further, the European Union's Digital Agenda [Eur12] includes goals which says that all European households should have access to a minimum download speed of 30 Mbit/s and that 50% should subscribe to broadband above 100 mbit/s by 2020. The Norwegian Communications Authority (Nkom) supports the 30 Mbit/s as definition for NGA [Nor14b].

Office of Communications (Ofcom), United Kingdom's national regulatory authorities for broadcasting, telecommunications and postal industries defines NGA as [Ofc08]: "New or upgraded access networks that will allow substantial improvements in broadband speeds and quality of service compared to today's services. Can be based on a number of technologies including cable, fixed wireless and mobile. Most often used to refer to networks using fibre optic technology".

However, this article [MCF11] from 2011 supports the confusion that no strict definition exists, but states out that there seems to be a "tacit agreement at the industry level" that a minimum download speed for NGA (or Next Generation Access Network (NGAN) which is used in this article) should be a 50 Mbit/s. Vorst et. al's study [vdVBvKB14] from 2014 attempts to determine the demand for bandwidth in 2020. The article suggest a sufficient bandwidth for an average user in 2020 to be approximately 165 Mbit/s (downstream) and 20 Mbit/s (upstream). However, [vdVBvKB14] calculates that the "mainstream users", which constitutes 60% of the potential market subscribers (opposed to "innovators" and "power users" which represents 18 and 2% respectively), would only need a 54 Mbit/s download bandwidth and 3,5 Mbit/s up.

Although in most cases there seems to be a focus on bandwidth, there is a consensus among governments, regulatory authorities and the industry that NGA should be based on architectures as FTTH, FTTC/VDSL and HFC (DOCSIS 3.0 and higher). With FTTC/VDSL as the clear bottom line when it comes to bandwidth, this will imply that the lowest accepted download bandwidth that a network can offer to be called NGA must be 50 Mbit/s, since this is the both promotional and realistic speed a household can expect to receive as a VDSL subscriber.

However, due to the variable and uncertain deliverable bandwidth over twisted pair with the FTTC/VDSL architecture, this thesis defines NGA to HFC (DOCSIS 3.0 or higher) and FTTH. Thus, NGA is defined by the available access technology and not by the available bandwidth. This is also supported by the Swedish Government Official Reports [Sve13].

2.4 Open Access Network

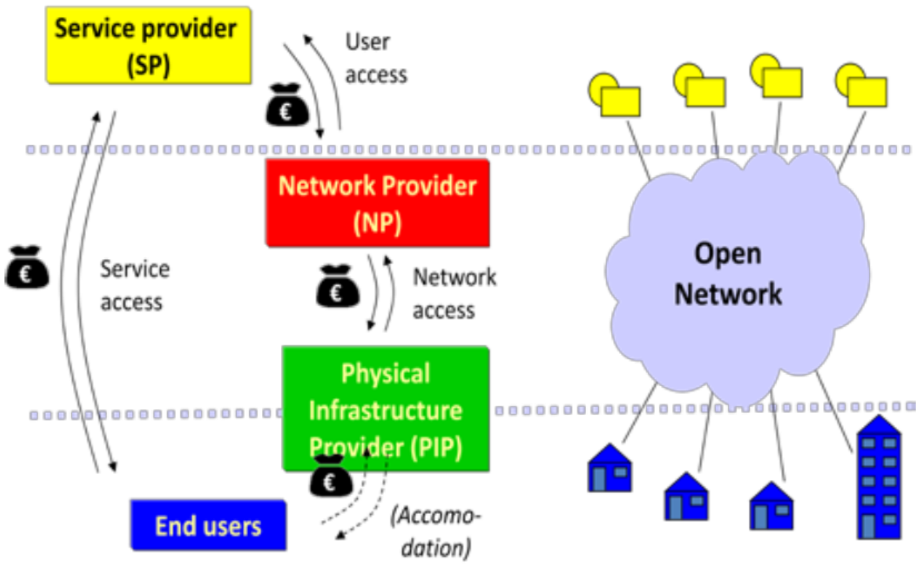
As for NGA there is no formal academic definition of an OAN, however it exist a consensus which appears throughout several articles and reports. This thesis uses the definition of an OAN from Forzati et al. [FML13] which is the following: “In the open access network model, the roles of the service provider and the network owner are separated, and the service providers get access to network and the end customers on fair and non-discriminatory conditions”. Figure 2.12 shows Forzati et al.’s definition of an OAN. Here there is a clear separation of the SP and the NP. The NP and the PIP can for practical reasons (these will be explained soon) be the same company.

Lin et al.[Lin06] also suports Forzati’s definition. Lin et al. defines an OAN as "A network where:

- the network operator and the service providers are separated
- the relationship between an end-user and a service provider depends on mutual agreements;
- the network operator is not involved in that relationship beyond the connectivity service;
- all end-users can choose a service from all service providers over the common infrastructure operated by the network operator"

A report from Organisation for Economic Co-operation and Development (OECD) [OEC13] also mentions Forzati’s article and investigates different policies concerning

Figure 2.12: Forzati et al.'s [FML13] Open Access Model



"open access" in OECD countries. OECD states that while there no single definition in the OECD countries, the open access policies share several common elements: "they refer to wholesale access to network infrastructure or services that is provided effectively on fair and reasonable terms, for which there is some degree of transparency and non-discrimination". This looks quite the same as [FML13]'s definition, although the major difference here is the lack of clarification that the roles of the service provider and the network owner should be separated.

The Swedish Association Metropolitan Networks (Se. Svenska Stadsnätsföreningen) [Sta11a] has a clear definition of an OAN [Sta11b] (English translation): "An open network is an infrastructure that is available to all market participants on equal terms. The network is open to all who want to rent fiber and for all who want to offer services in active networks". They use the term "infrastructure" as a generic term for both broadband, HFC and fiber infrastructure. Thus, this definition follows [FML13]'s definition.

This definition is also supported by Stephen Davies from Australian FTTH News [Dav09]. He points out the importance of an independent and separated network provider of the retail service providers. Further, he describes OAN more as a business model, rather than a infrastructure model, divided in three horizontal parts:

– Service Provider(s);

- Network Operator;
- Network Owner.

Here "Network Operator" and "Network Owner" are compared to figure 2.12 and [FML13]'s definition NP and PIP, respectively.

Further definitions of OANs that underpinning aforementioned definitions is Opticomm's [opt14] "In telecommunications, an open access network refers to a horizontally layered network architecture and business model that separates the physical access to the network from the delivery of services". There exist cases where the network operator and network owner is the same company for practical reasons , i.e. to improve efficiency and reduce operating cost (i.e. Sweden's City Network). The most important reason for the separation of service and network providers is that the network provider does not compete with others at the service level. In such cases, there will always be allegations of "favoritism, anti competitive conduct and theft of customer data" [Dav09].

[Lin06] list some of the benefits than an OAN provides for end users, the industry and society:

- The end-user can freely select the service from a given service provider that offer him the most attractive conditions, and he can combine different services from different providers;
- The service provider gets a chance to reach many users without having to own or operate infrastructure or active equipment;
- Competition will stimulate growth and enable public services to be more easily offered to the end-users which will benefit the whole society.

From end users' perspective, an example of an OAN is depicted in figure 2.13. Here all end users (the houses to the left) which is connected to PIP A's network, may choose freely between various SP, providers of Internet Protocol Television (IPTV) and providers Voice over IP (VoIP). An end usert might i.e. choose to only subscribe to VoIP services from SP3, IPTV Provider 2 and VoIP Provider 1.

2.5 Vertical Closed Network

As opposed to the OAN depicted in figure 2.13, figure 2.14 shows an example of a vertical closed network. Here the end users can only choose between the providers which PIP B has entered an agreement with. In this case this is SP 1, IPTV Provider 1 and VoIP Provider 1. It is also possible that the providers of a service might be the same company as PIP B. These different kind of market structures are described in the next section.

Figure 2.13: Open Access Network

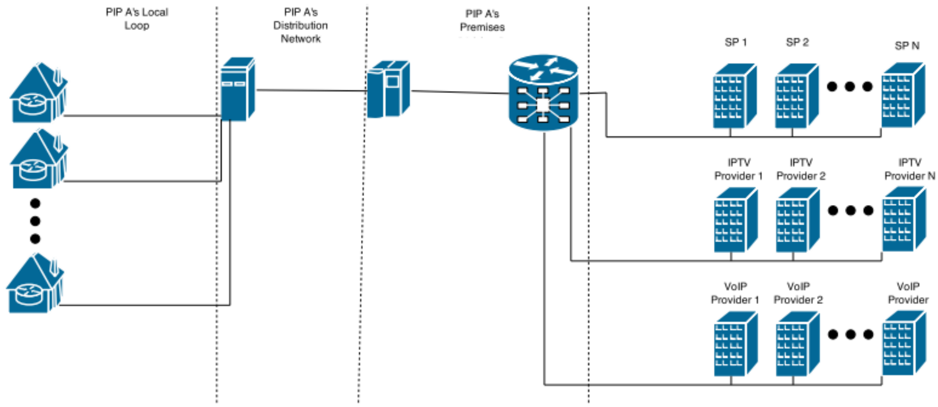
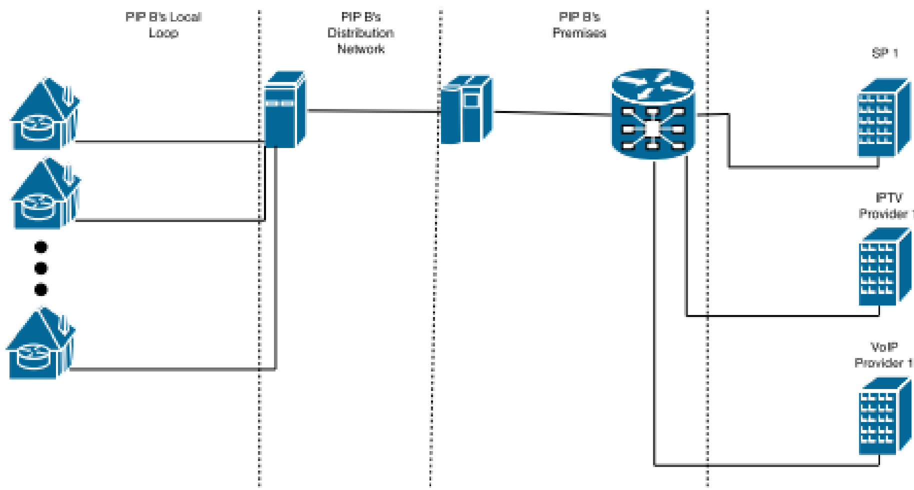


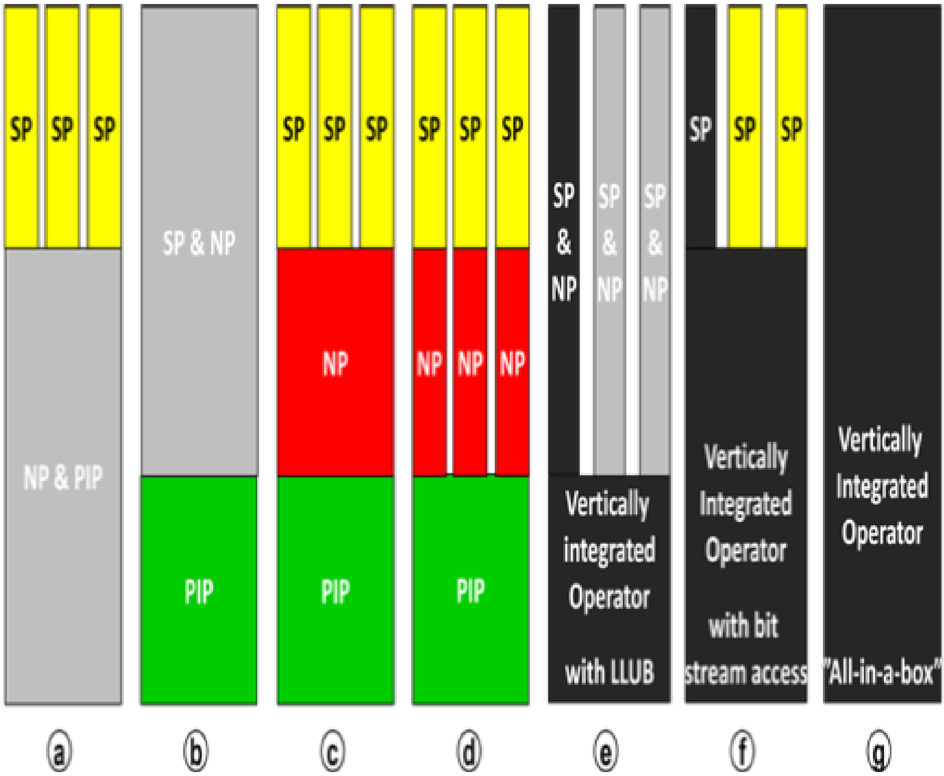
Figure 2.14: Vertical Closed Network



2.6 Forzati et al.'s Access Network Business Models

From top to bottom figure 2.15 the three different actors in the access network marked are as listed before the SP, NP, and PIP. Model A shows the case where the NP and PIP is the same actor. As mentioned in the previous section, this meets the requirements for an OAN as determined by Forzati et al. Model C and D also fulfils the requirements for an OAN. However, in model C all providers are different actors,

Figure 2.15: Forzati et al.'s [FML13] Access Network Business Models



while in model D the it exists more than one NP. For practical reasons this is seldom seen. The most common case is 1 PIP and 1 NP, where the NP operates the physical infrastructure on a contract spanning over a fixed number of years. Model b shows the case where the SP and NP is the same actor. This is not an OAN. Here there is only 1 SP, and if there more SPs were to connect, the incumbent SP should not offer services in the network other than taking the role as NP.

Model E, F and G are also not OANs. Here the black actor is the takes all roles for all cases, but in model E and F in various degree includes other actors to its physical network. As written in model E, this is the case of LLU explained in section 2.2.1 (or LLUB as written the figure). This is model is often seen in DSL networks. The same is for model F. Here the SP, NP, PIP is the same actor. Additionally it also grants access to other SPs to offer services in its network. As written in the figure this is the case of a bit stream access. This is also very common in DSL networks. Model G depicts a case where one and only one actor provides all services in the network.

In summary model A, C, and D shows OANs, while model B, E, F, and G are not. Model G is what is also known as a vertical closed network. How the the money flows in these models vary. But generally they work as depicted in figure 2.15.

The physical infrastructure, operated and laid out by the PIP, in characterised by high CAPEX, due to the high civil engineering cost, and low OPEX. It is also often build out in local areas, and when first put in the ground other operators naturally chooses to avoid the same areas due to the competition. This makes in most cases the PIP a monopolist and therefore a subject to regulation by the relevant authorities.

Chapter 3
Related Literature

3.1 Forzati et al: Open Access Networks and Swedish market in 2013

This paper, which is an updated version of [FLM10] from 2010, gives an overview of specific Swedish OANs and provides conclusions of its experiences, and provides the 6 different access network business models (depicted in figure 2.15). Forzati et al. concludes that for end uses, the process of connecting to SP is now a simpler task and the number of SP have increased. Further, municipalities focus more on creating and providing infrastructure, rather than competing commercial companies. However, Forzati et al. notes that due to the clearer separation, small municipalities have a hard time managing economically. Because of this, many municipality networks have merged or been acquired by competitors. At last, there is a trend that big SPs have taken the role as NPs. Although still not taking the role as SP in the same networks, this is seen as worrying by many municipalities.

3.2 Forzati et. al: Stokab, a socio-economic analysis

This report by Marco Forzati and Crister Mattson explores the socioeconomic effects of Stokab and Stokab's fibre network. Stokab is the owner and provider of a passive fibre network in the city of Stockholm. The network is an OAN, which allows other actors to take the roles as SPs and NPs. It finds that the socioeconomic effects which Stokab creates is estimated to be (based on 2013 currencies) approximately 2 billion USD. This is the result of "increased property value and revenues for the municipal housing companies, added value for their tenants, increased employment, Stokab's return, saving for local governments' ICT costs, as well as the increased economic activity in the supplier industry".

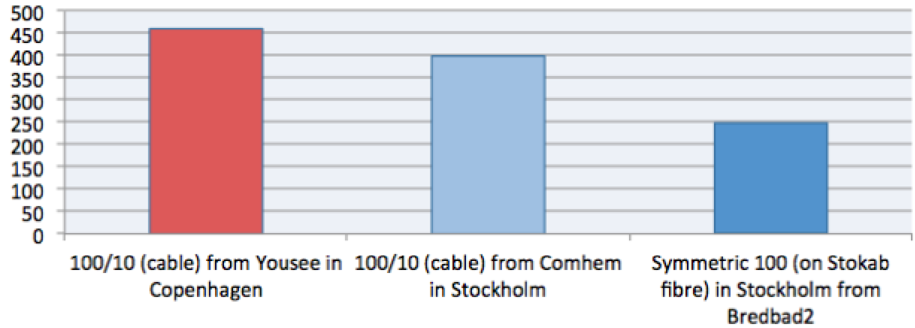
Furher, this report also contains a price comparison between Stockholm and Copenhagen. These cities are quite similar in size, population and economy. However,

Figure 3.1: The Fibre Situation in Copenhagen Compared with Stockholm [FM13].

	Stockholm	Copenhagen
City's involvement	High	Very low
Public funding	No state subsidy. Stokab is built with bank loans.	No state subsidy. Some tax credit.[23]
Fibre infrastructure owned primarily by	Stokab (munipally owned); Skanova in a minor extent	TDC (privately owned telecom companies, the former monopolist); Global Connect in a minor extent (especially in industrial areas)
Neighbourhoods with fibre	100 %	<60 %
Fibre-connected buildings (FTTB)	>90 %	15-20 % (not used today)
Dedicated fibre pair from each household to access node	Yes	No
Business model	Functional separation and open access	Vertical integrated operators
Access to dark fibre leasing	Yes, to everyone on equal and transparent conditions, from a neutral player (Stokab)	Limited access (from Global Connect, which also delivers services)

after 20 years of building Internet infrastructure, there are major differences in the fiber markets. This is depicted in figure 3.1. The first thing to notice is the city's involvement. This has resulted in an OAN model for Stockholm, which was the idea right from the start, while Copenhagen's Internet market is vertical closed. There is also a clear difference in fiber connected building and fiber coverage of neighbourhoods. As figure 3.2 shows, there is also a price difference in favor of Stokab.

Figure 3.2: Comparison of Consumer Prices (Monthly Price in SEK for 100 Mbit/s) in Stockholm and Copenhagen; Source: Online Information from each Respective SP, retrieved on 4 February 2013 [FM13].



3.3 Neumann: Structural models for NBN deployment

This article from Karl-Heinz Neumann [Neu10] examines different areas regarding NGA networks. Firstly if a national high-speed network is realizable in the following 6 European countries: Germany, France, Sweden, Portugal, Spain and Italy. According to Neumann governments around the world seems tempted with the idea of a nationwide NGA network. These governments believes that the large scale development of this kind of network in turn will result in a positive socioeconomic effect and creates incentives for operators to invest in NGA deployment. In extreme cases as in Australia, the government also takes the role as the PIP. However, most incumbent operators seems tepid to the idea of a full scale nationwide fiber investment. Incumbent operators seems more driven by the competition of new entrants of fiber networks and HFC operators, rather than the a possible positive investment in a nationwide NGA network. The hesitation of many operators regarding development of this kind is derived from the uncertainties profitability of NGA networks and its demand from end users.

Assuming development of either FTTN-VDSL, FTTH-PON or FTTH-P2P, Neumann finds that even with a monopolistic market structure, nationwide NGA deployment is not profitable in any of the six countries analyzed on the basis of current costs. In Sweden the cost in USD per home covered is 175 for VDSL, 463 for FTTH PON and 625 for FTTH P2P. However, including the last local loop, the cost increases to 415, 1500 and 1572 USD. He also finds that neither of the FTTX architecture economically supports the development of overlapping NGA networks. This is in rare cases only possible in dense populated areas.

Further, NGA coverage in non-profitable deployment areas can only be achieved with public funding or subsidies. Neumann supports other studies which lists the high CAPEX as the main barrier to NGA deployment, both for first and second movers. He also finds that new operators often encounter higher CAPEX than incumbents because of their small size and risk entering a new market. Neumann writes that the fiber penetration should lay between 50% and 100% to be economically viable. The importance of a penetration increases with the decrease of population density. Thus, penetration rate is a highly critical factor regarding NGA development.

3.4 BEREC: Report on "Open Access" Broadband Networks and Open Access

Body of European Regulators of Electronic Communication (BEREC) [BER14] is established by the European Parliament and of the Council. Its mission is: "Committed to independent, consistent, high-quality regulation of electronic communications markets for the benefit of Europe and its citizens". This report from BEREC examines how its member states are using various mechanisms, such as legislation, regulation, and rules regarding state aid, to develop both DSL and NGA broadband networks. In this context this report specifically examines how the member states is using three kinds of mandated access, which are "open access", regulated access, and "other" access. BERECS' member states all recognizes the importance of mandated access to encourage further investment in Internet networks, without building unnecessary overlapping NGA networks, and increase competition.

Firstly this report naturally looks at the term "open access". As stated in the report, "open access" is not defined in any legal document and is mostly understood as a form of wholesale access. However, BEREC notes that the term "open access" is used in the European Commission's State Aid Guidelines, and is here referring to the mandated wholesale access incumbent operators are required to give, allowing competing operators to offer services in its network. The European Commission defines wholesale access as "mandated wholesale access whereby operators are offered effective, transparent and non- discriminatory wholesale-access to the subsidized network(s)". BEREC further notes that over all through their member states "open access" and "effective wholesale access" are used interchangeably. Because of the current development in NGA networks (using the definition including HFC, FTTH, FTTB, and FTTN) BEREC states that it is impossible to define all types of "open access"/wholesale access and therefore uses the term "open access" in inverted commas.

3.5 OECD: Next Generation Access Networks and Market Structure

This report from OECD [OEC11], published in 2011, investigates the development of broadband marked structures in OECD countries concerning NGA networks, and its accompanying different regulatory policies and implications. The reports goal is to find best practises regarding regulatory policies to enhance further NGA development. An important finding this report does, which is highly relevant for this thesis, is the growing support in some OECD countries of functional and/or structural separation of the network from the provision of services. This is other words the structural separation which Forzati et al. defines as an OAN. The separation could according to this report provide incentives for innovation in both service providing and be a basis for innovation elsewhere in society. However, the regulation regarding this separation should also provide incentives for further NGA rollout and upgrading as this is the challenge for this kind of separation. The regulation should also make the PIP responsive to the SPs. In other words, the PIP should serve the SP and have incentives to always provide the best environment for the SPs to deliver satisfactory services to the end users. Further OECD underlines the importance of wholesale accesses in regulation of FTTX architectures, due to the limited socioeconomic potential of overlapping NGA networks.

OECD splits the OECD countries different kinds of involvement in NGA development in 7 categorizes. These categories and which countries belonging to them can be seen in table 3.1. Note that a few countries are present in more than one category. Norway is in the category "Determine where bottlenecks are and take action through access regulation", while Sweden is listed in "Government participation in NGA fibre deployment".

3.6 OECD: Broadband Networks and Open Access

This OECD report [OEC13] the term "open access" as BEREC [BER14], as described two sections earlier. It examines different "open access" policies and approaches. It states that throughout the OECD countries, there are seldom incentives for commercial network providers (using this thesis definitions of access actors NP and PIP) to grant access to its infrastructure. Thus, "open access" is almost without exception an initiative taken from the authorities, often accompanied by public funding. The reports sums up common elements in "open access" regimes in: "

- Access is provided at the wholesale level.
- Effective access is provided on fair and reasonable terms. Setting adequate price levels and avoiding non-price related discriminatory behaviours should play a major role in ensuring effectiveness.

Table 3.1: Approaches to NGA market structure, access and development in selected countries [OEC11]

Category	Countries	Comments
Primary reliance on market forces for NGAs	Finland, Hong Kong, China, Korea, Switzerland, United States	The presence of extensive coverage of cable service is an important factor
Determine where bottlenecks are and take action through access regulation	Austria, France, Portugal and most other OECD countries	Most countries are making some effort in regard to access regulation
Develop end-to-end infrastructure competition through LLU but without imposition of functional or structural separation	France, the Netherlands, Germany, Portugal, Spain and Ireland	The relative success of ex ante access regulation, including LLU is considered an important contributing success factor; Portugal was a pioneer in adopting the Reference Conduit Access Offer (RCAO)
Access regulation plus functional separation	United Kingdom, Italy and New Zealand	Functional separation has been installed as a complement to access regulation.
Facilitate deployment of a wholesale backbone network	Chile, Italy, Argentina	Government initiatives to catalyze or fund a high speed backbone network
Government participation in NGA fibre deployment	Australia, France, Japan, New Zealand, Portugal, Singapore and Sweden	e.g., government private sector co- operative arrangements have been used in these countries
Deploy a prospectively structurally separated NGA wholesale operator	Australia, New Zealand and Singapore	At the extreme, 100% government funded (although with intention of privatising in 8 years)

- Access should be provided on transparent and non-discriminatory terms or, at a minimum, a clear policy should be established as to the conditions that apply to the arrangement. Transparency may also be implemented through a public reference offer.
- To date open access has rarely been provided voluntarily, and it is usually the result of direct or indirect public intervention.

Further, this report states that the incumbent operator in Japan holds a fiber market share of 74%, which is extremely high for any operator throughout the

OECD countries. The Japanese government implemented unbundling of fiber in 2001, believing that removing this would have negative effect on competition. Japan is also in considering separation between SP and NP, to secure the open access policies. OECD also marks importance of balancing between incentives regarding further NGA development and competition in NGA networks. The incentives should reward risk taking and uncertainties.

Regarding HFC networks, it list Denmark and Canada as the only two countries where some kind of "open access" is imposed. Here bit stream access is available in HFC networks. For DSL, all but four OECD countries have implemented local loop unbundling.

3.7 OECD: The Development of Fixed Broadband Networks

OECD published in 2014 an extensive report named "The Development of Fixed Broadband Networks" [OEC14c] which looks at the development of fixed networks in OECD countries and how each country supports the Internet economy. The part of the report which is of relevance for this thesis describes: how OECD countries uses unbundling to promote NGA competition; examples of "open access" models; regulates the NGA market; obstacles for NGA development; and how OECD countries deal with these obstacles. OECD starts with stating that there are 3 areas which separates how NGA development takes place in OECD countries: "who deploys the networks; whether public funding is involved; and whether an open access model is used".

The first mainly area mainly concerns whether it is incumbents or new entrants which deploys NGA networks. In some cases it is the incumbent which deploys fiber, i.e. Japan (NTT), USA (Verizon) and China (several incumbent actors). An interesting note here is that, noted in the previous section, that the Japanese authorities imposes fiber unbundling. However, in European context, there are a limited number of incumbents which deploys fiber. In Europe there are mostly new entrants such existing communication providers upgrading its legacy networks to NGA networks. Other new entrants is electricity companies (which in some cases are municipally-owned). There are also cases where local and regional municipalities deploys its own NGA networks.

The second area, concerning public funding, also varies throughout OECD. The public funding might come from direct investment from the government, through indirect subsidies, or through financial aid at municipal level. The larges scale of direct investment in OECD is Australia, New Zealand, and Israel. Here the government has decided to deploy a national NGA network supported by the government itself. The Australian National Broadband Network, which is an OAN, is estimated to cost

41.5 billion USD. As of 2013, the plan is to deploy a nationwide FTTN network.

The open access model is the last area with major differences in the OECD countries. An interesting case of an type of open access in Switzerland. Here, when a new home is to be connected to a fiber network, the PIP is required to install a fiber cable with contains 4 fibers. 1 reserved for the PIP and the other 3 available for competitive SP. In this case, the PIP might also be a SP. Further, in most OECD countries, it is mandated for PIP to provide access to its ducts and conduits to make it easier to deploy NGA networks in order to make the deployment of fiber networks easier for new entrants.

3.8 FTTH Council Europe: FTTH Business Guide

The FTTH Council Europe is organisation working to accelerate the development of fiber-based communications. The FTTH Business Guide aims to give municipalities, governments and other actors an introduction to the different aspects regarding business plans, constructing, deploying and regulating the FTTH market. This guide includes an overview of 4 different business models viable for the FTTH marked. This overview is shown in figure 3.3. The models share many of the characteristics of Forzati et al.'s models. There are three levels, each which can be taken by up to three different actors. The leftmost model shows what is to this thesis defined as a OAN, as long there is a separation between the "Retail service providers" and "Network operator". Table 3.2 shows the pros and cons each role have in the FTTH business models.

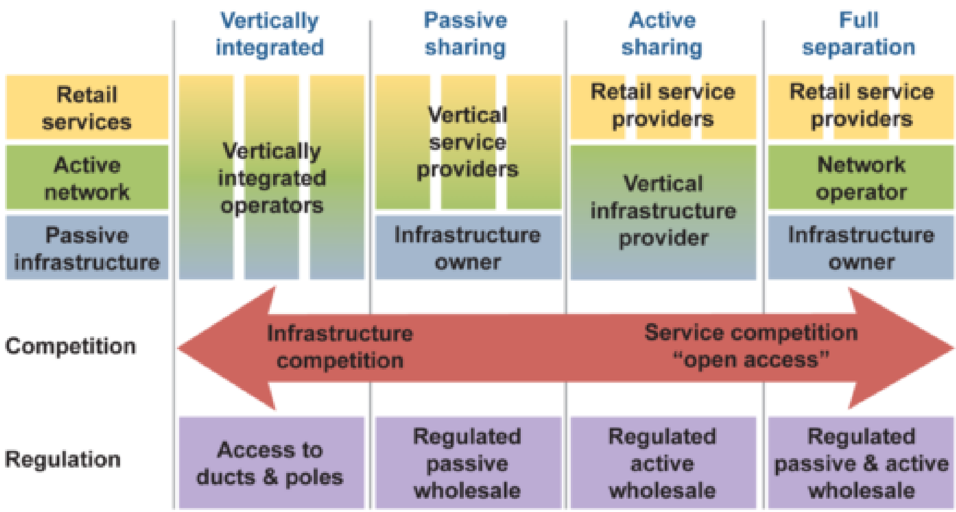
Table 3.2: Pros and Cons of [FTT13]'s FTTH Business Models

	Pros	Cons
Vertically integrated	Control total value chain and cash flow profile.	Complex operation and high execution risk.
Wholesale operator	Gains additional margins for modest incremental investment.	Must be technically credible yet flexible. Small operators may struggle due to lack of commercial and operational standards for wholesale.
Passive network owner only	Simple operations. About 50% of the revenue potential.	Lack of direct control over the revenue stream and marketing to the end-user.

3.9 Various Literature

Strøm et al. [SmV09] investigates in this report whether an upgrading of the Norwegian broadband network would be socioeconomically profitable. They show

Figure 3.3: FTTH Business Models [FTT13]



that non-regulated broadband monopolies with commercial interests has incentives to charge a higher price than it would be the case in a broadband market with competition. As a result of this, a apart of the customer base is excluded due to the higher price. This again results in a lower welfare potential than would have been the case with competition. Further they points out that NGA networks in Norway in most cases are monopolies, specifically in rural areas.

Regarding the critical penetration rate for FTTH development Jay et al. [JNP14] shows that this rate should be close to or above 50% to become profitable. They show that this number should be higher in rural areas. If a PIP decides to deploy PON FTTH in a "Less suburban" area (in which there exists no earlier NGA networks) it must at least expect a penetration rate of 69%. Should the same operator deploy a NGA network in a rural area the critical penetration rate is 100%. In comparison, if this operator deploys a NGA network in a "Dense urban" area, the critical penetration rate is just 26%.

Bekkers et al.'s "Fast Forward - How the speed of the Internet will develop between now and 2020" estimates the demand of bandwidth in 2020 to be 20.1 and 165.4 Mbit/s up and down, respectively.

Chapter 4
International Examples of Open Access Networks

There are two countries which has deployed OANs on a national level: Australia and Singapore. This chapter will introduce these OANs and their current status.

4.1 Australia

The Australian government decided in 2009 that it should deploy a national OAN to deliver high-speed bradband to Australia, called National Broadband Network (NBN). The government should take the role as PIP, opening up for SPs to provide Internet and other services in the network. The network should consist of an access technology mix, including HFC, fixed wireless access and satellite access, with FTTP as the main component. FTTP, which was not described in chapter "Theory: Internet Access Technologies and Market Structures" 2, is a collective term for FTTB and FTTH. The network was originally estimated to cost 30.5 billion USD in public funding, with a possible peak at 37.0 USD [NBN13]. Recent developments in the political landscape has downgraded this cost to 24 billion [The13].

NBN Co is the responsible government owned company to deploy the NBN. It was expected to deliver FTTP deployment to 93% of all premises in Australia by 2021. However, with the new government it is expected to reach 22%. Announced in 2013, the deployment of FTTP in brownfields was reported to be 48% behind schedule. Also reported, the greenfield rollouts were also behind schedule. Further, an independent evaluation of the NBN concluded that the NBN was "extremely optimistic and very unlikely to be achieved" [NBN13].

As stated by OECD in "The Development of Fixed Broadband Networks" [OEC14c] the NBN is maybe the world's most ambitious Internet access project. Further, OECD writes about, according to OECD, "one of the most comprehensive studies of the potential benefits of high-speed deployment". This study, carried out by Deloitte Access Economics, evaluates the effects of the NBN. The study estimated that the annual household benefits if would be approximately 3580 USD in 2020, in current dollars. Two-thirds of these benefits would be actual economical benefits. The rest would be indirect benefits such as:

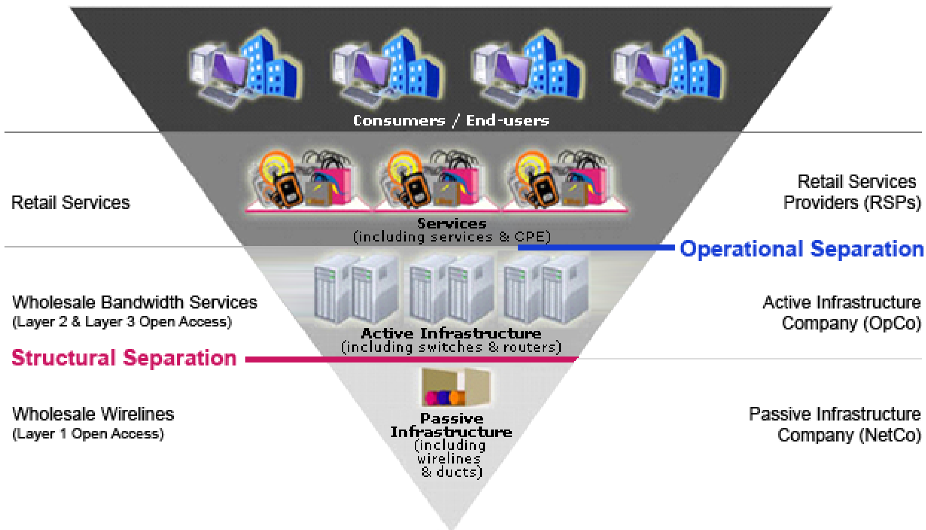
- Cost savings from municipal telecommunication expenses;
- Increased property values;
- Economic development, including firms' decisions about where to locate;
- Reduced travel expenses through use of telework and online communications tools;
- Improved productivity.

4.2 Singapore

Although Singapore is a considerably smaller country than Australia, its OAN is a good example of national NGA OAN [oSI12]. The Next Generation Nationwide Broadband Network (Next Gen NBN) is a network is a OAN owned by Singapore's Infocomm Development Authority of Singapore (IDA), the network was by 2013 deployed to 95% of all households and businesses in Singapore. Figure 4.1 shows the Next Gen NBN business model.

Compared to Forzati et al.'s OAN, here NetCo and OpCo is NP and PIP, respectively. IDA owns the network, but has chosen two companies to operate as NetCo and OpCo on their behalf. SPs, or in this context, RSPs, are granted access to the Next Gen NBN. The Singapore government is supporting the deployment with 562 million USD.

Figure 4.1: Singapore's Next Gen NBN [oSI12]



Chapter 5
The Internet Access Market in Norway and Sweden

This chapter will give a brief introduction to the two access markets, looking at each access technology individually.

The Norwegian access market has mostly developed without involvement from the government, were the opposite is true for Sweden. As mentioned is table 3.1, where Norway has determined where the bottlenecks for further NGA development is needed and used regulation to stimulate competition, Sweden has Sweden taken an active part.

DSL

The two DSL markets is quite similar in Norway and Sweden. As stated by [OEC13] local loop unbundling and bit stream are mandated for both incumbent DSL network owners, the Norwegian Telenor and Swedish Telia Sonera. The DSL market SPs are therefore subjects to high competition on prices.

HFC

HFC networks are not regulated in neither of the two countries. Dominant actors here are Canal Digital and Get in Norway, and Com Hem and Boxer in Sweden. Get and Canal Digital (owned by Telenor) has a accumulated marked share of 90.4%. Com Hem and Boxer have a market share of 21.5 and 20.4%, respectively.

Fiber

In an international setting Norway and Sweden is number 6 and 3 in fiber penetration of total households in OECD. However it is in the fiber market structures the biggest differences come to light. The Norwegian government has as mentioned in most parts entrusted commercial market powers to fiber development. Most fiber deployments in Norway are local and regional electricity companies. As stated by Søndeland [Roe08] the electricity companies possess great expertise in the development of infrastructure, but in most cases very limited experience in the role of NP and/or SP. This is the possible reason for such high involvement from these companies regarding the fiber development. This also supports OECD's assumption that most new entrants in the NGA deployment not are incumbents [OEC14c]. However, it should be noted that the incumbent DSL operator Telenor has a 13.4% marked share in the FTTH market. In Norway, most fiber PIP, except Telenor, have chosen to deploy FTTH P2P or FTTH AON architectures. Telenor has chosen FTTH PON [Nor10].

The most characteristic feature of the Swedish access markets is the municipality networks (Se. Stadsnät). Municipality networks are local or regional fiber network which are in some kind of way initiated, owned or supported (direct aid or subsidized by means of tax reductions) by local authorities [Lin06]. These municipality networks are all OANs. There are 155 municipality networks in Sweden [Sve14].

The Swedish municipality networks are owned by municipal companies, metropolitan area networks companies, energy companies or private companies. It is estimated that the municipality networks constitute 60% of the fiber access networks in Sweden.

A notable municipality network in Sweden is Stokab, Stockholm's municipality FTTH network [OEC14c]. Since 1994, 814 million USD has been invested to deploy a network which in 2014 covers 90% of households and almost 100% of enterprises in Stockholm. As an OAN, the network naturally grants access to SPs which wishes to offer services in the network. Numbers from 2008 states that there were as much as 60 SP in Stokab at that time.

Chapter 6

Methodology

To compare the two Internet access markets, this thesis has completed a study on their respective coverage, penetration, monthly subscription prices, entry prices, market structures, and government spending. This chapter provides an explanation of where the data is retrieved and an evaluation of their durability.

Nkom and PTS annually publishes reports about Norway's and Sweden's telecommunication market. It includes, among other things, data about nationwide coverage, penetration, prices, number of SPs, etc. Nkom also uses a consulting firm (Nexia) annually to investigate the coverage and penetration in Norway. All reports and numbers used are from 2013. The following list contains the sources from which this thesis has obtained its data basics:

- Nkom's annual report: [Nor14c]
- Nexia's coverage and penetration report: [Nex13a]
- PTS's annual report: [ot14]
- PTS's statistics web portal: [PA14]
- Swedish Government Official Reports [Sve08]
- Nexia's [Nex13b]

Additionally, to gather data on the Norwegian government spending on broadband development, official web pages have also been visited. More on this in section 6.4.

All SP and PIP from Norway and Sweden are available in Nkom and PTS annual report. This thesis has collected information about monthly subscription prices, entry costs, number of available NGA SPs in fixed networks, and which kind of bandwidth each SP/PIP provides, for a total of 102 and 111 different actors in Norway and Sweden, respectively.

Nkom states that there are 144 SPs in Norway. However, according to this thesis' data, 42 of these were either solely offering services to businesses or not listing their prices on their homepage. Thus, this thesis has collected data from 70% of all PIPs and SPs in Norway.

Because of the different market structure in Sweden, most of the of the data was collected in a different way. By going through the list of actors provided by PTS's statistics web portal, an actor could either be a SP or/and a PIP. In the case of a SP also being a PIP the data collection were the same as for Norway.

When the actor listed were solely a PIP, the number of NGA SPs, the number of access technologies available, the lowest price in each bandwidth interval, and entry costs were noted. More details regarding the price collection is explained in section 6.3. PTS states that there are 150 private SPs in Sweden, thus data from 74% of all PIP and SP i Sweden has been collected.

6.1 Market Structure

To determine the marked structures of Norway and Sweden, this thesis looks at the number of available NGA SPs for each access network. On the basis that this thesis excludes all DSL access technology in its definition of NGA, the number of NGA SP in the copper network is naturally 0. Also, by visiting all web pages of Internet access actors in Norway and Sweden, this thesis has investigated whether if the relevant actor is a PIP, SP or both.

6.2 Coverage and Penetration

As stated in the glossary, coverage is defined as: "Percentage of the total households/population in a geographical area which have access to a given access technology or bandwidth". While coverage is defined as: "Percentage of total households/population in a geographical area which have access to a given access technology or bandwidth and who have chosen to connect to such a service".

Nkom measures coverage by the number of households, both for available access technology and bandwidth. PTS measures also uses households as the base for coverage by bandwidth. But for access technologies, they use by population. Therefore, the coverage data regarding access technology in Norway and Sweden are not directly comparable, but the numbers still gives a good basis for comparison.

A more detailed validation of the data is given together with the results.

6.3 Prices

To compare prices between the two countries Purchasing power Parity (PPP) is used. OECD [OEC14b] defines PPP as:

> "PPPs are the rates of currency conversion that equalize the purchasing power of different currencies by eliminating the differences in price levels between countries. In their simplest form, PPPs are simply price relatives that show the ratio of the prices in national currencies of the same good or service in different countries. PPPs are also calculated for product groups and for each of the various levels of aggregation up to and including GDP."

The rates used throughout this thesis is 9.048246 for NOK and 8.718872 for SEK. These rates are extracted from the World Bank [Gro15] I.e. if a price for a 100 Mbit/s subscription in Norway costs 100 Norwegian Krone (NOK), this amount is divided by 9.048246, resulting in 11.05 United States Dollar (USD). The same is done for amounts in SEK, using 8.718872. Hence, if the same service costs 100 Swedish Krone (SEK), resulting in 11.47. This way of comparing broadband prices is also used by OECD [OEC14a]. It it also worth noting the general price level differences in Norway and Sweden. According to Statistics Norway [Nor14a] the general price level is 19% higher in Norway compared to Sweden. However, looking exclusively on the price level for communication services the same number is only 13%. This is important to keep in mind when reading the results. Hence, if the results shows that the Norwegian prices are between 13% and 19% higher than in Sweden, the general price level of Internet access services in the two countries can be said to be equal.

The prices for private Internet access subscriptions are gathered from each SP's homepage between 1st to 12th of December 2014. The subscription prices from each SP where sorted in different bandwidth intervals. By for a quick preliminary study it was observed that most of SPs provided services with these interval limits in both Norway and Sweden.

If there were more subscriptions in the same interval, the one which was lying closest to the top of bandwidth interval was selected, along with its associated price. I.e. if there were one subscription which offered a 500 Mbit/s download bandwidth and another which offered 1000 Mbit/s, the 1000 Mbit/s subscription was chosen, along with its associated price. Further, this price collection gathered solely prices for download bandwidth. This means that if there were two subscription offering the same download bandwidth and a different upload bandwidth, the one with the lowest price was chosen. In all cases this meant the one with lowest upload bandwidth.

Further, when looking at the entry cost for an end user, there are two types: New Entry Cost (NEC) and Existing Entry Cost (EEC). NEC is the price a PIP/SP charges the end used for connecting its household to a NGA network for the first time. The EEC is the cost a end user must pay to connect to a SP if there already exists a physical connection. This could both be for NGA and DSL services. If a SP offers both NGA and DSL services, the price for NGA services was chosen.

At last, this thesis has calculated how much each a household must pay per year from its income to connect to a NGA PIP/SP and subscribe to a (60, 100] Mbit/s bandwidth. The income which is used per household is the median equivalised disposable income per year for a household in Norway and Sweden. This is 31000 and 23000 US, respectively. The median equivalised disposable income is the "...total income of a household, after tax and other deductions, that is available for spending or saving, divided by the number of household members converted into equalised adults; household members are equalised or made equivalent by weighting each according to their age, using the so-called modified OECD equivalence scale" [eur14].

According to the U.S.Department of Commerce the median is a more accurate measurement for household income because it is less sensitive against extreme observations [U.S03].

All prices are available in Appendix B, C, and D.

6.4 Goverment Spending

To determine each nation's government spending on broadband development this thesis have examined government reports and budgets, as well as the Internet were necessary. The amounts collected are, as best as possible, actually spent money, not budgeted.

Chapter 7
Results

7.1 Marked Structures

In this section will investigate each access technology market structure and compare it to Forzati et al.'s (see figure 2.15).

DSL

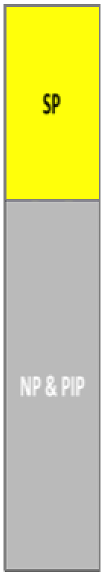
Both Telenor and Telia Sonera acts all three roles (SP, NP, and PIP) in the DSL networks, but are required to provide access to additionally SPs which want to offer DSL services. Thus, the DSL network in Norway and Sweden follows model E and F according to Forzati et al.'s model. Both local loop unbundling and bit stream access are used.

HFC

As mentioned in chapter 5 the HFC networks are not regulated in neither of the two countries. The actors own their own network and the end users are only able to select one SP when connected. Thus, HFC networks in Norway and Sweden follows model B and G.

However, Forzati et al.'s business models lacks a type of model which is not only used for HFC networks, but also for fiber networks (as described later). In many cases a business model depicted in figure 7.1 is observed. In this kind of model one actor takes the role as both NP and PIP, because of its practical nature, and enters an agreement with a SP to deliver the Internet and TV services in its network. There seems to be a mix of local HFC networks, providing services from the dominant actors, and the dominant actors as SP, NP and PIP in their own networks (business model G).

Figure 7.1: Access Network Business Model H in Norway and Sweden for HFC and Fiber Networks



Fiber

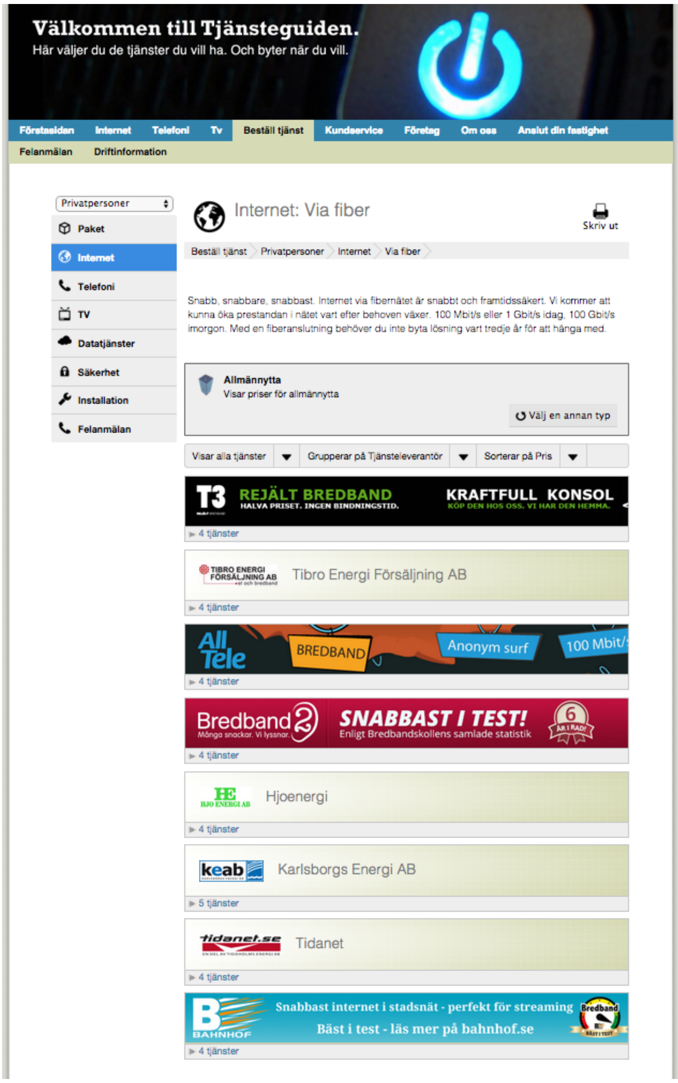
The fiber networks in Norway all but two behaves as model B, G and this thesis own model H. This thesis finds two OANs in Norway in the fiber access market. As mentioned, the majority of fiber networks in Norway are deployed by local electricity companies. The 5 fiber companies with the largest market share accumulates a market share of 59.9%. Thus, the rest of the fiber providers in Norway is filled with smaller actors. In many cases the PIP enters an agreement with 1 SP to offer Internet access in their fiber network. In this case model G is neither entirely correct. A more accurate model of most Norwegian fiber access markets is depicted in figure 7.1. There are also examples where the PIP acts as a SP for Internet and offers another SP to offer TV services in their network. An example of this is Eidsvida [Nor10]. In this case model A is more accurate, but it is still considered a vertical closed network, as the end users can not freely choose its Internet SP.

The fiber networks in Sweden tells a different story. Out of 99 fiber actors, in which are 83 PIP of fiber networks 35 deploys a vertical closed network business model, while 48 implements an OAN model. As seen in section 7.3 "Prices" this has impact on the prices in these networks.

Figure 7.2 shows an example of a web page available for end users to chose a SP from Tibro Energi [Tib14], a municipal network provider in Sweden. It shows 8 available

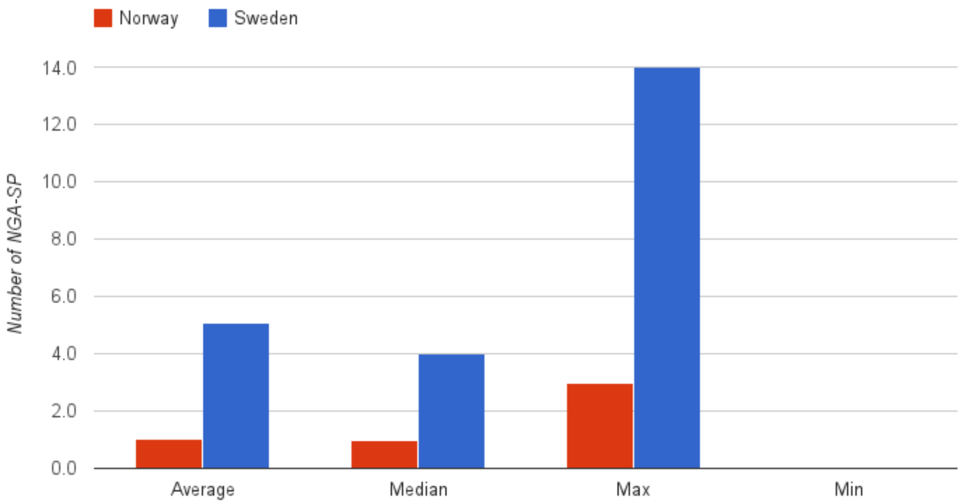
SP all providing FTTH subscriptions. After an end user has connected to Tibro Energi's network, it can freely choose to connect one of the SP listed. The FTTH access market in Sweden is therefore following model A for OANs and G for vertical closed networks.

Figure 7.2: Screen Shot of SPs in a Swedish Municipal Network (Tibro Energi)



Another interesting finding is depicted in figure 7.3. For each network this thesis has investigated it was noted how many NGA SPs there were in the network. There is clearly higher competition per network in the NGA market in Sweden than Norway. As there are only two NGA networks in Norway which has an OAN model, the competition for NGA SP in Norway is almost nonexistent. FTTH SPs in Norway competes against either DSL SPs or in few cases HFC SP. In Sweden the market is different. As much as 14 SPs can be found in one fiber network.

Figure 7.3: Number of NGA SPs for Fixed Networks in Norway and Sweden



There are however recent developments in the Norwegian FTTH market. Telenor has been mandated by Nkom to enable wholesale access to its fiber network. Telenor will implement a concept called VULA, which enables additional SPs to offer Internet access to end users, using Telenor's fiber network. VULA somewhat similar to bit stream access. Telenor's fiber network is a FTTH PON architecture. This would mean that Telenor's fiber network would look like model F in the nearest future.

7.2 Coverage and Penetration

Table 7.4 shows the coverage and penetration for all three access technologies in Norway and Sweden.

Both countries have excellent coverage for DSL, which is as expected. The first area the countries differs are the HFC and fiber coverage. Norway has a 49% HFC coverage, while Sweden has 37%. For Sweden this is consistent with [Lin06] which in 2006 states that "Sweden has few cable connections compared to other countries".

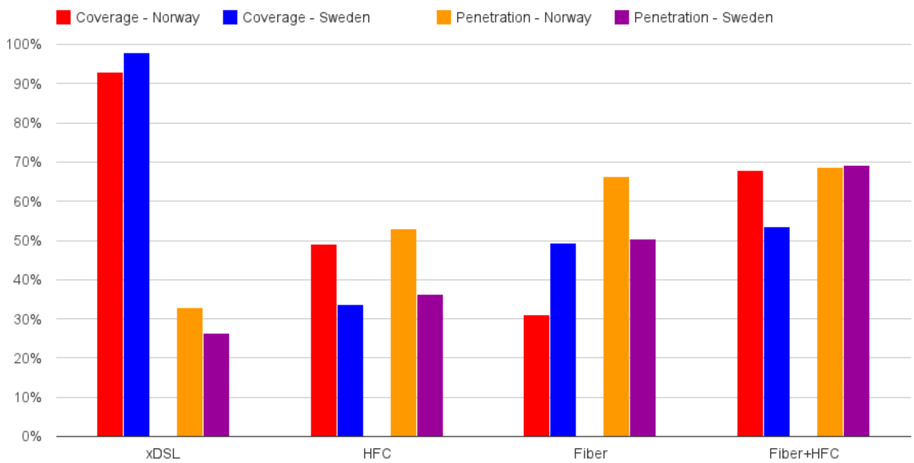
Note that this is for both countries DOCSIS 2.0. There are no numbers for DOCSIS 3.0 or higher in Norway, while from Sweden this number is 29.39%. There is also a difference in fiber coverage. 31.0% and 49.9% for Norway and Sweden, respectively.

An interesting finding is the overall NGA coverage. Norway beats Sweden with 14,4 percentage points.

Further, an interesting point is that Sweden seems to have a greater overlap of HFC and fiber networks than Norway. Adding the coverage of HFC and fiber together the result is 86.9%, while the total coverage of NGA networks in Sweden only reaches 53.3%. Thus 25.1% of Swedish households have access to both HFC and fiber. The same number for Norway is 12%. It should be pointed out that PTS does not operate with a collected coverage of Fiber + HFC as Nkom does, so the number for coverage of Fiber + HFC in Sweden in obtained from the nationwide coverage of a download bandwidth of minimum 100 Mbit/s for fixed networks. Since HFC and fiber are the only two technologies which are able to deliver such a bandwidth, this number should provide a sufficient base for comparison with the collective Norwegian coverage of fiber and HFC.

The penetration in Norway is 53.1% for HFC and 66.4% for fiber, while for the Sweden the same numbers are 36.3% and 50.45%. Norway beats Sweden in both areas, while Sweden beats Norway in the penetration for NGA networks by 0.7 percentage points.

Figure 7.4: Coverage and Penetration per Households in Norway and Sweden

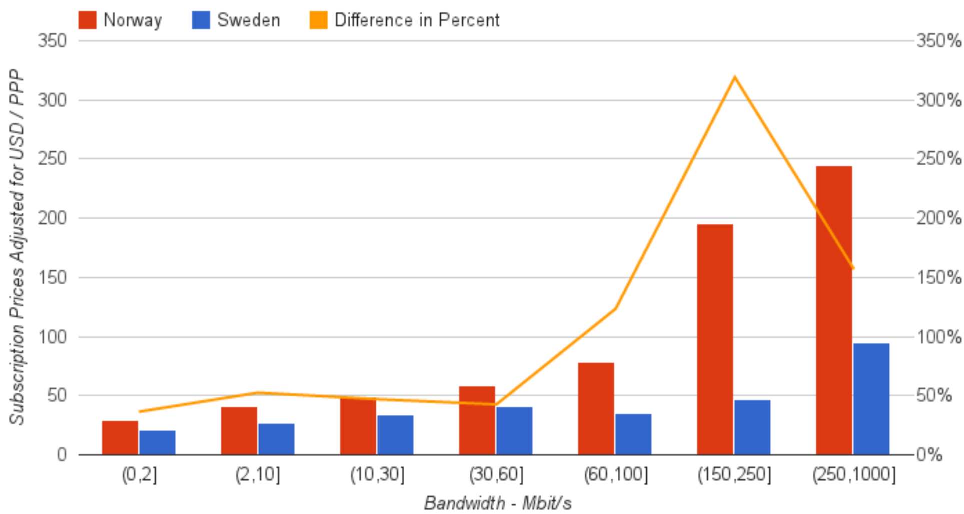


7.3 Prices

Figure 7.5 shows the monthly subscription prices adjusted for USD/PPP in Norway and Sweden. It clearly shows higher prices for all bandwidth intervals in Norway. Due to only one Swedish subscription in the (100, 150] interval, both the Norwegian and Swedish numbers in conjunction with this interval are excluded from the figure. The Norwegian prices are on average 111.7% higher. Looking at NGA services, the intervals (60, 100], (150, 250], and (250, 1000], the the Norwegian prices are at average 200% higher than the Swedish. Note that in the interval (60, 100] also includes some VDSL subscriptions. Still, this gives a fair picture of the overall price level for NGA services.

The DSL prices lies on average 44.7% higher in Norway (excluding the (60, 100], which is here considered a NGA service).

Figure 7.5: Average Subscription Prices in Norway and Sweden Adjusted for USD / PPP



Since the marked in Sweden contains a mix of OAN and closed networks, it is possible to compare the prices in these two different types of networks. This is done in figure 7.6. From the data there were 30 closed networks and 50 OANs. The remaining actors were SP offering services in multiple networks.

In the closed networks there was only one SP available. The PIP could also be the SP, but this is not mandatory. As described in the previous section, a PIP could make an agreement with a SP to deliver services in their networks. In the OANs there were 2 or more SPs. As depicted in figure 7.6 the prices in the closed networks were higher than the OANs. On average the subscription prices in closed networks lies 18% higher.

This is also supported by this article [Sve14], which states that the prices in OANs constitutes 80% of the prices of in closed networks. As stated in the previous section, this thesis found 2 OANs in Norway. While obviously not a significant data set, the prices here are on average 31% lower than in Norwegian closed networks.

Figure 7.6: Average Swedish Subscription Prices in OANs and Vertical Closed Networks Adjusted for USD / PPP

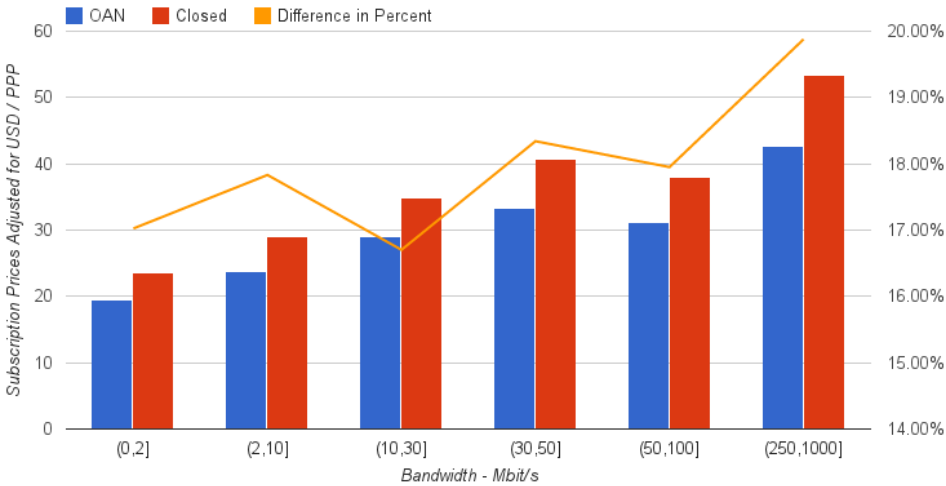


Figure 7.7 shows the NEC for NGA services in Norway and Sweden adjusted for USD/PPP. As depicted the NEC is 74% higher in Sweden than Norway. The median is slightly lower at 71%. The lowest NEC in Norway and Sweden is 55 and 29 USD/PPP, respectively. It might seem that OANs promotes lower monthly subscription fees and EEC, but higher NEC.

Figure 7.8 depicts the EEC for NGA and DSL networks. As mentioned earlier, if a SP offered both NGA and DSL services, the cost for connecting to the NGA technology was chosen, regardless of price. Figure 7.8 shows a higher EEC for Norwegian end users. The average EEC is 71 and 48 USD/PPP.

Figure 7.9 shows the NEC and EEC for end users in Sweden, depending whether the end user connects to an OAN or closed network. 7 out of 8 of the lowest NECs in Sweden were for connections to a closed networks. The 9th lowest were an OAN with 12 SPs. It is clear that in OANs, where the competition is bigger, the EEC is lower than in closed networks. It is also clear that the trend where the NEC is higher and EEC is lower for OANs also is present inside Sweden.

The proportion of how much a household in Norway and Sweden must pay connect to a NGA network and subscribe to a (60, 100] Mbit/s bandwidth is depicted in

Figure 7.7: New Entry Cost in Norway and Sweden Adjusted for USD / PPP

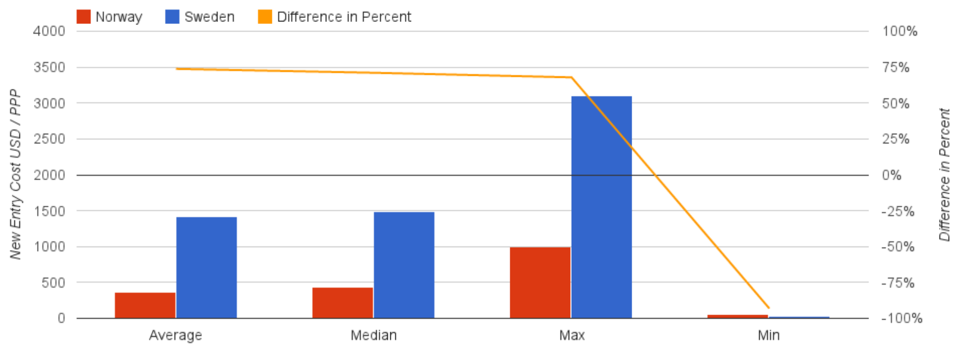


Figure 7.8: Excisting Entry Cost in Norway and Sweden Adjusted for USD / PPP

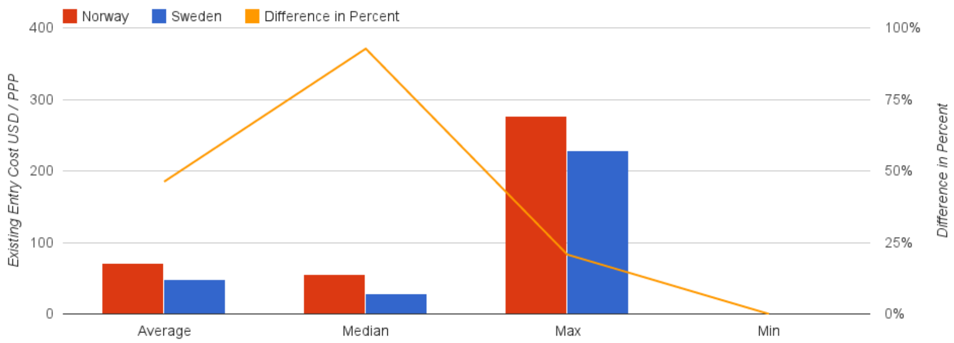
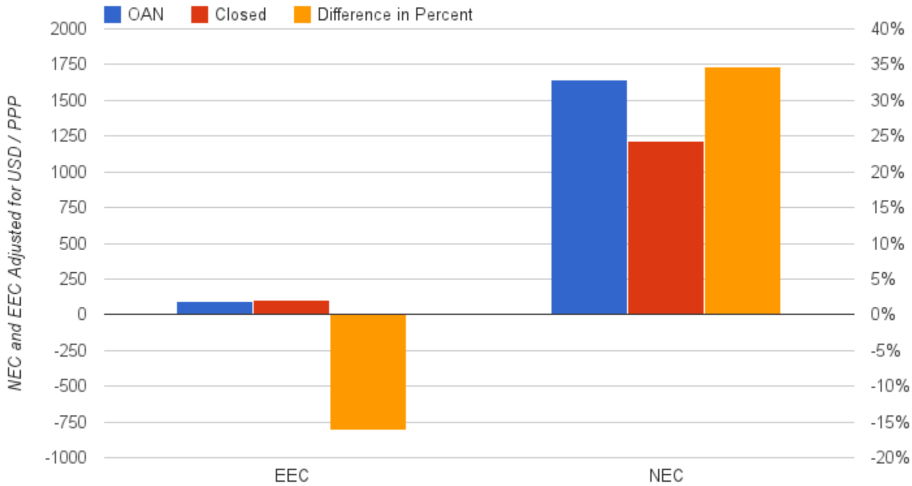


figure 7.10. Is shows that a median household in Norway must pay 4.4% of its income, while a Swedish household must pay 7.6% of its income. Thus, the median household in Norway is better of when it lacks connection to a NGA network. When the connection is in place, the situation turns. Now the Swedish household only uses 1.7% of its income on a yearly basis, while the Norwegian household must pay 3%. Looking at the net present value in figure 7.11 it is clear that after just about 18 month, the Norwegian and Swedish households are even. It is obvious that the low monthly price in Sweden weighs up for the higher NEC.

This is explained by looking at the yearly cost for a a (60, 100] Mbit/s bandwidth subscription. The Norwegian price is 140.4% higher than the Swedish, while the Norwegian NEC constitutes only 69.8% of the Swedish.

Figure 7.9: NEC and EEC in Sweden for OANs and Vertical Closed Networks Adjusted for USD / PPP



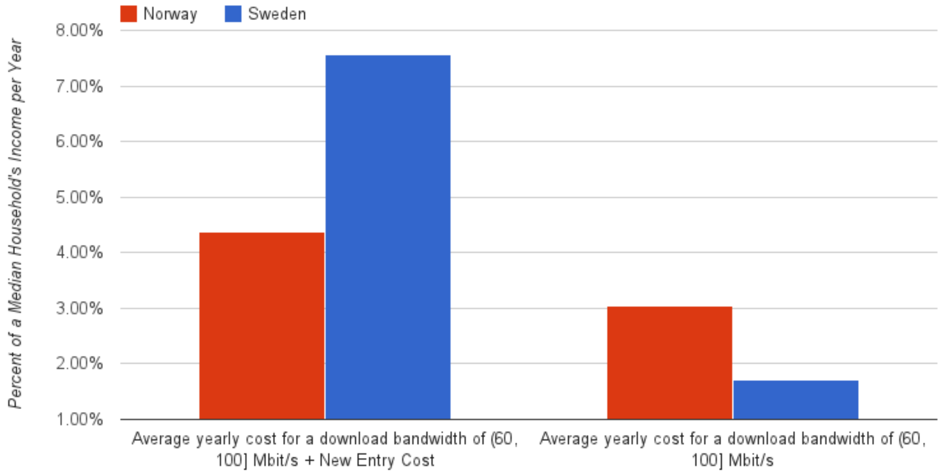
7.4 Government Spending

Figure 7.12 depicts each government's spending on broadband development. The more detailed data can be seen in appendix E. The Norwegian government started supporting broadband development in 1999 and the Swedish in 2000, with its first spending in 2001. Hence, the aid has prolonged over 15 and 13 years, respectively. As seen in figure 7.12 the Norway has used 207.9 million USD/PPP over a 15 year period, while Sweden has used 685.8 million USD/PPP over 13. Per year this equals 13.9 and 76.2 million USD/PPP, respectively. The Swedish government aid has as figure 7.12 shows been 230% bigger than the Norwegian.

The two different approaches to public intervention is clearly visible when it comes to government spending. The Norwegian spending is mostly used on broadband development in areas which would be unprofitable without state aid. However, EFTA Surveillance Authority recently approved the Norwegian government's nationwide state aid plan to deploy broadband infrastructure. The total amount the Norwegian government is planning to use is 220 million USD/PPP. The state aid fulfils the conditions which EFTA demands, which includes that the networks should impose technological neutrality and wholesale access. There is not available any time estimate on how long this aid is to be distributed. However, this lays close to what Norway has spent over the last 15 years.

If one looks at the Internet access deployment as a joint effort between the government

Figure 7.10: Percent of a Median Household's Income per Year for an Average (60, 100] Mbit/s Subscription Cost in Norway and Sweden



and the end users, and makes assumptions not so far from reality it is possible to perform an interesting calculation. Assuming an average price for a (10,30] Mbit/s subscription to be 49 and 33 USD in Norway and Sweden for the last 15 years and a steady growth of broadband subscribers since 2000. The number of subscribers in Norway and Sweden in 2000 were 23,297 and 249,000. Further, assuming there were no fiber subscribers in either of the two countries in year 2000. Also, using the average NEC and EEC from this thesis as base for the same costs for the last 15 years. The total sum which the Norwegian and Swedish subscribers have paid for Internet access is 1 billion and 1.3 billion USD. Added with the government spending the amounts are 1,2 billion and 2 billion USD. If divided on the population in Norway and Sweden, this equals 243 and 225 USD. A difference at only 8%. The calculations can be seen in appendix F.

Although a very simplified calculation, over a period of 15 years the government and end users in Norway and Sweden has paid almost exactly the same amount.

Figure 7.11: Net Present Value of Yearly Average Household Cost Subscriptions in Norway and Sweden

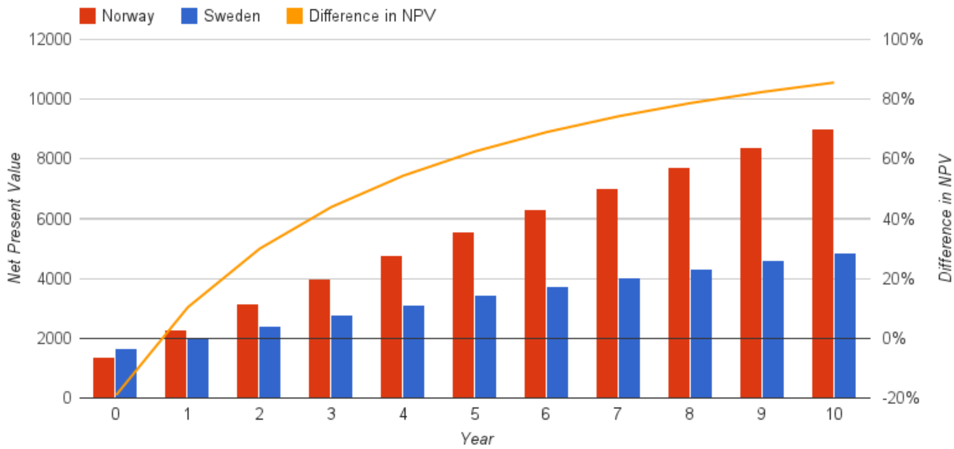
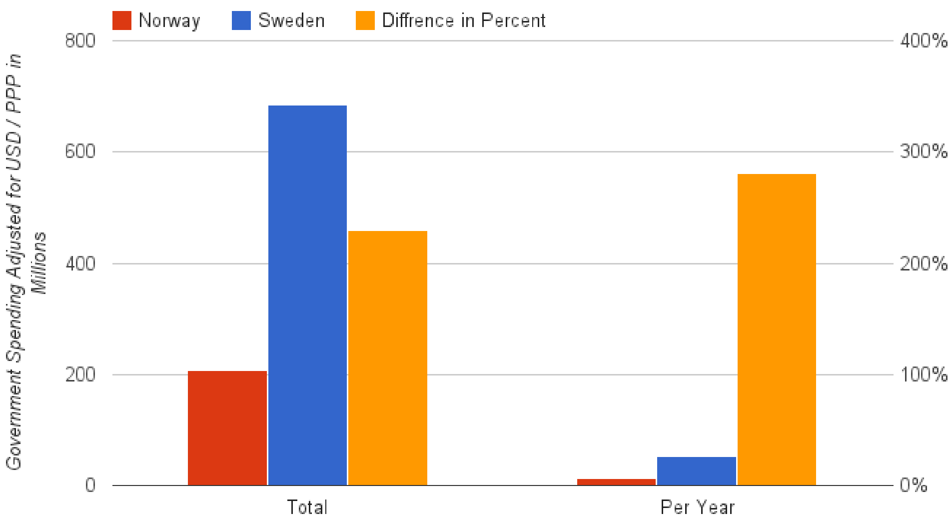


Figure 7.12: Government Spending on Broadband Development in Norway and Sweden



Chapter 8
Discussion

This chapter will in each section discuss the major findings derived from the results.

8.1 The Overlap of HFC and Fiber Networks

An important discovery from coverage of networks in Norway and Sweden is the higher percentage of overlapping HFC and fiber networks. The findings suggest that 25.1% of Swedish households have access to both HFC and fiber. The same number for Norway is 12%. It is difficult to determine an unequivocal answer as to why the overlap is bigger in Sweden, but it is possible to speculate in some hypotheses:

1. The DOCSIS standard was at the time of the first fiber deployments in Sweden not considered to be able to deliver future proof bandwidth, and this attitude is still present;
2. HFC network's limited opportunities for wholesale and Sweden's desire for OAN are not compatible.

The first fiber deployments took place in Sweden in 1999. At that time DOCSIS 2.0 were present and was able to deliver a theoretical 38/27 Mbit/s downstream/upstream bandwidth. Already these bandwidths were small compared to fiber. Further, VDSL also reaches these bandwidths. The DOCSIS 3.0 came in 2006, able to deliver a theoretical bandwidth of 160 to 240 Mbit/s downstream and 120 Mbit/s upstream. According to [Lin06] in 1999 approximately 50% of Swedish households were connected to FTTH, the DSL networks naturally quickly overtook the lead. However, it shows the early commitment to fiber in Sweden. Two quotes from [Lin06], in the chapter named "FTTH: The Swedish Perspective" reads: "Nevertheless, there is a widespread belief among most players on the market that fibre is the only really future-proof solution for broadband access" and "The future is spelled FTTH". As this chapter is written by three Swedes suggests some kind of commitment to fiber at that time.

Although wholesale access is possible through bit stream in HFC networks, the practical feasibility is limited because it requires that the owners must make costly physical changes to the HFC network. An effect of this could be Sweden's rather little faith in HFC as a durable future-oriented network where competition is possible.

8.2 The Overlap's Impact on the Swedish Fiber and HFC penetration

As seen from the results Sweden has a lower penetration rate for both HFC and fiber than Norway, 36% versus 53% for HFC and 50% versus 66% for fiber. The explanation for this might be the bigger overlap of HFC and fiber networks in Sweden. The fiber development in Norway is in a greater extent made by commercial actors, with little support from the government. In this case it is most likely a greater focus on deploying fiber in areas where there is no competition from HFC network and thus the overlap becomes smaller. The fiber deployment in Sweden is mostly done by municipally actors, thus is the fiber deployment mostly done in more populated areas where a HFC networks already exists. It is therefore possible that the lower penetration rate is a result of higher competition between HFC and fiber networks. The additional utility an end user achieves by switching from HFC to fiber is too small, compared with switching from DSL to HFC or from DSL to fiber. It would be interesting to see if the penetration of HFC and fiber was significantly lower in areas of overlap, compared to areas where there was little or no overlap. It is not possible for this thesis' data to provide an answer for this.

A report carried out by TERA Consultants from 2013 [TER13] provides an example on the challenges that arise when there are overlapping of HFC and fiber networks. A company in Denmark deployed a FTTH network in an area where it already had deployed a HFC network. After 2 years, numbers from this company showed that even though the premium of switching from HFC to FTTH was a 30% lower monthly subscription price for the same service, the penetration for FTTH in this specific area was lower compared to other areas were FTTH was the only option other than DSL. In Sweden's case, where HFC subscription prices are situated on the same level as FTTH prices, the competition is obvious hard. The overlap may therefore be a factor in the lower HFC and fiber penetration in Sweden compared to Norway.

8.3 The Price's Impact on Penetration

It seems like the NEC is a definite factor in fiber penetration. As figure 7.10 shows the annual cost, which includes the NEC, for connecting to a FTTH network in Sweden constitutes 7.6% of a median household's income per year. The NEC is alone 74% higher in Sweden compared to Norway. Even though the Swedish end user in the long run is better of than the Norwegian, this high entry cost is intimidating to many end users.

8.4 The Market Structure's Impact on Prices

If one takes into account Norway's generally higher price level compared with Sweden, the Internet access prices are significantly higher in Norway for the end user than they are for the Swedish end user. A plausible explanation for this is the different market structures. On average the prices are 111.7% higher in Norway. It is however interesting to look at the DSL and NGA markets separately. There is high competition in the Swedish market for the SPs to deliver Internet access. The main essence of OAN model is naturally to allow greater competition and lower prices, which is clearly reflected in the Swedish prices. It is nevertheless surprising that prices in the DSL market is on average 44.7% higher in Norway. As both BA and LLU is mandated in the Norwegian and Swedish DSL copper network to stimulate higher competition the price difference between the two countries is 25.7 percentage points higher than what the price level for communication services would suggest.

For NGA access the prices in Norway are on average 200% higher than the Swedish. This is obviously very high and it is evident that it is here the effect of the different market structures are most evident. The Swedish NGA SPs are competing against each other, while the Norwegian NGA SPs in their respective networks deliver services without competition. The SPs in Norway are in many cases also the NP and PIP, or the PIP only allows 1 SP to offer services in its networks.

As mentioned, a minimum penetration of 50% is needed for a FTTH network to be profitable. In the case of more rural areas this penetration rate should this rate of penetration approach 100%. It is reason to believe that the Norwegian builders of FTTH networks uses the end users which have chosen to connect to cover up for the loss of not connecting the last end users in the area. Hence, the already connected end users subsidizes those customers who have not chosen to connect to the FTTH network. This is of course speculation, but it can still be an explanation of why the prices are so much higher in Norway. However, it shows how the vertical closed network model provides to a greater extent financial security to those who choose to build out fiber because they have control of the entire value chain. It exists a countermeasure to the uncertainty of achieving the required penetration rate which is implemented largely in both Norway and Sweden. This countermeasure involves by not deploying fiber before the PIP gets a certain percentage penetration of the applicable area. If enough end users choose to accept the fiber is deployed.

It also seems evident that the market structures clearly has an impact on the entry costs. Because of the vertical structure and control of the entire value chain, the

Norwegian fiber deployment actors does not fear that when an end user connects to its FTTH network, it might lose this end user to another FTTH competitor. The end user is bound to chosen FTTH PIP/SP in the foreseeable future. Therefore the FTTH actor can lower the entry cost, both EEC and NEC, and cover the NEC with a higher monthly rate. This is not the case for the Swedish FTTH deployment actors. Its only income is the NEC and the price which SPs pays to offer their services in the PIP's network.

However, looking at figure Figure 7.11 "Net Present Value of Yearly Average Household Cost Subscriptions in Norway and Sweden" the OAN model clearly show benefits regarding prices for customers in the long run when they first choose to connect to an FTTH network.

The difference in price between OAN model and the vertical closed model not only appears between Norway and Sweden, but also within the Swedish NGA market. As seen from from figure 7.6 "Average Swedish Subscription Prices in OANs and Vertical Closed Networks Adjusted for USD/PPP". In Sweden, the average subscription price in vertical closed networks lies 18% higher than for Swedish OANs. The entry costs are also effected. The NEC for Swedish end users in OANs are 35% higher, than for Swedish end users connected to vertical closed networks. The EEC is also consistent with the results between Norwegian and Swedish EEC. Due to the competition, the EEC is lower in OANs than in vertical closed networks.

A last explanation for the high difference in NGA subscription prices might also be the difference in civil engineering costs in conjunction with the deployment of new fiber. However, this thesis finds no evidence of significantly higher civil engineering costs in Norway compared to Sweden.

8.5 The Government Spending's Impact on Coverage

Over the last 13 years the Swedish government has used 685.8 million USD/PPP, 230% more than the Norwegian government has used over 15 years. As it is not within this thesis scope to determine any socioeconomically effects of government aid regarding the different kind of fiber deployment and market structures, the difference in government aid clearly shows the different approaches to NGA deployment done by the two countries. It it also consistent with other reports regarding NGA deployment of OANs, which states that most implementations of wholesale access in NGA networks is a result of government intervention and not on a voluntary basis by the market.

It also suggest that the fiber deployments in Norway are more demand driven than Sweden's, which are more supply-side driven. This might also be a factor regarding the lower fiber penetration and higher fiber coverage in Sweden compared to Norway.

8.6 Answering the Problem Description

Although the focus of this thesis has changed since the problem description was written, it is still worth responding to the core of it. As stated in the problem description: "This master thesis conduct a case study of a national open access network in Norway. It will look at its:

- positive and negative socioeconomic aspects;
- business models and value chains;
- obstacles for realization and benefits of implementation.

This master thesis will also explore if an open access network in Norway exists, has been attempted and if there exists plans for it. At last it should compare Norway's broadband market to international open access networks and classify it after the access network business models from [FLM13]".

It is hard to say anything tangible of a full scale national NGA OAN as there are no comparable networks other than the NBN in Australia and the Nex Gen NBN in Singapore. Experiences from Australia shows that a national OAN is an extreme and advanced project with many pitfalls. The network in Singapore also falls short as a transmissible example since Singapore as a country is really just a big city. Also seen by the comparison between Norway and Sweden with its different market structures and government participation, it is possible to arrive at acceptable conditions with different approaches. Also, as Neumann's study concludes [Neu10], a nationwide NGA network deployment is not profitable in any of the six countries analysed.

As described in the introduction, this thesis will not this thesis aim to describe socioeconomic effects of a national NGA OAN. But it is possible to describe some of the possible business models and value chains. Forzati et al.'s model C seems like a possible business model. This model also shares the same as the Australian NBN. Here, the government takes the role as PIP and it is announced at regular intervals of a certain number of years a competition to take the role of NP in different regional areas. At last, SPs are provides access to this network. The clear obstruction by this kind of network is the complexity. This is the clear experience derived from Australia. Further, as Norway already is a country with good coverage of NGA networks, the existing networks must in some way be regulated and imposed by national authorities to implement the OAN model. If a national NGA OAN market in Norway behaves as the Swedish FTTH OANs, the possible benefits of such network would be lower monthly subscription prices and higher NEC.

This thesis has also found two examples of NGA OANs in Norway. Where one of these networks are quite similar to Swedish municipality networks (See [Kra14] the city network in Norway). Further, Telenor's FTTH network is subject to wholesale access using VULA. This is a step in the direction of a NGA OAN with great coverage.

Chapter 9
Conclusion

The choice of market structure in Norway and Sweden has evident impacts on both price, coverage and penetration. The most obvious impacts are the effect on subscription prices, existing entry costs and new entry costs. The OAN model and other models with some kind of open access clearly favors competition on retail level with the result of low subscription prices. The clear downside is the high NEC which seems like a significant hindrance to fiber penetration. However, this might be the specific case for the comparison of Norway and Sweden, and not for OAN business models generally.

Forzati et al.'s model G and this thesis' H, hence the vertical closed networks, gives the actor which deploys NGA networks a far more safe and demand driven approach. The clear advantage of these business models is that the PIP/SP gets a certain assurance that investment will be repaid through broadband subscriptions. The clear disadvantage of a vertical closed access networks is that the end user is locked to a provider, and that there will be substantial, if not impossible high, costs associated with switching from one provider to another.

In summary this thesis' findings is the following:

1. The overlap of HFC and fiber networks, and the high new entry cost in Sweden are significant factors in terms of the lower penetration in Sweden compared to Norway of the aforementioned access technologies;
2. OAN business models causes lower subscription prices and existing entry costs than vertical closed networks;
3. Vertical closed network business models causes lower new entry costs than OAN business models;
4. Vertical closed network business models and limited government intervention secures demand driven fiber rollout;
5. In the fiber market a Swedish end user will, with its far lower monthly subscription price than a Norwegian, quickly equalize the benefit the Norwegian end users achieves with its low new entry cost.

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Appendix A

Tables of Coverage and Penetration Norway and Sweden

Table A.1: Minimum Download Bandwidth Coverage in Norway and Sweden [Nor14c] [Nex13a] [ot14] [PA14]

Minimum Download Bandwidth	Norway	Sweden
2 Mbit/s	100%	99%
4 Mbit/s	99%	99%
10 Mbit/s	99%	99%
30 Mbit/s	72%	73%
50 Mbit/s	64%	49%
100 Mbit/s	63%	54%

Table A.2: Access Technology Coverage and Penetration in Norway and Sweden [Nor14c] [Nex13a] [ot14] [PA14]

	Coverage		Penetration	
Technology	Norway	Sweden	Norway	Sweden
xDSL	93%	98%	35%	27%
HFC	49%	33%	57%	37%
Fiber	31%	49%	71%	51%
Fiber+HFC	68%	54%	74%	71%

Appendix B
Norwegian Price Data

Service Provider	Fixed Broad-band	Fiber	HFC	xDSL	Checked	(0,2]	(2,10]	(10,30]	(30,60]	(60,100]	(100,150]	(150,250]	(250,1000]	ECN	ECE	NGA SP
3net AS	x	x	x		x	319		429	649	849		1049		4890	1490	1
ACN Norway AS					x											
Alta Kraftlag SA	x	x			x	249	349	469	649	759				2900	500	1
Andøy Energi AS	x				x	299	399									
AS Distriktsnett	x			x	x	349	499							990	990	0
Atea AS region Øst					x											
Austevoll Kraftlag BA		x			x		448	548	648	898				4490	500	1
Ballangen Energi AS	x			x	x	339	499								300	0
Bardufoss Kabel-TV	x				x											
Berger IKT	x				x											
BKK Marked AS	x	x			x				449	549	649		1490	6490		1
Bofiber AS	x	x			x			398	498					5998		1
Bredbåndsfylket Troms AS					x											
Breiband.no AS					x											
Broadnet AS					x											
Braathe Gruppen AS					x											
Bykle Breiband AS	x	x			x				449	649		749		8000	1500	1
Chili Mobil AS					x											
Dalane Breiband AS	x	x			x				449	549	649	749		8000	1500	1
DataGuard AS	x			x	x										1100	
Dataoppdrag AS					x											
DKNett AS	x		x	x	x			475	575					0	0	1
Drangedal Everk KF	x	x			x				449	549	649		1490	3900	500	1
Eidsiva Bredbånd AS	x	x	x	x	x		299	399	549	749				985		1
Eltele AS					x											
Enivest AS	x	x		x	x	298	348	448	548	899				5990	995	1
Etne Elektrisitetslag SA	x	x			x			498	699					3900	0	1
Evenes Kraftforsyning AS	x				x											
EVRY AS	x				x											
Finnås Kraftlag SA	x	x			x				498	669	899		2490	2990	500	1
Fitjar Kraftlag SA	x	x			x				595	895				4995	2500	1
Fræna Breiband AS	x	x	x	x	x		299	399	499	995				3995		1
Furuno Norway AS					x											
Fusa Kraftlag	x	x			x				449	549	649		1490	6000	1900	1
Gauldal IKT AS	x			x	x		328	398	548						0	0
Get AS	x	x	x		x		299	399	499	599	899	2459			0	

GIG Networks AS		x			x											
GigaFib Holding AS					x											
Go Link AS (Notcom)					x											
Grongnett AS					x											
Hadeland og Ringerike Bredbånd AS	x	x			x				449	549	649		1490	5900	500	1
Hagen TeleConsult AS					x											
Halden Dataservice AS	x	x		x	x	304	364	425	549						900	1
Hallingdal Breiband AS	x	x		x	x	299	399	499							1250	1
Hallingdal Kraftnett AS					x											
Hammerfest Energi Bredbånd AS	x	x	x		x		349	499	649	899						1
HardangerNett AS	x	x		x	x			349	498	699	899		2490	4900	1000	1
Haugaland Kraft AS	x	x			x				498	669	899		2490	2400	0	1
Hello AS					x											
HemneNett AS	x	x	x	x	x	299	392	439	499					2990	690	1
Hesbynett AS	x	x		x	x		298	348	548						690	
H-Nett Bredbånd AS					x											
Homebase as					x											
Homenet AS	x			x	x		299	399	449	479		499		995	500	
Hålogaland Kraft AS	x	x			x			449	549	849		3490	5990	3900	0	1
Iaksess AS					x											
Ibidium Norden AS					x											
ICE Norway AS					x											
Infonett Røros AS	x	x	x	x	x	298	328	398	498	798						1
InfraNord AS	x	x			x		372	721	1100	1100				4990	500	1
Instrumenttjenesten AS					x											
Intellit AS					x											
IPLink AS	x			x	x		329	419	499					0	0	
Istad Nett AS					x											
Jæren Kabelnett	x		x		x	375	515	550	675					600		1
Klepp Energi AS	x	x			x			449		849		3490	5990	1400	500	1
Kompetanse Nord AS					x											
Kragerø Energi Bredbånd AS	x	x			x				449	549	649		1490	3900	0	1
Kvamnet AS	x	x		x	x		399	449	569					3830	1830	1
Kvantel AS					x											
Kvinnherad Breiband AS	x	x			x				449	549	749			1950	500	1
Lier Fibernett AS	x	x			x				449	549	649		1490	3990	750	1

Lindtel AS					x											
Lofotkraft Bredbånd AS	x	x			x				479	599	849		1690	5400	499	1
Loqal AS	x	x	x	x	x		299	399	499	599		2459			0	1
Lycamobile Norway Ltd					x											
Lynet Internett AS	x	x			x		297		399	499			1499			
Lyse Fiber AS	x	x			x				449	549	649		1490	1400	0	1
Meløy Energi AS, avd. fiber					x											
Mobitalk AS					x											
Modum Kabel-TV AS	x	x	x	x	x	149	339	489		1599		2499				1
Monsternett AS					x											
MultiNet as					x											
Neanett AS	x		x	x	x	329	419	499						750	690	1
NEAS Bredbånd AS	x		x	x	x		699	649	749					1990	0	1
Net2you AS	x			x	x	249	549									
NettStar AS	x			x	x	299								499	499	
Network Norway AS					x											
NextGenTel AS	x	x	x	x	x	299	349	449	999	779						
NextNet AS	x			x	x	309	329	399	469					995		
NK-Nett AS					x											
Norcall AS					x											
Norcom Norefjell AS	x		x	x	x		150							2500		1
Nordicom Norway as					x											
Nornett AS	x	x	x	x	x		359	499	599	899						1
Norsk Kabel-TV AS	x		x		x		299	399	499	599	899	2459			895	1
Notodden Energi AS	x	x			x				449	549	649		1490	3900	0	1
NTE Marked AS	x	x			x				449	599				4900	499	1
Nye Totalnett AS	x			x	x		379	479						500	0	
Okapi AS					x											
OpenNet Norway AS	x	x			x	0	269		299	349		399	749	9000		3
Orange Business Norway AS					x											
Orkidenett AS					x											
Oyatel AS					x											
Phonect AS					x											
Phonero AS					x											
Phonzo AS					x											
Phonzo Privat AS					x											
Powertech Information Systems AS	x	x		x	x			298	498						990	1

Primafon AS	x			x	x	265		285						599		
RadioLink Telemark AS	x				x											
Rauma Energi Bredbånd AS	x	x		x	x	259	359	449	549						395	1
RingNett AS	x	x		x	x		359	399	469					4990		1
Romerike Bredbånd AS	x	x	x	x	x	199	349	379	569	990			2490		990	1
Romm AS	x		x		x	248	348		448	548	848					
Rybeltron AS	x		x		x		220	400	480					3350	600	
Sandefjord Bredbånd KF	x	x			x				449	549	749		1490	3900	750	1
Scan Net AS	x		x		x		249	399	599	799				789	590	1
Seram IKT AS					x											
Signal Bredbånd AS	x	x			x				449	599	649		1490	4400	1400	1
SKL Marked AS	x				x				498	699	899		2490	2400	0	1
Skånevik Ølen Kraftlag SA	x	x			x			498	699	995				3900	1500	1
Sogn Service AS	x		x	x	x	150	350	550						1850		1
Sognenett AS	x	x		x	x	329	345	449	599	899				4990		1
Sortland Elektro AS	x				x											
StayOn AS	x			x	x			299		399				695		
Stayonline as	x			x	x	298	398							399		
Stordal Breiband as					x											
SuCom AS	x	x	x	x	x	299	349	399	499	649				750		1
Suldal Elverk KF	x	x			x				498	699	899		2490	3900	1500	1
Sund Bredbånd AS	x	x			x				469					7000		
Svorka Aksess AS	x		x		x				649						0	1
Tafjord Marked AS	x	x			x				499	599	649		1490	6490	399	1
TDC AS					x											
Tel-Ag AS	x	x	x	x	x			349	538	638	1338		4990			1
Tele2 Norway AS					x											
Telefiber AS	x	x			x				449	549	849			3900	499	1
Telenor AS	x	x		x	x		349	399	549	899				4990	299	1
Telepartner AS					x											
TeliaSonera Norway AS					x											
Telio Telecom AS	x			x	x			299	499						300	
Telipol AS					x											
Tinn Energi AS	x	x			x		424	524	634					2490		1
Tranøy Telecom as	x				x											
Trollfjord Bredbånd AS	x	x	x	x	x		409	449		699	1099			1990		1
Tussa IKT AS	x	x	x	x	x	249	399	488	588	938				4990	990	1
Tveco Elektronikk AS	x		x		x	185	350	399	499	599	899	1490		795		1

Tysnes Breiband AS	x	x			x				498	699				5000	0	1
Varanger Kraftutvikling AS	x	x		x	x		390	499	549	740				4800		3
Venabygd Breibandlag BA					x											
Ventelo AS					x											
Verdal Kabel TV AS	x				x		698	798		998				499		1
Verizon Norway AS					x											
Vesterålskraft Bredbånd AS	x	x			x				479	599	649		1490	4900	490	1
ViaSat AS					x											
Viken Fibernett AS	x	x			x				449	549	649		1490	1900		1
Vitnett AS	x	x	x		x	199	349		395	795		1140		1960	690	1
Voiplink AS					x											
Voss Kommunikasjon AS	x				x											
Xfiber AS					x											
Xito AS					x											
Ytre Rælingen Antennelag SA					x											
Z Nett AS					x											
Ørskog Breiband AS					x											
Årdalsnett AS	x			x	x		349	399	499					1990	990	1

Appendix C
Swedish Price Data

Service Provider	Fixed Broad-band	Fiber	HFC	xDSL	Checked	(0,2]	(2,10]	(10,30]	(30,60]	(60,100]	(100,150]	(150,250]	(250,1000]	ECN	ECE	NGA SP
31173 Services AB		x														
3W Solutions AB		x														
AB iP.1 internet till före-tag		x														
Access IT Sweden AB		x														
Adamo Europe SL		x														
Adminor AB		x														
Affärsverken Karlskrona AB	x	x	x		x		198	238		279		395	745	8500	199	9
Alenet Communication AB		x														
Alingsås Energi Nät AB	x	x	x		x		208			249		328	589	11250	199	14
AllTele Allmänna Svenska Telefonaktiebolaget		x														
Alltele Företag Sweden AB		x														
Alltele LDA		x														
Arjeplogs Kommun		x														
Arkaden Konsult AB	x	x			x			250								
Arvidsjaurs Kommun	x	x	x		x	144	204	264		234					199	7
AT&T Global Network Services Sweden AB		x														
Azent Bredband AB		x														
B2 Bredband AB		x														
Bahnhof AB		x														
Bahnhof Unipessoal LDA	x	x	x		x											
BearCom AB		x														
Bengtsfors Energi Nät AB	x	x	x											25000		
BIVA Bredband i Värend AB	x	x			x		199	230		225		349	547			13
Bixia		x														
Bjurholms Kommun	x	x	x							285				3500		2
Bjäre Kraft Bredband AB	x	x	x		x	185	219	239		269		459				5
Bjäre Kraft ekonomisk förening		x														
Bjärke Energi AB	x	x	x				208			269		329	875	17800		9
Black Internet AB		x														
Blixtvik AB		x														

Blixtvik Calypso AB		x													
Bodens Energi Nät AB		x													
Bogal AB		x													
Bollnäs Energi AB	x	x	x		x		266	316		325	399	995	10000	500	1
Borderlight AB	x	x	x		x	195	295	335		395					1
BoreNet AB		x													
Borgholm Energi Elnät AB		x													
Borås Elnät AB	x	x	x			179	158		224	244	419				9
Boxer TV Access AB	x	x	x				269	339		339	499	779			
BRAVO	x	x	x										4990		
Bravo Bredband AB		x													
Bredband 2 AB	x	x													
Bredband i Gislaved Gnosjö AB		x													
Bredband i Kristianstad AB	x	x	x		x	199	249	349	299	299				990	1
Bredband i Kristianstad Nät AB	x	x	x				229			224				249	11
Bredbandsson AB	x	x	x	x	x		219	289		289				300	1
Bredbandsteknik 2000 i Karlshamn AB	x	x	x		x		189	390		275	529	975		250	10
Bredbandstjänster i Dalarna	x	x	x		x	199	249	369	449	275					1
Brinet AB		x													
BT Nordics Limited UK Filial															
BygdaNet Ekonomisk Förening		x													
Bålsta Kabel TV		x													
C-Sam AB	x	x	x		x	159	195	335		395	475				1
Cable & Wireless Sweden AB		x													
Canal Digital Kabel		x													
Canal Digital Sweden AB		x													
Carlslids Bredband Ek. för.		x													
Carlstad Hosting AB		x													
Cepus Internet Solutions AB		x													
Clue AB		x													

Colt Technology Services AB		x														
ComHem AB	x	x	x		x				289	339		429	899	249	249	
Comne Work AB		x														
Conect AB		x														
Connectel AB		x														
converGate24 AB		x														
CRW Data AB		x														
Dahema Sambandservice & garnisonsnätet		x														
Daladatorer i Mora AB	x	x	x		x	145	235	255		350						
Dataphone Scandinavia AB		x														
Devicom AB		x														
DGC Access AB		x														
Direct2Internet AB		x														
Dorotea Kommun		x														
Ekhosat Kabel TV AB		x														
Eksjö Energi Elit AB	x	x	x		x	249	249	349	399	449	499	699		7500	499	1
Electronet Solutions AB		x														
Elverket I Vallentuna AB		x														
Enbjärde&Johansson Konsult AB		x														
Engboms Network Solution AB		x														
EPM Data AB		x														
Excedo Networks AB		x														
Falu Elnät AB	x	x	x	x	x	123	183	233		244				14000	194	9
Falu energi & vatten AB		x														
Fast TV		x														
Fastbit AB	x	x	x		x	249	309	339		349				13500	0	1
Fiberdirekt AB		x														
Fiberstaden AB	x	x	x			199	219			299				12000		5
Finspångs Stadsnät, Finet AB	x	x	x		x	159	209	269		293				14900	250	4
First New Media Scandinavia AB																
Firstnet Solutions in Sweden AB		x														
Fouredge AB		x														

fredan		x													
Fredan AB		x													
Garnisonsnätet Bredband AB		x													
GleSYS Internet Services AB		x													
Glocalnet Scandinavia AB	x	x			x				349					495	
Gotlands Energi AB		x	x			207	237			392			15000		4
Gästabudstaden AB	x	x	x				280	344		344	359	829	15000		6
Gävle Energi AB	x	x	x	x	x	259	299	329		349		998		1950	1
Gävlegårdarna	x	x	x												17
Götalandsnätet AB	x	x	x		x	279	219	379	450	339				695	1
Göteborg Energi GothNet AB	x	x	x										25000		10
Habo Kraft AB	x	x	x	x		215	259	349							1
Halmstadept AB		x													
Hanse Communication AB		x													
Haparanda Kommun		x													
HebyNet AB	x	x	x		x	69	219	229	259	299	399	899	13900		1
Heby Stätsnett	x	x	x				195			215	345	578			8
Helsinge Net Ovanåker AB	x	x	x		x	174	240	285		335			8250	1500	1
Hemmanet AB		x													
HerjeNet AB		x													
Herrljunga Elektriska AB		x													
Hessleholm Network AB	x	x	x		x	219	189	269		299			12995	599	1
High Performance Data Center Svenska AB		x													
Hjo Energi AB	x	x	x	x	x	199	249	289		369			7000	199	12
Hofors Kommun	x	x	x		x	144	204	218		234				199	7
HSB Malmö Ek. Förening	x	x	x												12
Hudiksvalls kommun		x													
HåboNet AB		x													
Härnösand Energi & Miljö AB	x	x	x		x	213	233	244		297	397				
HögsbyNät AB	x	x	x		x	199	275	375	375	475			4995		
Ide & resurscentrum i Ljungby AB		x													
Infracom AB		x													
Insat Net AB	x	x	x		x			295	395	445				575	

Interoute Communications Limited		x													
Interoute Managed Service Sweden AB		x													
Interoute Sweden AB		x													
IP Delivery Group Scandinavia AB		x													
IP-Only Telecommunication AB		x													
IPbolaget Skandinavien AB		x													
IPCell AB		x													
Ipeer AB		x													
IT mästaren Mitt AB		x													
IT System i Dalarna AB		x													
IT Åre AB		x													
IT4U Sweden AB		x													
ITCONNECT AB		x													
Jokkmokks Kommun	x	x	x			144	204	234		234				199	8
Junet AB	x	x	x		x		249	319	359					699	
Jämtkraft Telecom AB	x	x	x				211			279				249	8
Jönköping Energi AB	x	x	x					195		249			14500		1
Karlsborgs Energi AB	x	x	x	x	x	179	249	289		369			13250	249	8
Karlskoga Bredband AB	x	x	x				211	225			329	589	13500		6
karlstad	x	x				143	203	217		233	418				10
KnivstaNet AB	x	x	x						259	299	399	899	13900		1
Kommunicera i Umeå AB	x	x	x				174			234	314	1195			5
Kramfors Media Teknik AB		x													
Kristinehamns kommun	x	x	x				195			215	345	758		199	9
Kungsörs Fastighets AB		x													
Kungälv Energi AB	x	x	x			208	248	69	298	308	318	1064	24500		9
Kustbandet AB		x													
Köpings Kabel TV	x	x	x	x	x	150	240	265		290			5995	0	1
LA Cable AB	x	x		x		99	199	299						195	
Laholms Bredbandsbolag AB	x	x	x		x		295	339		339				350	1
Laholms Bredbandsbolag AB (2)		x					225	285		325				195	1
Lan Assistans & Konsulting AB		x													

Le-vonline AB		x													
Lidén Data Internetwork AB		x													
Ljusnet AB	x	x	x	x	x	225	275	325		345			10000		1
Local Internet Provider AB		x													
Logica Norr AB		x													
Lulebo AB	x	x	x		x	215	235	324		249				325	10
Lyssna & Njut AB		x													
Malå Kommun	x	x	x												3
Mariestad Töreboda Energi AB	x	x	x		x	199	215	245		275			15000	195	7
Media Network i Halmstad AB	x	x	x			139	187	218		255	445	765	18000		10
Mediateknik i Varberg AB	x	x	x				179	219		249		995			1
Megaphone AB		x													
Micro Tec i Laholm AB	x	x	x		x		295	339		349				355	
MobileCity Sweden AB		x													
Mälardalens Datorförening		x													
Nano It Services AB		x													
National Internet Service Provider		x													
Net at Once Sweden AB	x	x	x		x		299	349	399						
Net IT Internet Solutions AB		x													
NetIT, Network Information Technology Co		x													
NetProvider Nordic AB		x													
Nitma AB		x													
NordiskaServercentralen AB		x													
Norrtälje Energi AB	x	x	x			48	69								3
Norrtälje Energi Försäljnings AB		x													samme som over
Norsjö Kommun	x	x	x		x										3
Nossebro Energi Försäljnings AB	x	x	x	x	x	199	259	299		339			27000	300	1
Nynäs Stadsnät AB	x	x	x			270	329			379			12000		1
Nässjö Affärsverk AB, Bredband		x													na

Obduro Network AB		x													bed
Olofströms Kabel-TV	x	x	x	x	x	225	295	325	375	395			12995		1
Omninet AB		x													na
Open Broadbandnet Sweden AB		x													kjøpt av telenor
Openbit - Skara	x	x	x		x	199	215	245		275			13500	199	7
Opentbit - Lindköping	x	x	x		x								13300		7
Orange Business Sweden AB		x													
Osby SN	x	x	x				195			215	345	578			8
Oskarshamn Energi AB	x	x	x				195			215	245	578			8
Ownit Broadband AB		x													
Oxyfi AB		x													
PCCW Global B.V.		x													
Perfect Communication Sweden AB/ePhone		x													
Perspektiv Bredband AB	x	x	x		x	199	159	299		210	429				3
Perstorp Näringslivs AB															
Peter Lindström Elektronik AB	x	x		x			190		290					490	
Phonelink Scandinavia AB		x													
Phonera AB		x													
Phonera Företag AB		x													
Phonera Networks AB		x													
PiteEnergi AB	x	x								279	389	739			7
PI:SE AB		x													
Power och Random T-lane AB		x													
Procyon AB		x													
punktR AB		x													
Quadracom Wireless AB	x														
QuickNet AB	x	x				115	185			205	479				
Rix Telecom AB		x													
Robertsfors Kommun															
Ronneby Miljö & Teknik AB	x	x	x					198		259	395	745	20000		
Roslagen Broadband Network AB															

RSL COM Business AB															
Rätt Internetkapacitet i Sweden AB (RIKSNETT)															
SalaNet AB	x	x	x				195			215	345	578			8
Sandviken Energi AB	x	x	x				195	295		395	495	895	14995		1
Satellitbolaget AB															
Satellithuset i Limmared AB	x	x		x		150	199	295		395	495			495	
SAVMAN AB	x	x	x				249	299		349			4995	250	1
SB Broadband Operations AB		x													
Secure Transmission Sweden AB		x													
Serverado AB	x	x			x	229	249	319						395	
SIHI Scandinavia AB		x													
Skellefteå Kraft AB	x	x	x				199			249	420	899	24900		8
Sorsele Kommun	x	x													2
Spray Telecom AB		x													
Stockholms Stadsnät AB		x													
Straznet AB		x													
Sunderbyn kabel-TV förening	x	x		x											
Sundsvall Elnät AB		x													
Suravision AB	x	x	x		x			330		370					
Swedavia AB		x													
Swepet Satellit AB		x													
SYSteam Nät AB		x													
Söderhamn NÄRA AB	x	x	x	x	x	169	235	285		345			9500		1
TDC Sweden AB		x													
Teknik i Media Datacenter Stockholm AB		x													
Teknik- och stadsbyggnadsförvaltningen, LaNet		x													
Teknikbyrån i Sweden AB		x													
Teknikmejeriet AB		x													
Teknorama Data AB		x													
TelaVox AB		x													
Tele-Man AB	x	x			x	199	249	299							
Tele2 Sweden AB	x	x	x	x	x	259	229	339	409	299	399	799			
Tele2 Syd AB		x													

Tele2Vision AB		x													
Telecom3 Sweden AB		x													
Telen Sweden AB		x													
Telenor AB		x													
Telenor Sweden AB	x	x	x		x		299	389	439	369	369	899			
Teleservice Bredband Skåne AB	x	x	x	x	x	250	210	320		250	390		15900		1
Teletek 5060 AB	x	x			x			349	399					595	
TeliaSonera AB	x	x	x		x	269	329	359	419	379	499	999			
Tibro Energi Försäljning AB	x	x			x	199	255	289		369					8
Tidaholms Energi AB	x	x	x	x	x	199	255	289		369					8
Timepiece-Servicos De Consultoria Lda		x													
Traffic Center AB		x													
Transit Bredband AB	x	x	x	x	x	179	339	329	379	399				99	
Trelleborgs Byakontakt Ek. förening		x													
TV-Net		x													
Tyfon Svenska AB	x	x													
Ulricehamns Energi AB	x	x	x												15
Umeå Energi Elhandel AB		x	x				319			443		1285	12500		6
Uppsala Stadsnät AB	x	x	x				195			215	345	578			9
Vaggeryd Energi AB		x	x	x			350	350	350	350			2490	0	1
Varberg Energi AB	x	x	x		x		155	215		225		969			7
Varberg Energimarknad AB		x													
Wasadata System AB		x													
Vattenfall AB		x													
WDM Nordic Computer Management AB		x													
Vellinge Wireless AB		x													
Venatech AB		x													
Verizon Sweden AB		x													
Vetlanda Energi & Teknik AB		x				140	204	218		234			15000	199	9
Via Europa i Lund AB		x	x												
Viking Tech AB		x													
Vilhelmina Kommun		x													
Vindelns kommun		x	x										10000		3

Visionutveckling Internet i Göteborg AB		x												
Visit AB		x												
Voice Integrate Nordic AB		x												
Voicetech Sweden AB		x												
Väddö Media Information IS AB		x												
Vännäs Kommun	x	x	x	x	x				349	335		12000		3
Värnamo Energi AB	x	x	x		x		295	345	395	445		2875		1
Vökby Bredband AB	x	x	x				199	239	289	329	399	4995		1
Ymex AB		x	x		x	249	299	349	419				590	
Zedcom ISP AB		x												
Åre Network AB		x												
Åsele Kommun		x		x										
Åstorps kommun		x												
Åtvidabergs Fjärrvärme AB		x												
Åtvidabergs Kommun		x				212	347		387			4995	1995	1
Älvsbyns kommun	x	x	x		x			250		250			300	1
Ödeshögs kommun		x										4995		
Örecom AB		x												
Örkelljunga Bredband AB		x										20000		
Örnsat AB		x												
Österlens Kraft AB	x	x	x	x		149	229	299		299		10000		1
Överkalix kommun		x												

Appendix D
Price Comparisons

Table D.1: Subscription Prices in NOK for Fixed Access in Norway

BW [Mbit/s]	(0,2]	(2,10]	(10,30]	(30,60]	(60,100]	(100,150]	(150,250]	(250,1000]
Average	282	396	468	565	733	754	1827	2159
Median	299	350	449	499	749	749	1490	1490
Max	375	699	798	1100	1100	899	3490	5990
Min	150	297	289	395	399	499	699	999
Per Mbit/s	141	39.53	15.65	9.40	7.33	5.21	8.06	2.30

Table D.2: Subscription Prices in SEK for Fixed Access in Sweden

BW [Mbit/s]	(0,2]	(2,10]	(10,30]	(30,60]	(60,100]	(100,150]	(150,250]	(250,1000]
Average	208	250	310	393	329	499	442	877
Median	199	240	324	399	342	499	414	899
Max	279	350	389	450	449	499	699	999
Min	145	155	215	289	210	499	328	589
Per Mbit/s	104	24.95	10.34	7.86	3.29	3.33	1.77	0.88

Table D.3: Subscription Prices Adjusted for USD / PPP

BW - Mbit/s	(0,2]	(2,10]	(10,30]	(30,60]	(60,100]	(100,150]	(150,250]	(250,1000]
Norway	30	41	49	59	79	87	195	244
Sweden	21	26	33	41	35	57	47	95
Difference in Percent	39%	55%	48%	43%	126%	52%	319%	157%

Table D.4: Entry Prices Adjusted for USD / PPP

	New Entry Cost		Existing Entry Cost	
	Norway	Sweden	Norway	Sweden
Average	372	1418	71	48
Median	431	1490	55	29
Max	995	3097	276	229
Min	55	29	0	0

Appendix E

Government Spending in Norway and Sweden

Table E.1: Table of Government Spending in Norway and Sweden. Numbers are in Millions

	Year - From	Year - To	Sum Local Currency	Sum USD/PPP	Note or link
Norway					
High speed Communication Program (No. Høykom)	1999	2007	600	66.3	www.snl.no/H%C3%98YKOM-programmet
Ministry of Government Administration, Reform and Church Affairs	2007	2007	377	41.7	www.regjeringen.no/nb/aktuelt/foreslar-ytterligere-255-millioner-krone/id466678/
Nkom	2014	20014	160	17.7	www.rogfk.no/elevportalen/Internet/OEkonomisk-stoette/Regional-utvikling-RUP/Stoette-til-bredbaandsutbygging
Ministry of Local Government and Regional Development	2007	2012	485	53.6	[Nex13b]
Municipal Investment	2007	2012	109	12	[Nex13b]
Ministry of Local Government and Regional Development	2013	2013	150	16.6	www.statsbudsjettet.no/Revidert-budsjett-2013/Statsbudsjettet-fra-A-til-A/Bredbaringnd/
		Sum	1881	207.9	
		Per Year	125.4	13.9	
Sweden					
Rural Development Programme (Se. Landsbygsprogrammet)	2007	2012	495	56.8	All swedish numbers are from [Sve13] and [Rik13]
Rural Development Programme	2013	2013	183	21	
PTS	2012	2012	158	18.1	
Goverment Aid	2001	2007	3809	436.9	
Regional Structural Fund (Se. Regionala Strukturfonden)	2007	2013	279	32	Only from 1. January to 25. March
PTS	2010	2014	178.5	20.5	
Ducting Support (Se. Kanalisationsstödet)	2008	2014	105	12	
Municipal Aid (Se. Kommunalt Stöd)	2001	2007	772	88.5	
		Sum	5979.5	685.8	
		Per Year	664.4	76.2	

Appendix F

Joint Effort Broadband Development

Table F.1: Norwegian End User Contributions

Year	Number of Subscribers	Number of fiber subscribers	Number of subscribers (not fiber)	Yearly paid subscriptions	Yearly NEC	Yearly EEC
2000	23297	0	23297	1141553	0	1654087
2001	147185	31006	116178	8731349	11534331	1654087
2002	271072	62013	209060	16321145	11534331	1654087
2003	394960	93019	301941	23910942	11534331	1654087
2004	518847	124025	394822	31500738	11534331	1654087
2005	642735	155031	487703	39090534	11534331	1654087
2006	766622	186038	580585	46680330	11534331	1654087
2007	890510	217044	673466	54270126	11534331	1654087
2008	1014397	248050	766347	61859923	11534331	1654087
2009	1138285	279056	859228	69449719	11534331	1654087
2010	1262172	310063	952110	77039515	11534331	1654087
2011	1386060	341069	1044991	84629311	11534331	1654087
2012	1509947	372075	1137872	92219107	11534331	1654087
2013	1633835	403081	1230753	99808904	11534331	1654087
2014	1881610	465094	1416516	114988496	11534331	1654087
Yearly growth	123888	31006	Sum	821641692	161480637	24811305
			Total Sum	1007933634		

Table F.2: Swedish End User Contributions

Year	Number of Subscribers	Number of fiber subscribers	Number of subscribers not fiber	Yearly paid subscriptions	Yearly NEC	Yearly EEC
2000	249000	0	249000	8217000	0	1118256
2001	372888	31006	341881	13328495	43966886	1118256
2002	496775	62013	434763	18439991	43966886	1118256
2003	620663	93019	527644	23551486	43966886	1118256
2004	744550	124025	620525	28662982	43966886	1118256
2005	868438	155031	713406	33774477	43966886	1118256
2006	992325	186038	806288	38885972	43966886	1118256
2007	1116213	217044	899169	43997468	43966886	1118256
2008	1240100	248050	992050	49108963	43966886	1118256
2009	1363988	279056	1084931	54220459	43966886	1118256
2010	1487875	310063	1177813	59331954	43966886	1118256
2011	1611763	341069	1270694	64443449	43966886	1118256
2012	1735650	372075	1363575	69554945	43966886	1118256
2013	1859538	403081	1456456	74666440	43966886	1118256
2014	3113400	1158000	1955400	140956200	43966886	1118256
Yearly growth	190960	77200	Sum	721140281	615536406	1118256
			Total Sum	1337794943		