User involvement in FTTH deployments as a key to success

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A tots.

Especialment als futurs i sempre recordant als que ja no hi són.

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Abstract

Broadband connections are becoming an essential service of any home. To be connected at more than 100Mbps, to 1Gbps, or to 10Gbps, is more an economical problem, rather than a technological one. The dissertation purpose is to proof that users are the key piece of the fiber access networks – especially of Fiber to the Home – by developing a techno-economic sharing access network scenario model. Currently, the network is dominated by Top-down deployments made by telecom operators that still see in the user the consumer of their services. However, this dissertation implements a Bottom-up approach, and the user becomes a stakeholder of the access network. Moreover, he turns into one investor of the fiber work, and gets more benefits by adding more users, thus deriving into a community-shared network model. The role of State, Municipalities, and private operators are analyzed as possible factors that may help or hinder those user initiatives.

Resum

Les connexions de banda ampla estan esdevinguent un servei essencial per a qualsevol llar. Estar connectat a més de 100Mbps, a 1Gbps, o a 10Gbps, és més un problema econòmic que no pas un de tecnològic. Aquesta Tesi té com a propòsit demostrar que l'usuari és la peça principal de les xarxes d'accés de fibra – en especial dels de Fibra Fins a la llar – tot desenvolupant un escenari de model tecno-econòmic de compartició de xarxa d'accés. Actualment, la xarxa està dominada pels desplegaments de Dalt cap a Baix fets per operadors de telecomunicacions que encara veuen en l'usuari el consumidor dels seus serveis. Tot i això, aquesta Tesi implementa un model de Baix cap a Dalt on l'usuari esdevé part de la xarxa d'accés. És més, es converteix en inversor de la xarxa de fibra i obté mes beneficis quants més usuaris agrega, derivant així en una xarxa compartida per la comunitat. El paper de l'Estat , els municipis i els operadors privats són analitzats com a possibles factors que poden ajudar o dificultar les iniciatives d'usuari.

PROLOGUE

“*An investment in knowledge*
pays the best interest.”
- Benjamin Franklin

After many years of scientific advances and innovative research, one would imagine that cars were going to fly and that everyone would have more than 1Gbps broadband connection at home – with all related services like 3D-personification, Smart buildings, telemedicine, and all the possibilities that any engineer expects to see one day. Reality is always harder than our imagination. No flying cars and no 1Gbps available to all homes (meaning that all those brilliant services are still not available). Although this is not a so positive start, there is a bright side, and it is showing that at least some countries are reaching the fiber deployment goal, like Japan and Korea, and many others that are getting good mobile coverage across the entire country. However, not all models can be copied and exported around the globe (also it seems that some attempts on including wings to cars have succeed, but nothing comparable to a common car that levitates as all the designers and movies have shown to us). So, some of the initial questions that motivated me to study and write this Thesis were: Is there anything I – or we – can do to have everyone connected to fiber? Is there someone that enables or hinders the deployment of networks? How operators are incentivized to deploy new networks? Can my community deploy a telecom network? Is it legal to share a connection? How could I achieve a better retail offer at home? (In my mind telecom lines were more than amortized by any operator that can run them).

Some of those questions were troubling me when I met and faced the regulatory field. There is where one can find the National Regulatory Authorities (NRAs). Entities devoted to study and set a framework to develop the telecommunications market. Those NRAs are very different when compared to one another, and the rules and frameworks they make or establish can differ from a small bit to be totally opposed. Basically, they are implemented according to their local markets, usually a country, and they are also differentiated about their independency – from political control – about making new rules and sanctions. It is here where most of the research in my field is carried about. Sometimes you may even feel anxious to read and finish the new rules, or even help to discuss them in a prior request before their approval. The questions I was making are usually answered in this ecosystem of regulators and operators, and most of my studies will be related to some directives and laws, but also to some decisions operators make to cover or not a new area.

The principle focus on optical fiber comes when one realizes that after more than 40 years of the Internet existence, access networks installed – prior to its creation – are still connecting the end-users to it. I am talking about Copper lines (now considered legacy infrastructure) that were installed as telephonic networks. Not only they are not data driven networks, there are also others, like cable networks, that were deployed to transmit television through them. Because of that, when the protocols that can run a fiber are studied in depth, you realize that a faster network should be the only access network type to be installed in new homes when we are talking about exchanging data, and not to include in here latency or jitter problems. Also fascinating, is that although we talk about optical fiber, there is a myriad of options to deploy a fiber network, as this thesis will show, but we can all agree that they allow to accept the increased volume of exchanged data, already noticeable, and that will lead to some future products and service models (I also was expecting to see the killer-app for fiber when I started to write this thesis, but as usual, the Data growth, and Big Data interconnected to other Big Data to make decisions in real time will lead to optical links as the best solution).

The context of the writer should also be taken into account when reading this thesis. It has been written in the center of the turmoil of the 2007 crisis – I set no end to it, because its effects are still living in today's economy and are expected to affect the next decade. It was also called the mortgage crisis because of its starting failure point on controlling the mortgage delinquencies and the rising number of foreclosures. Those passed from a 2% averaged ratio to 40% in 2008. But, although funds are quite difficult to obtain, the telecom sector has continued to invest: it has been decreased the mobile roaming costs across Europe countries; the LTE has been nearly deployed in USA and Europe; licensed spectrum has suffered some changes, specially to make available more spectrum to mobile communications; nearly 10 million households have been connected to fiber in Europe and 10 million more in USA; Google has become a network operator; and on the personal side I have become a husband and father.

The Internet has also evolved during the writing of this thesis, and also has played new roles when a military war occurs; it gets connected all the people from both sides at all time. Not to talk about the spying and security area, which has become a central point to make decisions after Edward Snowden and Julian Assange case, but also by groups of hackers that coordinates some computer attacks like Anonymous (just to say the first that came to my mind). Also some great events happened, like two scientists that have sent messages from one brain to another through the Internet and that we have reached the furthest point in human history, the communication that has been established between Earth and Pluto, or landed in Mars and the Rosetta-Philae into a comet.

One hot topic that this thesis will try to avoid is the control over the Internet (US, China, UK, and the powers to control parallel networks not connected to the internet). Politics also affect when we can experience for the first time a digital market. In this digital market it seems that there are no country borders and taxes, and products can be sold and bought from anywhere to anywhere; real goods have to pass through country borders if you buy something and taxes are a really difficult matter that may apply to the data carried over one country (and all the peering battle that could be extended from this point). This leads to say that not Network Neutrality Stuff will be found inside this thesis, although the data priorization over the network is something that will affect all the players in the service side and that will also have some effects to the network operators.

The Digital Agenda in Europe was launched in 2010, and it brought whit it the possibility to follow a scoreboard per country in a way to spur the installation of new networks. The truth is that those networks are starting to become a reality. It can be seen a 5% of fiber connectivity here, a 10% there, but the goals are to connect everyone at 30Mbps and half the population to 50Mbps. My opinion is that the Commission relies on wireless and mobile networks to achieve those goals, something that would explain the importance to deploy 5G mobile networks before 2020 and give wireless connectivity to a greater speed than today's one. And all of this brings me to remember that all those great mobile and wireless networks will need a backhaul, and it can only be fiber if latency and data rates continuously improve for those technologies.

So, show me the fiber! – Parallelism to the movie Jerry Maguire said sometimes with my friends. This thesis shows some of the reasoning to deploy a fiber network and how Bottom-up broadband networks, especially when big communities or municipalities are involved, can become a reality and considered user-data-network-driven.

I was attracted by the idea that a community, and its municipality (as the idea of local community gets bigger), can change and act in their small local area. They can decide if it is better to have a new public stadium, a new public library or a new bronze statue. They even can plan water, gas, and energy if there is no service, and also can discuss the best routes to accomplish the deployment of those networks. So, why they cannot decide about having a telecom network? I started this thesis with the aim to solve this last question, and when you read this thesis you will understand some of the thoughts I had and how I think they could be achieved – spoiler: it is difficult but not impossible. My impression is that sometimes we (human beings) are really complicated. Rules to prevent failures from the past, or rules that set competition, are sometimes the ones that may prevent the network to become a reality today.

This thesis is a compendium of my 4 years studying fiber networks, and also meeting with access network researchers, workers from different fiber networks and telecom operators, workers and policymakers from different public and private institutions, and mayors and community leaders.

I only expect that the reader will have also a critical read, and it may bring some discussion to any of the points written in this thesis. Something that I learned is that even if we (researchers/ policymakers/ carriers/ students) can imagine and define future networks, the truth is that users have more power than sometimes one would imagine, and that impressive solutions to some of us may finish in a dead end if the market do not adopt them.

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Chapter 1

INTRODUCTION

"The Internet lives
where anyone can access it."
-Vint Cerf

1.1. Background

The era of a copper-line based technology connecting each home seems to come to an end, and the deployment of a new network has already started. If anyone searches for fiber deployments, he will find that they started long ago. Grimado and Colucci (1986) supposed that Fiber to the Home (FTTH) deployments would be the best technological solution to change and replace the copper network since 1986. So, after about 30 years from that finding, are we all connected to fiber now?

The truth is that currently not even in the countries with strong economies fiber-based technologies have reached all homes. Perhaps we will not reach them all based on what happened with the coverage of copper-based networks, as they did not reach that goal either – the average coverage percentage for fixed telephony in EU27 is 71% according to the last household survey from the EC(2012), although Germany, Sweden, The Netherlands, Malta and France are above 85% fixed coverage. In many of those leading economies, policymakers have identified the need for universal access to broadband services as a critical component of their Digital Agendas, see Annex I for a full list of the consulted ones in this Thesis – what is called a Digital Agenda is a plan to boost the digital infrastructure that can boost the economy of the country.

These Agendas are including the goals and coverage per country to boost the deployment of the new network.

Since 2010, USA and EU have published its own Digital Broadband Agendas: Digital Agenda for Europe by the European Commission (2010), and The National Broadband Plan for USA released by the FCC (2010). The coverage goals are impressive, as both want to achieve a nearly universal coverage. About speed, it is not stated which Technology should be implemented – something that all we expect from regulatory field that is not linked to specific technologies – but it includes speed as a main driver for Technology replacement, like 30Mbps, 50Mbps or 100Mbps. Consequently, those two economies are making progress on their deployments, mainly on wireless networks like the 4th Generation of mobile connectivity (4G) or also known as Long Term Evolution network (LTE). Again, the question would be, where is the fiber?

Fiber, as a next step on fix connectivity, is implemented in plenty of regions worldwide. If we take into account data provided by the FTTH Council (2015) the household penetration rate allows to acknowledge that fiber is deployed in nearly all the developed economies, see Figure 1.

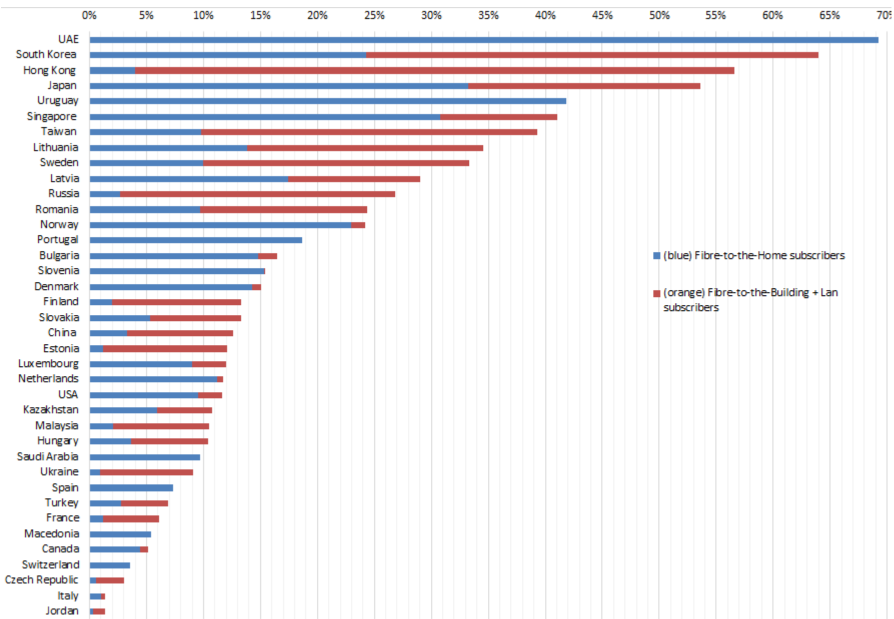

Figure 1. Household penetration of economies with the highest penetration of FTTH and FTTB+LAN. Figure included from the FTTH Council (2015).

In some cases, the fiber implementation is a specific country goal like Japan or New Zealand. In other scenarios, it is a matter of differentiation like incumbents as BT in UK or new entrants like ONO in Spain – although afterwards they can be acquired by larger firms like Vodafone that want to entry the fix market with a combined fix and wireless solution. In a few cases, it is also possible that users start this change like a community driven project in the Netherlands, with the Reggefiber case, or the Fiber From the Home (FFTH) project in Spain driven by Guifi.net in the region of Catalonia.

The current situation is that some of those scenarios bring different outcomes. We observe on one hand a group of countries that are really advancing to reach the 100% of fiber coverage, like Japan or Korea. On the other hand, other countries are just starting to deploy the foundations of the future fiber network, like Spain or Germany. In Spain, a 19.1% of the total broadband connections are served by fiber, or Germany, that has reached an 18.7% of fiber connections on 2014, see the European Commission (EC, 2014) for a full list of those percentages, or check the Ministry of International Affairs from Japan for any updated data on their coverage (MIC 2014).

Where all those projects merge is about the importance of one single variable: the take-up rate. Once an area is covered, the take-up rate is defined as the number of homes (subscribers) buying those new offers sold over this new technology. For that, pricing becomes an important factor. Back in 2010, a 100Mbps download speed – or even 50Mbps – were a rare offer sold around Europe and US. The retail price for those offers was valued as gold or diamonds, and it was supposed to be sold/subscribed only to/by some people who really wanted/needed it. Some argue that it was to differentiate themselves (operators) from others (mainly to wealthy areas as a new product), but it also was proved the positive impact it had in the country economy, see the study of Katz et al. (2008) about the impact of fiber in Switzerland.

Within the current regulatory framework in Europe, to achieve the goals of coverage and speed of a nearly universal 30Mbps Europe in 2020 – with half of it connected to speeds of 50 Mbps or more – provided one of the best frameworks to study how fiber-based networks were going to evolve. The possibility to achieve incremental speeds, to 10Gbps or 100Gbps, helped to postulate optical fiber as one of the possible network technologies to handle the future demand and network capacity increase.

1.2. Motivation

The motivation for writing this thesis, and to devote some research years to it, is mainly because we wanted to analyze the evolving fiber-change around the globe, but specially to identify what are the main drivers that help to boost it, and how the user is involved in them.

The user is still accounted as a consumer in any fiber deployment. From the early pilots and tests, like the one from UFINET in Spain or the one that used Paris' sewers[1], to the country deployments, like the NBN deployment in Australia, where you can still check your optical fiber availability based on your address.[2] Because of that, the possibility of finding a new role to the user, like the one he had in Web 2.0 is still not being totally explored.

This motivation – and part of the conclusion – is engraved in the Title of this Dissertation: *User involvement in FTTH deployments as a key to success.* What we aimed to proof in this Thesis is that there is a feasible way of deploying fiber that can be triggered from the user decision of wanting and aiming to have a fiber-based connection.

First, we thought that to analyze user involvement was good to follow the classical top-down deployment approach followed by telecom operators: from their core transport network to the user's home. First scenarios followed this method.

While writing this thesis, the concept of Bottom-up Broadband came up in a project that the research Group I am with at UPF, NeTS, was involved. The project was set inside a European Project implementing different deployment pilots proposed by communities

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[1] See the Paris' sewers news in the Wall Street Journal in 2009. Available from http://www.wsj.com/articles/SB116311331721719120

[2] See the NBN availability web page. Consulted in March 2015 at http://www.nbnco.com.au/connect-home-or-business/check-your-address.html

themselves. Our work was to select the ones that could proof their sustainability or that could have a high impact on the community that was asking to implement them, see our work at (Barcelo et al., 2012). This concept of starting the network from the user point of view and deploying the fiber until reaching the operator's network really changed the way of constructing the dissertation model and helped to propose the new deploying model included in this thesis as one of the main results.

1.3. Objectives

The main objectives of this thesis have been to set the variables that can help a fiber network roll out and including the user as an active stakeholder to it – users going further than just being broadband consumers. Following the same path that Open Source projects did, the best way to learn how the organized themselves is the Cathedral and the Bazaar ideas brought by Raymond (1999), the idea was that collaboration can occur also in networks, like hackers do in the book, by sharing how they are going to develop their part of the network and knowing what others have already deployed and installed. The aim is that it would help, in many of the analyzed factors, by decreasing the costs to deploy the network and, at the same time, decreasing the retail-price-offers that consumers get for their broadband connections. Listed in this point are some of the issues that were considered an objective of this thesis. Taking into account the user perspective, helped to propose new objectives and to study the potential effects over existing operators.

The high cost of civil works, which is thought to be around 40% to 70% of the total budget, see (Casier et al., 2008), is one of the main drawbacks when a fiber project has to be installed. Another one is that deployments occur in areas where demand is badly approximated. Because of this higher cost, a main first objective of any fiber model is how to decrease/reduce/adjust/share the deployment cost of a new network installation. In the case of placing the user playing a key-role part in the deployment, the objective was to analyze if it helps to ease some of the difficult parts of a deployment, like the rights of way in the private properties, or if it could bring any new benefit to both, users and operators, by raising demand and decreasing the price.

One interesting objective was to analyze the effect of the *Uncertainty introduced by the regulatory framework*. Not in the way that Van Schewick (2007) does for Network Neutrality, but more approximated to the work of Blackman (1998) analyzing the effects of converging media and broadband networks and proposing scenarios with the possible regulatory effects, or the work from Crandall et al. (2013) with the effect of unbundling over competition.

The main objective was to *analyze the effect of the current deployment models by introducing the user on them* and measure if he can have a real impact on the network. Users may have different motivations to do that, but price seems a convincing motive to a big community[3] to make the change happen.

The main objective brings with it some necessary steps to understand and research to allow the study of the user effects of deploying him parts of the network. First, a technological objective, as a fiber-based solution has a myriad of possibilities to be implemented and there should be all studied and select the best option[4]. Another important point is to study its feasibility and sustainability. If operators are not succeeding in deploying fiber is because of the upfront cost they must do when deploying a new network and the time they will be able to operate before having a payback for their investments. By being the user one of the stakeholders, the model will study if the retail-price offer and speed connectivity are improved in time for the user compared to the traditional top-down approach.

[3] Communities include individuals that are eager to want a connection, but also some others that with a copper-based connection are more than happy to live with. As the motive of this thesis, is the study of fiber networks upgrade, and how users may have an effect to it, one of the main drivers to change from legacy networks to fiber networks for this second group of people is a pricing one.

[4] Not only that, the user now is the point where the network begins, so it will be the first mile problem and not any more the last mile problem.

1.4. Contributions

This thesis main contribution is to confirm that a user's deployed network can solve the last/first mile deployment problem and provide a new way of deploying a fiber network infrastructure. This new way of rolling out the fiber cable from the home should be included as a Fiber case model.

One of my last papers is the one that resembles more to the conclusions of this thesis. Of course, it comes after tackling all the other objectives stated in the prior point, and mainly based on the research of the last three objectives. This paper showed that the model of a user community deploying their network is feasible and sustainable. Not only that, we also show that operators should better know this model as it has an impact onto their current deployed networks and the way they estimate the take-up rate percentages. It was presented to the ITS conference in 2014, see (Domingo & Oliver, 2014).

Another main contribution of this thesis has been on the research area of sharing infrastructure facilities – mainly ducts, conduits, poles, cabinets, etc. – directly related to the problem exposed of civil works high costs. The conclusion is that fiber network deployments costs can be reduced between a 5 to 21% of the initial budget when sharing rules are applies. The impact on the reduction will mainly depend on the selected fiber deployment type – Chapter 3 shows the different deployments. It also includes an analysis of the regulatory impact over the operator time to get its upfront-invested money, the payback period, which leads that sharing option decreases the payback time of any FTTH deployment between 3 to 7 years. Part of this work has been already presented to the TPRC conference and in this thesis includes some of its findings; see (Domingo & Oliver, 2011). The same paper, without modifications, was published by different electronic journals[5]

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[5] Domingo, A., Oliver, M. (2012, February). Modeling the effect of duct sharing in a NGAN competition market. *Regulation, Antitrust & Privatization eJournal - Industrial Organization*, Vol. 4, No. 16.
Domingo, A., Oliver, M. (2012, February). Modeling the effect of duct sharing in a NGAN competition market. *Global Business Issues eJournal*, 02/2012, Vol. 2, No. 23.
Domingo, A., Oliver, M. (2012, February). Modeling the effect of duct sharing in a NGAN competition market. *Industrial Organization: Theory eJournal*, Vol. 4, No. 9.

More contributions have been set following the objectives of studying other technologies that may affect the deployment on the short term. Some technologies, like wireless or cable technologies including as its main examples 3G, LTE (4G), Wi-Max, or Docsis 3.0 can become temporary cheaper solutions to avoid the cost of the fix network's change. On the other hand, recent wireless solutions are in need of faster and bigger (with more capacity) backhauls. In this case, fiber is one of the best-positioned technologies to accomplish this purpose. For instance, new 5G base stations are going to be deployed, bringing with them to live the concept of smallcells[6]. Because of these mobile stations, it will give a new reason to mobile operators to bring fiber to plenty of new areas – as those antennas need a core and distribution network. This would make the claim that *other cheaper technologies than fiber can solve the peak-increase speed* to be partially true, as at the end, it will only postpone the fiber roll out into several phases and delay its arrival to the home for several years.

During the study of this thesis, I discussed some draft articles with some of the Spanish regulator workers. That regulator is now merged into the Spanish supra-regulator of energy, telecommunications, transport and postal service, and market competence; the joint of this four is called: *Comisión Nacional de los Mercados y la Competencia* (CNMC)[7] – former *Comisión del Mercado de las Telecomunicaciones* (CMT). The contribution here has been higher than any paper will do, as it directly effects current

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Domingo, A., Oliver, M. (2012, May). Modeling the effect of duct sharing in a NGAN competition market. *Applied Econometric Modeling in Microeconomics eJournal*, Vol. 2, No. 90.

[6] Smallcells are mobile base station with minor coverage areas than the current ones. Their footprint is as a maximum of two Kilometers radius coverage in rural areas to a minimum of ten meters coverage in cities, sometimes even renamed as Femtocells or Picocells. Thus, they will use the access point at the user's home to get mobile extended coverage, and again, the backhaul to serve those users will take advantage of the future fiber upgraded network.

[7] During the research of this thesis, I really enjoyed studying the transition from the single market to the competitive market in Spain, mainly driven by the unbundling of copper lines. The point is that they used to compare the possible regulation of the Broadband market in Spain with some experts. It is also important to enlighten that I am with a public institution and my work is done under public research funds, not from any other interest than discussing network cases. Therefore, my contributions help to provide more feasible scenarios that can be affected by new implemented regulations.

regulatory decisions that can be based on new problems, and other times including some scenarios that were not taken into account.

This thesis also contributes with the exposition of different worldwide fiber scenarios, some of them presented in ITS conference last year, and this year to the Broadband Communities magazine, see (Domingo et al., December 2014) and (Domingo et al., 2015). These scenarios help to realize how big is the problem of the upfront investment that operators must do, and also show how some of them solve it by buying an existing carrier; two current examples of this case are Vodafone buying ONO in Spain, and the possible Orange (France Telecom) buying Jazztel.[8] On the other hand, some big infrastructures are build – like impressive bridges or high-speed trains – that can cost many times a full country implementation of a fiber to the home project. In here, one of the possible investors and formulas to get as stakeholder is the Public Administration. It seems to be one of the keys to surpass the budget barrier, like the case of Japan. But, as this thesis will show, if the barrier is the last mile of a fiber deployment, the user can be the one that can solve this point, and even support it with its own money, like the Guifi.net or Reggefiber cases.

Another contribution made by analyzing different scenarios is about the operators with a significant market position (Telefónica, BT, Telstra) and how they get rid of the legacy network – copper-based lines. On the one hand, it is always good to own the legacy infrastructure, as you only have to pass a new fiber cable through it. On the other hand, once you connect and install the new equipment, you have to sustain and maintain the old machinery to all the users that are still connected by copper lines and do not want to change to a fiber or cable solution. OpEx in this case can only increase, as the operator sustains two networks and neither of both is fully used – fiber mainly decreases the OpEx when compared to copper networks, so this handicap is a real nightmare for setting a payback time or a possible return of the investment. This thesis shows why a small country like Andorra opted to offer fiber and remove the

[8] Both cases are mobile based companies, with a few connected fix households (Vodafone and Orange) that buy a fix company (ONO and Jazztel) to entry the market with a bundled offer of mobile + fix + TV + data. Merging prices have been € 7.220 M for Vodafone buying ONO, and the price for Jazztel is still waiting the approval of European Commission.

copper line, that way, the OpEx decreased as expected of a fiber network in front of the copper lines and they now sustain a nearly completed fiber network. Compared to a community area that opts to deploy fiber, it provides another reason to opt for the porposed model in this Thesis.

1.5. Methodology

The methodology named as *Techno-economics* consists on evaluating the feasibility and the sustainability of a technological implementation. To do so, do not expect to have a full balance account of a company, in here, it will be taken into account some of the parameters that have a major impact on the ROI of the project, or the payback time – both measures are valuable to see the feasibility of the project. On the sustainability side, the model allows studying how to improve an economical plan to develop the technological project and the feasibility comes to analyse how high the impact of the variables introduced is.

This methodology brings complementary information to the technical one for different networks comparisons. The results of this methodology are reached by analysing the business models that runs behind a possible network implementation or the possible migration plan to develop a new network. It has been used from research groups, like Gent or Athens University, see (Verbrugge et al., 2006) and (Katsianis, 2004), to operators like Telenor, see (Telenor, 2009).

A Techno-economic evaluation can be set according to the next methodology work-wheel, see Figure 2. This methodology is well described in (Verbrugge et al., 2009) where it is explaned how it can be related to the Plan-Do-Check-Act (PDCA) cycle, see the first description at (Deming, 1986).

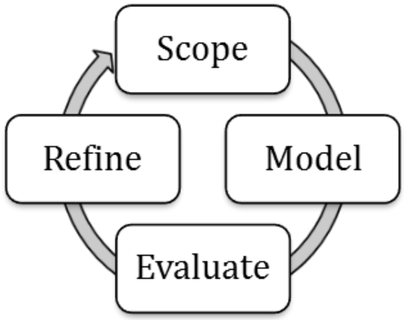


Figure 2. Techno-economic methodology.

This methodology starts by setting the *scope* of the business case (not including all the variables in depth). In this first point, it is very important to select all the variables that will define the model and that will be applied to different scenarios to compare them. Here, is the point where a problem is partitioned to small ones, like the region or type of deployment (e.g.: one municipality area can be subdivided into lower partitions of different category types: urban, suburban, rural areas) or technology type (e.g.: FTTC, FFTB, FTTH).

It is also very important to define the project by selecting the duration of it. This means that if we set the model variables for a twenty years scenario, we must take into account possible equipment renovation, evolution, and even include some discounts in CapEx costs. However, if instead of twenty years we choose five years, it only will be necessary to set a slow decrement in costs and the results of the forecast possibly will have more correlation with a real implementation. All the errors introduced by each variable, and all hypotheses related to them, can add more deviation ranging from a long-term period of time (more than twenty years) to a short one (five years).

In this phase, it is very important that data gathering include current prices to approach as much as possible the projected model to a real case that we want to implement. Related to the Thesis, it has been correlated with a pricing study from different countries, and an in-site measurement of data from one deployed fiber network. Regulatory disputes are also a good source of information. Disputes bring resolutions in an official public document that includes real data from operational costs and some infrastructure-related costs. Slides and talks with operators are also some of the sources used in this Thesis.

Finally, there are also a set of sources coming from different analysts. Main references of this last group are Analysis Mason, IDATE, WIK-consult, FTTH COUNCIL (all of them, Europe, Americas, Asia-Pacific, Africa, MENA) and some possible universities that we have been working with from NeTS group at UPF like Ghent University – Iminds(working together in some research), MIT (CSAIL-ANA, group where I stayed as PhD visiting student), and EOI-TU-Delft. A last group of information source is the one obtained from direct talks with Telecom operators, which also brings validation to data and cases; the list would be long in here.

According to the methodology, the next step is to approach the real business case by describing its cost and revenue *model*. I have focussed on the elemental components of the model, the expensive ones, and then choose progressively all the small sub-problems that do not have a big impact on the result of the forecast. According to the real case that we are investigating, it will be very helpful to separate costs and revenues according to a three-layer model for every operator and its main core business (explained in Chapter 3 where one operator can have more than one role):

- Physical Infrastructure
- Communication and Management
- Services

Once the model is completed, it will be important to *evaluate* the real implementation of it according to the cash flux of an operator. It will also be done a sensibility analysis that will allow further *refine* of the model in another iteration of the entire techno-economic process. In the evaluation phase, it will be important to measure the effects of user involvement and foresee possible regulative decisions that affect NGAN implementation as *ex-ante* fixed prices for ducts sharing and public-private deployments where user is part of the public investor.

1.6. Thesis Organization

The thesis is organized as follows. Chapter 2 introduces the literature review that includes technical, economical and regulatory sections. Chapter 3 details each country fiber deployment goals, and how their Digital Agendas are used as main reference for future deployment plans. Chapter 4 describes the different FTTH deployment models and introduces a general fiber deployment. Chapter 5 evaluates different real cases from around the world by analyzing their deployment and investment types. Chapter 6 summarizes how pricing and other points are set in the user proposed community-model. Chapter 7 evaluates the different impacts of a user deployment model. Finally, a conclusions chapter helps to recap the proposed scenario and the pros and cons it may have when implemented from the different perspective of users, operators and public administration.

Chapter 2

LITERATURE REVIEW

If you don't have time to read,
you don't have the time (or the tools) to write.
Simple as that.
-Stephen King

This literature review chapter answers to the necessary current research that is helping to develop this Thesis and its techno-economical model where the user is a central part of the model and that allows us to study its feasibility and sustainability. Hence, this Thesis includes technical, economical and regulatory sections that can make consider this Thesis as a multidisciplinary approach Thesis, but with a strong technological content.

2.1. Introduction

This Thesis is placed inside the three described areas. Not only in the central jointure point, where all the three are sharing some points, but also when two of them have in common some of their research, or when the combination of both is necessary to obtain the final results. As Figure 3 shows, each of the described points have more weight than others. Thus, this Thesis should be described as a Thesis that applies a Techno-economical methodology primarily based on Technology and that includes Pricing, described as economics in the literature review. Regulation, as a cross-cutting issue, is related to all the other two and it is a common research field to all the main issues, and it has an effect over all of the chapters and research done during this four years. One for Telecom infrastructure and fiber itself. Another one with Techno-economics evaluations, but mainly economics. In addition, a third section that presents several studies and research on broadband pricing and regulatory implications. All the three sections have several regulatory references as a cross-cutting issue related to all the other three.

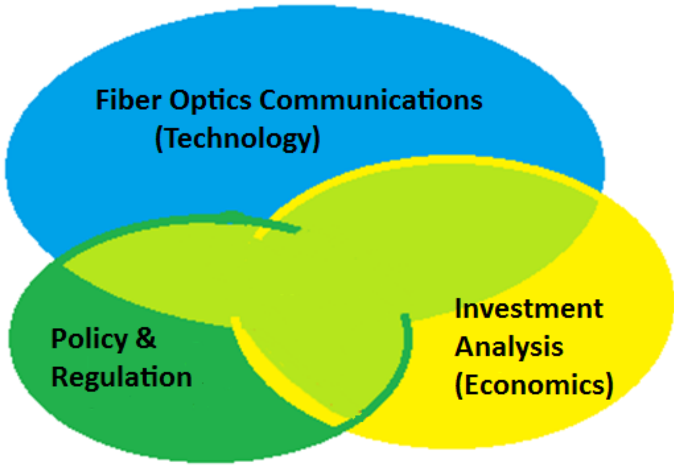


Figure 3. Thesis related areas of study. The pale green color shows the Thesis main focus from the three main areas that are part of this Thesis.

2.2. Telecom Infrastructures

Telecommunication infrastructures were originally associated with operators. Voice calls were the main income for operators, followed by the interexchange of data after a long time only carrying voice from one place to another. The horizon goal set by the Digital Agenda to reach each European home with a minimum connection speed of 30Mbps is challenging the operators to upgrade their networks in a short period of time, with the common horizon of 2020. This milestone is also made even more challenging with the inclusion of the objective of 50Mbps coverage for half of the connections in each country. We refer to Chapter 3 for a further discussion of Digital Agendas and their development.

During the last decade, technological improvements have been made primarily in the area of wireless broadband reaching hundreds of Mbps. In most of these developments, non-standardized solutions are used, like the Wi-Fi in the UHF bands described by Sanabria-

Russo et al. (2012), which are emerging from a vast body of research undertaken in the last few decades, and which are primarily suitable for regions with difficult geography according to Tahon et al. (2011).

On the other hand, fixed infrastructure has been seen as costly and not beneficial. The potential of ICT is seen in the European Commission as a way to address some of the challenges that are currently existing (e.g.: ageing population, climate change, efficiency of public services).

Optical fiber networks are also expected to be a key driver in enforcing innovation. They are becoming a fundamental infrastructure fuelling both regional and global knowledge economies. Although initial studies – like the ones from Katz et al. (2008) and Koutroumpis (2009) – quantified the impact of telecommunication services on economic activity through job creation, housing rents and industry structure, other studies – for instance see the one from Gillet et al. (2006) – claim for further investigation into the NGANs' specific impact by including more variables. This thesis differentiates the areas by population density and the different impacts of selecting fiber network deployments like the type of fiber rollout (aerial, buried, over façade), the topology selected (point to point, point to multipoint), or the contribution of the final user to roll out the fiber and become an stakeholder of the network.

Differences between the ways in which regulation enforces competition are vast, from strict *ex-ante* rules to progressively *laissez-faire* regulations that follow a set of basic principles with either periodic or constant review mechanisms. Experts are debating on how the use of shared regulatory frameworks will facilitate NGAN roll-out in all areas, with no clear conclusion. *Ex-ante* regulations may be uncertain and diffuse because of the complexity of NGAN per se, along with their heavy dependence on geography and density. Again, like Tahon et al. those variables related to the area are covered by Cave and Corkevy (2011).

Sharing infrastructure concept is wider than the scope of this research. This Thesis focuses in the part of sharing that can maximize the impact on lowering the overall investment. For instance, one of the key points analyzed was the impact of trenching, and how ducts are a key point requiring huge investments. Domingo and Oliver (2011) provided how sharing this key infrastructure can have a positive impact on lowering the total deployment budget by an approximate 40%. We were not the first to say so. The impact of trench-sharing is commonly proven effective, but this is only a necessary precondition to analyze the behavior of the investors, which usually assumes a public actor. It has also been proven effective in urban areas in which most of the infrastructure has to be rebuilt. Infante et al. (2008) provided a clear and successful example where the joint of operators, Barcelona's municipal one and Telefónica private one, in the 22@ district – where most of its infrastructure was rebuilt – allowed creating a municipal fiber wholesale connectivity in this district. In exchange, Telefónica won connectivity to all the area.

Considering that civil-works costs make up between 50-60% of the total budget, see Van Ooteghem et al. (2011), infrastructure-sharing is one of the first points to tackle when aiming to make investments economically feasible. The EU has been stated which formula allows a public entity to be part of a private investment (i.e.: a Public Private Partnership – PPP). The basic principle is that this public entity does not undermine competition. In October 2011, an investment of €9 billion was approved within the Digital Agenda framework, with the main objective to dedicate a significant amount of resources - seven of the total nine billion - to high-speed broadband infrastructures (EC, 2011).

According to the possibility of public aid, the EC designated three area types which were classified with a given color (EC, 2009). Black, Grey or White areas were designated according to more competitive areas to the ones requiring a complete intervention to cover its broadband demand. It is important to emphasize that cable operators are only taken into account in black areas. In grey and white areas, they are not considered a serious competitor to FTTH networks (not even with Docsis 3.0).

One of the first well documented examples was the one exposed by Sadowski et al. (2009) about Nuenen, in the Netherlands, which showed how public administration could lead a fiber deployment by getting the permission of investing the public budget on this technological project while joining a private investor to reach its sustainability. The Stokab case, analyzed by Forzati and Larsen (2008) also provides an example on how the public administration, in this case the city of Stockholm, can provide connectivity every time it opens one new street in their city – if we think about that model, all streets in a city are open once one year or another. Thus, in some years, we could get a full city connected. A last referenced case is the one provided by the FTTH Council (2011) from Asturias. There, they received European funds to develop the region and they decided to invest it by creating a distribution core network that would connect all the villages in the Asturias' region, this network would be only to offer as a wholesale service to operators on top. Those cases point out that for areas with a huge broadband demand, or where the revenues allowed some quick return to the firm and a feasible return to the public administration, some of the PPP have also been feasible to deploy fiber to not only a city but to an entire municipality or region.

About Telecom infrastructures exists a vast list of cases; the most relevant ones to this thesis are included in Chapter 4. The ones exposed in this literature review are the main references to others included in this thesis and the research we have been doing during these last years. This literature review point would be uncompleted if we do not include how sharing can be always beneficial to a new deployment. It is interesting how Pereira and Ferreira (2012) analyze the case of sharing parts of the network infrastructure to promote competition in NGAN, something that this Thesis centers on fiber deployments and not to all NGAN based technology (that include wireless technologies and cable technologies).

2.3. Techno-economics evaluations

Most of the existing literature on fiber deployment cost models is centered on a small deployment area or region, and thus, they are specifically designed for each case. For example, Sadowski, Nucciarelli, and Rooij (2009) analyzed with a techno-economic model the case of Nuenen in the Netherlands within the context of a Private Public Partnership run by a set of municipalities that were also implementing a NGAN in the area. The study concluded that a minimum of 52% of take-up rate was required to achieve profitability, using an open access municipal network as a common infrastructure to deploy the services.

Chen et al. (2010) studied the different fiber networks and their cost and reliability providing some conclusions on how there should be set a trade-off between network CapEx and OpEx to sustain good service reliability. It is important to remember that not all decisions are good in terms of economic impact, but they should provide a network that is sustainable in time, and this is a good input for this Thesis.

Lehr, Sirbu, and Gillet (2004) analyzed where to open a municipal network by studying and setting all the different models for an open access models. The given examples are from the US, and show that municipalities are the first movers to solve the last mile implementation under no competition regulation.

Other studies of rollout models, (see some examples in Tahon et al. 2014, Casier et al., 2008, Corning, 2009), are mainly focused on the network cost estimation and other infrastructure implications. The results from these papers allow framing the costs of deploying an FTTH network between $666 (urban areas) and $2,666 (rural area) per connected household.

The analysis of vast areas can unnoticed some details but allows obtaining averaged global results for entire countries or even larger areas. For example, the EU uses a classification called NUTS – Nomenclature of territorial units for statistics – that defines a hierarchical system for dividing the territory for the purpose of collecting statistics, socio-economic analysis and framing regional policies. The cost of achieving universal service goals in Europe for fiber deployments was estimated in €300Billion by McKinsey. A recent estimation, according to the FTTH council Europe (2012), the same cost would be close to €202 billion by using NUTS 3, the smallest area's type.

The availability of infrastructures, such as fibers, posts or ducts, and the regulation of its use by operators, mainly to enforce competition, has been analyzed by the literature. A techno-economic analysis done by Van der Wee et al. (2014) gives insights of how fiber models on point-to-point access may affect different area types (dense urban, urban and rural) and quantifies how low density areas generate longer returns. Briglauer and Gugler (2013) state that Europe may be lagging behind in the deployment of FTTH and recommends the use of ex-ante regulation of NGAN to get a more flexible pricing system and reduce the risk of fiber investments.

As noted in Clark, Lehr and Bauer (2011) the traffic-related costs, while representing a small share of total costs, are nevertheless significant. Thus, in some cost models enabling general availability of order-of-magnitude improvements in access speeds will likely result in significant increases in aggregate traffic loads and will result in increased usage costs that are not always considered. This last work shows how techno-economics may solve a big problem by slicing it in small and solvable ones, but sometimes it may lose the big picture and forget about interconnection problems when focusing on the last mile problem.

2.4. Pricing

Nowadays, the broadband demand is doubling every year. This growth, however, is not constant over time, as we have observed fast growths in only three months' time in some areas (Odlyzko, 2012). Although we now that, the basic rules of supply and demand are not guided only by the final price and quantity. For instance, Regulatory 3.0 by Noam (2010) suggests a paradigm balancing regional granularity and allowing for more stable conditions to attract new investors that can ensure capital expenditures in the fiber deployments. The residential scenario results into the use of one fiber network platform, or two at most, that may provide sufficient capacity to support all the possible future services. Thus, broadband is affected by more variables that can contribute with different weights to determine its final retail offer price.

Focusing on those variables, Wallsten and Riso (2010) did an interesting analysis of the contribution of variables to retail prices, such as data Caps, or installation fees. The analysis, based on datasets from the FCC and OCDE, showed the existing difficulties when using pricing datasets to get comparable results. For example, the weight of retail offers depending on the fraction of subscribers engaged (when available) would provide more realistic analysis using those datasets. On the other hand, as they are as a snapshot of a period of time, the more accurate data one can get, the results can held as indicators and they allow doing some recommendations of what is happening or predict what will happen when some actions are applied.

Other literature is centered in evaluating how network facility competition is affecting prices in some countries. A recent example is Calzada and Martínez-Santos (2014) that examines broadband access prices in a set of 15 European countries. The analysis done goes beyond broadband and includes pricing as well as Internet adoption among those countries according to consumer segmentation.

One interesting variable for this Thesis is to relate those pricing offers to the broadband speed. One regulatory example that has a direct effect on broadband speed is the one provided by the Spanish NRA. It determines 30Mbps as the maximum speed to regulate wholesale access CMT (2009) and CNMC (2014). Thus, policymakers are supervising wholesale offers below that speed (30Mbps), but do not require operators to offer wholesale services at higher speeds nor regulate the pricing of such services when offered. 30Mbps is also the speed goal for the European Digital Agenda to be reached by 2020, taken as a technology change. As it will be seen in Chapter 3, that speed rate is the common threshold among the different digital plans and agendas.

Crandall, Ingraham and Singer (2004) boost the facilities-based growth when unbundling is as costly as deploying a new network in the long run. Years later, Crandall, Eisenach and Ingraham (2013) analyzed more than 15 countries that used unbundling policies and concluded that those policies over fiber networks may have a negative effect on broadband adoption in the long term. In that sense, the use of accurate cost models for fiber deployments would provide a minimum threshold for broadband pricing to achieve profitable broadband investments.

Chapter 3

DIGITAL AGENDAS AND FIBER STATUS

“The only reason for time is so that everything doesn't happen at once.”
-Albert Einstein

After introducing the motivation and the goals of this Thesis, it is good for both, the author and the reader, to share a common view about the fiber state around the globe under the period of study of this Thesis.

As the quote of this chapter tries to point out, not every country is evolving at the same path and speed, but, after time, we observe that fiber deployment continues its growth despite new technologies entry the telecom market. This chapter provides general observations about political and regulatory goals, reflected on the general fiber coverage that the different analyzed countries have. It is contrasted with other research works targeting the same situation.

3.1. Digital Agendas and political goals

Countries have adopted national Digital Agendas to promote increased universal service access to broadband services. Although most countries agree in the importance of having huge broadband deployments, they broadly differ in the way of establishing their goals.

The motivations for adopting such plans are several, but most of them are based on economic development of the country. A growing recognition among economists and policymakers point out that broadband definitely contributes to economic development, employment and innovation positively by impacting on GDP growth. The literature in this direction is vast, developing complex models that are often linked to specific regions and moments. Katz, Zenhäusern, and Suter (2008) estimated the positive effect of the deployment of a new broadband network on the creation of new jobs in Switzerland. Koutroumpis (2009) analyzed the positive impact of broadband on GDP growth and determined that the effect was higher on countries with higher broadband penetration rates. Katz and Suter (2009) estimated the economic impact of the stimulus plans in rural areas spurring economic activity and transparency rising $840 billion by 2012.

Those studies only take into account economic impact of "broadband" without really differentiating the "only fiber" as a new type of broadband connection. This Thesis, as it is focused on the analysis of fiber deployment, will go one step beyond, and it will only take into account implementations based on fiber-based technologies. Two things that Digital Agendas show in Table 1 and Figure 4 are:

- There is a widespread adoption of goals implying target speeds of 100Mbps or higher (representing an order of magnitude improvement compared to today's offer) for NGANs. Even many of the plans with lower targets may be focused on establishing minimum performance standards for the highest cost customers or defining near-term goals.

- The leading countries (those with ambitious goals with respect to speeds, coverage and timing, see top right of
- Figure 4) have targeted near universal availability; whereas some other countries (including the US and Germany), have more conservative coverage goals. Part of this is due likely to the greater costs implicit in serving less-dense communities – commonly called as rural gap, see LaRose et al. (2007) were they explain that problem in the US and how it has not been possible to close it yet.

Table 1 summarizes a number of the Digital Agendas' goals in terms of the households to be covered, the peak download speed, and the year by when the target should be achieved. This table was set in November 2013. Because of that, some of the goals may be outdated – especially the ones with an earlier target year than 2015.

Table 1. Digital Agendas targeted household coverage, peak speeds, and year for accomplishing the goal.

Country	Acronym	Household coverage target [Percentage %]	Download peak speed target [Mbps]	Year
Austria	AT	100	25	2013
Belgium	BE	90	50	2015
China	CN	45	30	2014
Czech Republic	CZ	100	10	2013
Germany	DE	75	50	2014
Denmark	DK	100	100	2020
Greece	EL	100	100	2017
Spain	ES	50	100	2015
Finland	FI	99	100	2015
France	FR	100	100	2025
Hungary	HU	100	30	2020
Italy	IT	50	100	2020
Japan	JP	100	100	2015
Luxembourg	LU	100	100	2015
New Zealand	NZ	75	100	2019
Portugal	PT	100	30	2020
Sweden	SE	90	100	2020
Slovakia	SK	100	30	2020
United Kingdom	UK	90	50	2015
United States	US	75	100	2020

Figure 4 plots this data in terms of the target speed (Y-axis) versus the percentage of households to be served (X-axis). From the clustering of goals towards the upper right-hand of the figure, it is clear that most countries are targeting substantially expanding coverage towards faster broadband (with many targeting 100Mbps or better service) for the vast majority of households (with many at 100%).

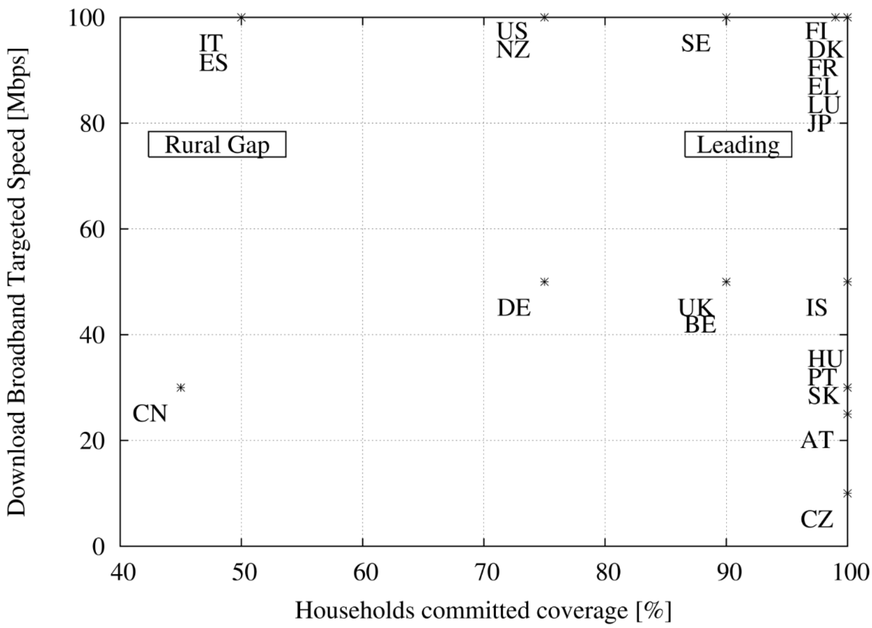


Figure 4. Digital agendas map. Country households committed coverage versus broadband targets.

Much of the heterogeneity in digital plans/agendas is associated with differences in national market conditions. For example, countries differ widely in terms of their levels of economic and broadband development (and not surprisingly, both are positively correlated), in the costs of meeting universal service goals, and in their willingness to embrace activist industrial policies. The challenges are much greater for less developed markets with less dense populations. This helps to understand why China (CN) or Italy (IT) and Spain (ES) appear less ambitious than France (FR), Germany (DK), Japan (JP), or Finland (FI). Nevertheless, it is surprising how many of the countries have adopted ambitious plans to deliver order-of-magnitude improvements in broadband performance as a universal service goal.

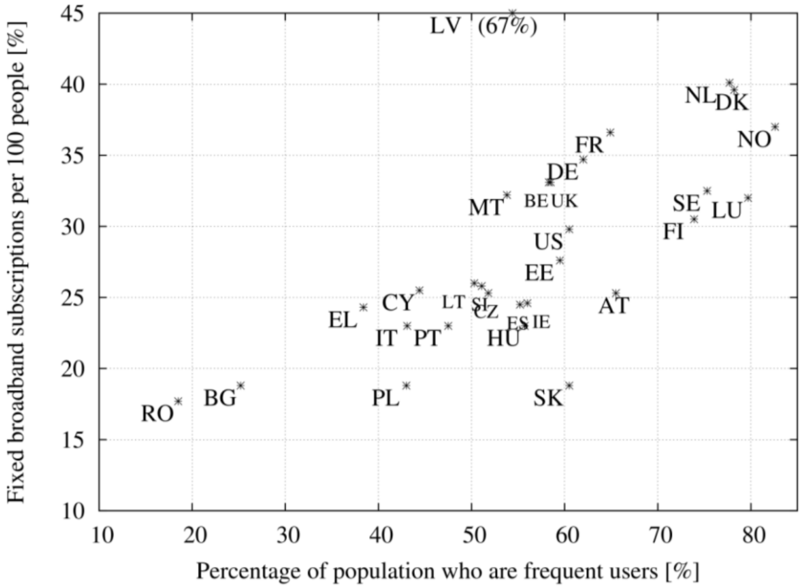
Among the leading countries, several are already well-advanced in deploying fiber-based NGANs. This includes a number of Asian countries like Japan, Hong Kong, Taiwan, and South Korea. The last one already has widespread availability and adoption of broadband services offering 100Mbps and higher access speeds.

Singapore iDA is a special case in Asia (see Annex I), which represents one of the earlier Digital Agenda plans launched in the 1990s. Today, the NGAN in Singapore has reached a possible full coverage, with more than 95% of homes passed. Hong-Kong and South Korea, are two other examples of NGAN leaders.

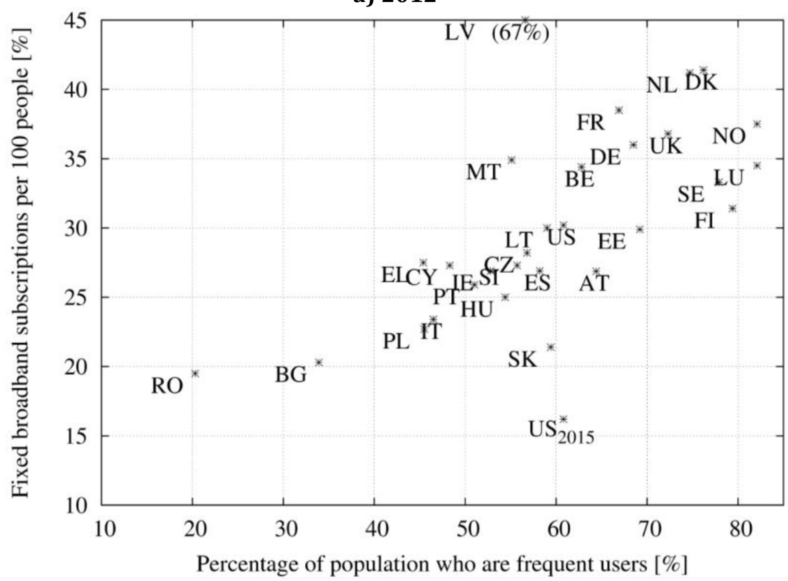
As Einstein said: "*The only reason for time is so that everything doesn't happen at once*". If we compare that statement to the current fiber deployment pace, we can see that all those plans and network evolutions tend to improve speed, although they will create new gap between different regional areas. Therefore, time will allow connecting all those regions with a fiber-based NGAN.

3.2. Fiber coverage and adoption

The previous section has introduced the concept of heterogeneity in Digital Agendas directly associated with differences in national market conditions. It was reasonable to expect that there would be a positive correlation between the quality of broadband and Internet usage. This is observed in Figure 5 a) and b) that are plotting the percentage of population that are frequent Internet users (X-axis) against the percentage of population that subscribes to (fixed access) broadband services per 100 people (Y-axis). Figure 3.a) Plots it for year 2012, and an evolution of it is placed in 2014 with Figure 5.b).



a) 2012



b) 2014

Figure 5. Relation between users demand and broadband implementation. The two pictures differ from its Data year: a) is a picture from 2012, and b) is an image for 2014, and an inclusion of US in 2015.

The data source for both Figure 5.a and Figure 5.b, come from the OECD (2013), US department of Commerce 2013. *Latvia should be set higher in the figure, but is so high that it leaved all the others together and distorted the view and porpoise of showing correlation. In the case of Latvia, mainly Riga and some cities are fully covered.

Riga with around 710.000 inhabitants concentrates a high percentage of Latvia’s population, which is of 2.200.000. Speeds offered there are reaching 500Mbps.

Figure 6 provides the mashup of the figure 3a. and 3.b, allowing us to better copse the change in fixed broadband adoption after two years period. What it can be determined is that fixed broadband adoption has been rising in all countries but the US – after its broadband definition change.

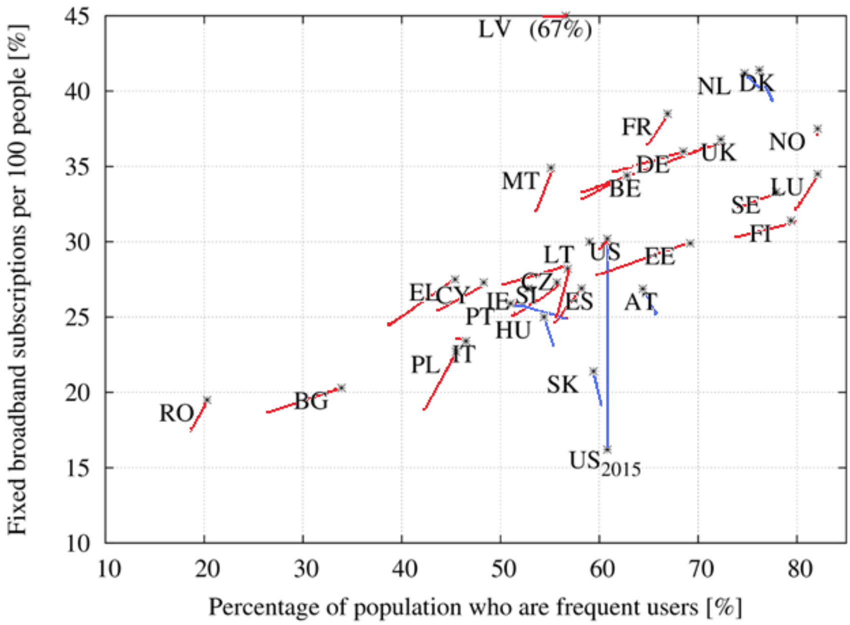


Figure 6. Relation between users demand and fixed broadband implementation. This picture shows the evolution path from 2012 to 2014. Red color describes an improvement in the two variables. Blue color describes a decrease in one variable.

Some remarks about the differences that some countries experienced in a two years period are noticeable in the advance of countries like Bulgaria (BG), Portugal (PT) and the United Kingdom (UK) with a huge positive increase in both fix broadband subscriptions and frequent users. Some other countries, like Poland (PL) or Slovakia (SK) are also increasing their broadband subscription but they have a slightly decrease in spreading the usage of the Internet, bringing some caution on the motivations of changing to a broadband subscription – caution in the sense that in this case retail price offers' discount can derive to good drivers to change but not necessarily motivate to use more intesively the network. Also noticeable is that two of the leading countries, the Netherlands (NL) and Denmark (DK) are experiecing a slightly decrease on the population who are considered a frequent user. A big change can be observed for the US, as a global referenced market by deciding to change the definition of broadband, and therefore, having the biggest decrease in what is considered to be a fixed broadband market penetration.

Broadband significantly enhances the quality of a subscriber's Internet experience, and thus, increased Internet usage and broadband access are mutually re-enforcing. Markets with advanced, high levels of broadband access penetration and Internet usage support both the commercial and political demand for more aggressive NGAN strategies. Observation of this positive correlation helps motivate interest in improving broadband quality with the expectation that higher broadband quality enables new and improved (interactive, rich media) applications which stimulates the consumption per subscriber and aggregate demand, motivating further demand to expand aggregate capacity. This positive-feedback response is an example of the positive network externalities that the transition to universal service for an enhanced NGAN enables. That is, the value of broadband to subscribers increases with the total number of subscribers, so long as the growth in subscribers is not offset by increased congestion costs.

Therefore, the positive effect of network externalities can be noticed when a larger broadband network makes it feasible for each subscriber to communicate at broadband speeds with a greater number of broadband users and applications. This way, they are obviating the alternative of defaulting to lower-speed or less-connected forms of communication. Moreover, a larger potential market for broadband users motivates increased investment in complementary goods like broadband-enabled content and applications, which adds to the quality of the broadband experience.

As a negative externality, there is the congestion, which can make broadband less valuable as subscribership grows and share the network. As Bauer et al. (2009) explained, congestion happens as we share some of the parts, even if we do not know which parts the operators are sharing. The expansion of the NGAN to higher speeds creates the potential for increased range of peak/average per-subscriber data rates that accentuates the capacity provisioning challenges, and the difficulties inherent in forecasting future NGAN investment requirements. As with telephone provisioning, we do not expect everyone to be using their broadband (or telephones) at the peak data rates continuously and at the same time, allowing for significant statistical traffic aggregation and resource economies for shared components – on the other hand, we can foresee people consuming their Data caps when applied.

Broadband definition has been a matter of concern while doing some worldwide definition. There is no universally accepted definition of what constitutes an ultrafast broadband – or a global broadband definition. In Europe, services offering speeds of 30Mbps or faster are classified as ultrafast for the purposes of collecting statistical data. This thesis considers the ultrafast broadband – to differentiate this definition from the different broadband country-based definitions – a connection with more than 30Mbps[9]. Many DOCSIS 3.0-enabled cable networks and VDSL services, which are not running on FTTH, can also support 30Mbps services. However, a sustained investment in dense neighborhood fiber to support mobile broadband and expand backhaul and NGAN capacity will enable even higher data rates over these non-FTTH infrastructures. The FTTH network, used to estimate CapEx requirements, will certainly support 1Gbps (and potentially higher data rates) and so it is a useful target for the long-run NGAN.

According to European and US data, universal service availability to broadband is close to being realized, but new definitions should come when we realize that the goals are feasible, or nearly realized. As mentioned above, in 2015 USA is launching a new update of their broadband definition. They aim to include a download speed of 25Mbps and an upload speed of 3Mbps, instead of their current definition of 4Mbps download and 1Mbps upload. This change reinforces the need for fiber, as this thesis do, just see Figure 7 to understand that a definition of broadband can help people to realize

[9] Usually, broadband in the engineer and regulatory fields is defined by the amount of exchanged-information in a time duration, and in this case, in bits per second. Just to remember, a bit can only be understood as binary number, and it is the smallest information to be exchanged with the values of “1” or “0”.

that they not have broadband. We have not done a market research, but we can consider the word broadband equals to a good connection, so now, if the operator cannot tell you that you have a broadband connection it may generate new demand in plenty of consumers.

Currently, the US was really advanced in broadband coverage and closing the digital gap, now, they leave plenty of areas re-qualified as none-broadband-covered areas. This fact implies that in the near future, competition policies and laws may be not apply in some of the areas – at least they should change the regulatory definitions – something that may help to deploy new networks that compete in the new ultrafast broadband definition. On the broader sense, it also helps to realize to the general public that they are uncovered with a broadband connection, and it may rise broadband demand coverage, or even rise the support to a new public involvement into deploy a new network. This lack of competence can be seen in Figure 7 with the data extracted from the FCC 2015. If we compare the right side, the percentage of US homes without a broadband connection will rise from 3% to 16%. But it will also undermine competence, as 45% will have only one broadband provider, were now a 66% had 3 or more providers. As we can see this can give us a hint on how to analyze the fiber market in the future, as we can expect that other states will follow the US definition, and connection speed and technology speed indicators will be the ones that will allow to decide between one or another connection, so, the *broadband* definition may be left aside.

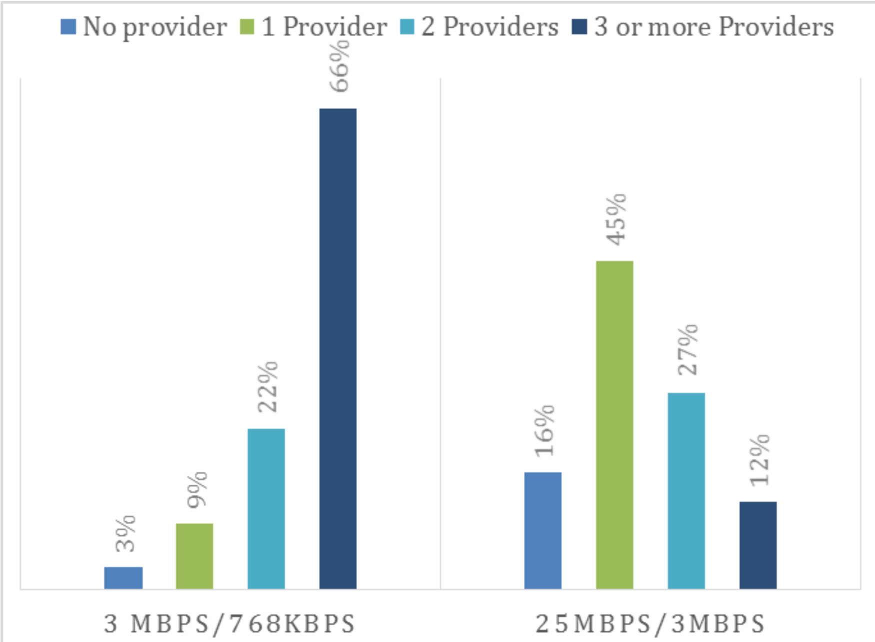


Figure 7. Number of available providers classified by the speed they can offer in the USA with data from FCC (2015).

In Europe and the U.S., a wide range of tariffed ultrafast broadband services are already available in a number of markets (i.e., services offering peak data rates of 30Mbps or higher). Figure 8 plots the same OECD data from Figure 5 with the Y-axis replaced by the percentage of subscribers with broadband access service in excess of 30Mbps per 100 people. This shows the same sort of positive correlation as in Figure 5 a & b, but it is shifted downward because lower speed broadband customers are excluded. In this case, we can see an approximation of Broadband implementation around the globe when Broadband is considered a connection of 30Mbps or higher. The US is included as one of the leading countries, instead of being relative to each country definition of broadband, this objective figure plots each country according to their fixed broadband access speed.

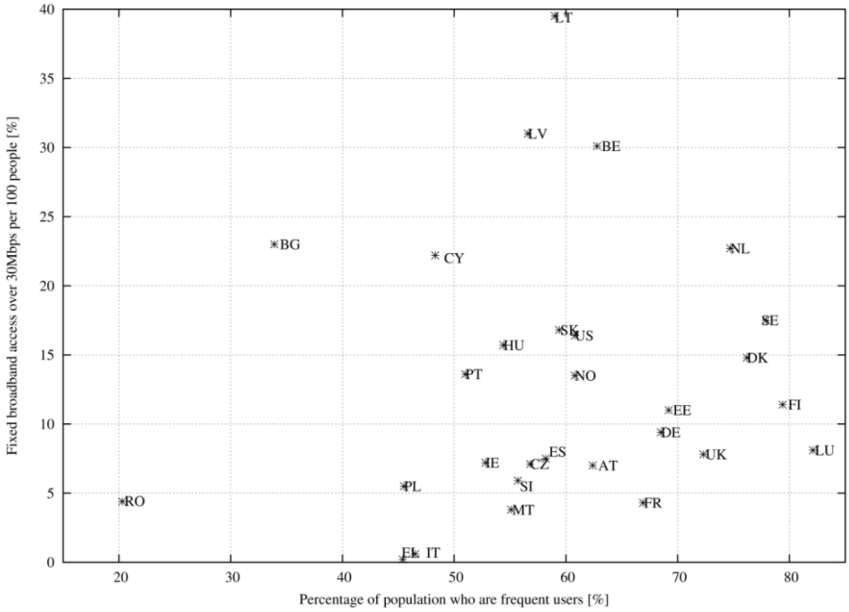


Figure 8. Fixed broadband access over 30Mbps vs. the percentage of population who are frequent users.

Adoption of ultrafast broadband services remains low for multiple reasons. First, ultrafast services are less likely to be available. Second, (and as we might expect), tariffed prices are higher for higher-speed-tier services. Third, many consumers may not see a need for ultrafast broadband service (in today's Internet where most broadband connections are much slower), or sufficient value to demand acquiring the higher connection price. Figure 5 shows that the US is performing above most of the countries that where reaching quotes above 25% of fix broadband adoption in Figures 3.

The choice of 30Mbps and above can be subject to different regulatory treatment for the ultrafast broadband services offered on it. For example, in European wholesale markets, policymakers' price regulate wholesale offers below 30Mbps, but do not require operators to offer wholesale services at higher speeds nor regulate the pricing of such services when offered. In addition, policymakers may adopt multipart broadband policies that promote ultrafast broadband to a subset of households while simultaneously promoting at least a minimum level to all households.

Furthermore, the connection between NGAN speed and the user experience is not linear and the optimal provisioning of access speeds and backbone capacity depends on traffic usage patterns. Today, few customers might be able to see much of a performance difference between 30Mbps and 1Gbps NGAN service, but this may change over time as per subscriber and aggregate usage changes over time.

If we consider video as the main consumer of the network bandwidth capacity, we can see that YouTube and Netflix videos start to be HD, and some will even start to be super-HD, meaning that every time they see an upgrade to a part of their users connections they can upgrade the video quality content. Some analogies can be done to SD cards for cameras, as when they started to offer bigger capacity, the pictures also increased from 1.2 to 10, 20, 42 Megapixels, and they continue to increase the image quality as the cost of cameras capacity decreases. Thus, for many of today's consumers, the 30Mbps and 1Gbps services might be considered as substitutes; and service providers may further control usage-related costs by employing data volume caps or other non-linear usage-based pricing. For instance, Telefónica and Vodafone in Spain are going to apply data caps on all its mobile offers after more than a decade of not including them.[10]

[10] Vodafone and Telefónica will charge new subscribers, according to news read in El Economista (Spanish newspaper)

- Movistar http://www.eleconomista.es/tecnologia/noticias/6665642/04/15/Movistar-comienza-a-cobrar-el-exceso-de-datos-por-15-centimos-el-mega-.html#.Kku8J72VF6Yltb6

- Vodafone http://www.eleconomista.es/tecnologia/noticias/6467011/02/15/Vodafone-cobrara-por-defecto-el-exceso-de-datos-a-nuevos-clientes-desde-el-lunes.html#.Kku8sJP6ZfDsAiH

Chapter 4

FTTH TECHNOLOGY

"Ideas do not always come in a flash
but by diligent trial-and-error experiments
that take time and thought."
- Charles K. Kao

Optical fiber deployments depend not only in the material, but also on the network architecture that defines the available speed to every user. Those topologies also help to shape and understand the cost variables to be taken into account in the Thesis model. This chapter provides the fiber solutions and the definition of the network model implemented in this Thesis.

4.1. Optical Fiber

Optical Fiber is nothing else than a cable that allows driving light from one extreme to the other. As simple as that, it has cost more years than other cable types to be a real alternative to information communication. Electrical cables and coaxial cables started the race of its implementation with one advantage: they were working at distances enough to communicate between a central point to the users homes and fiber did not. The material was the reason why optical fiber roll out was delayed, and the reason to not be taken into account as a possible cable in an access network choice. Recently, in 2009, the Nobel Prize was awarded to Charles K. Kao for his achievements on studying materials that allowed transmitting further the light inside the optical fiber.[11]

[11] http://www.nobelprize.org/nobel_prizes/physics/laureates/2009/press.html

The current fiber type is made of a glass material – mainly silica – but also of different materials that allow its transmission range to evolve from the first meters to the current 80 to 120 Km without amplifying the signal between the two connected points. The important part of it, is how light can enter and be guided all the way to its destination. Moreover, it has some advantages compared to electrical cables, as it is robust against interferences made by any electrical cable close to it.

The speed is far beyond discussion. No other technology has proven to reach 20Gbps and 40Gbps a common communication for long distances (mainly carriers use those speeds in transport networks). NTT in Japan has proven that it can transmit more than 111Gbps per wavelength in its core network – this result allowed them to achieve a 14Tbps connection in 2006 over a single optical fiber.[12] Two years ago, Bozinovic and Yue et al. (2013) published in the Science Magazine that they could reach a speed of 400Gbps using four angular momentum over one wavelength. We have to remember, that typically fiber operates at different light wavelengths and that are lasers the ones that send the electrical information transformed to light pulses. They even took profit of the possibility to use multiple wavelengths at the same time to reach 1.6 Terabits per second transmission over 1.1 kilometers.[13]

NTT, the Japanese incumbent is one of the leaders in studying how to implement really breaking-through transmission systems to achieve a new maximum speed over its fiber network, thus lead them reaching a new record in 2013. A speed over 1 Petabit per second – 10^{15} bits per second. NTT collaborated with NEC and Corning to achieve it.[14] Although these experiments provide more arguments to acknowledge that fiber is currently prepared for future increases in the communication market, it is also necessary to analyze the deployment types that this thesis will include in its models.

[12] http://www.ntt.co.jp/news/news06e/0609/060929a.html

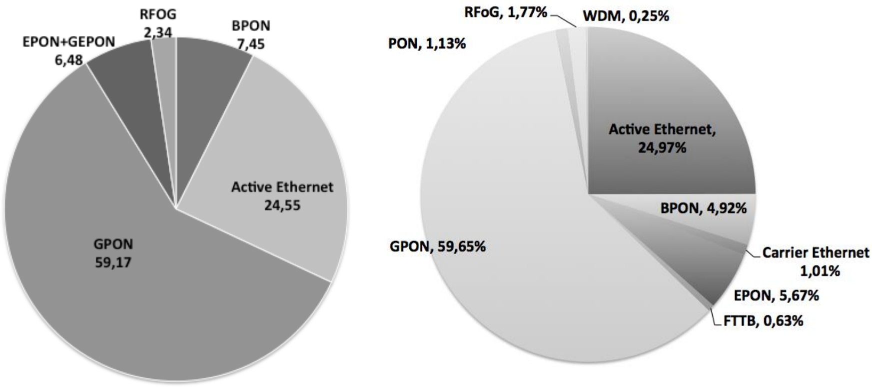
[13] As this paragraph shows, the distance is really dependant on the laser type. It leaves as common knowledge the 20Km as the distance between a user and the operator's central point.

[14] Some links to the conference exposition: http://2013.ecocexhibition.com/node/28986?destination=newslist/optical-news

The main focus of this thesis is in the last tram of the access network, which refers to the gap from the last point of the Core network of the telecom operator (the Point of Presence—PoP) to the Optical Network Terminal (ONT) at the user's home, commonly known as “Last Mile Problem”.

4.2. Passive or Active Optical Networks

Passive Optical Networks (PON) is the technology widely used by telecom operators when deploying an optical fiber network. These European incumbents selected PON division instead of a point-to-point deployment: Telefónica, Telecom Italia, British Telecom and France Telecom. Moreover, GPON is also the US preference in FTTH projects. If we take into account the next figures, Figure 9 a & b, GPON has been established as the US fiber-based NGAN deployment preference holding a close to 60% choice sustained during the 4 years of this Thesis. It is important to say that Active Ethernet is the second choice, and that in 2015 there are spotted the first WDM-PON deployments, this technologies are all explained in the following point.



a) 2011 **b) 2015**

Figure 9. Technology selected to deploy fiber-based NGAN in USA. Source: data extracted in two different times from Broadband Communities Magazine www.bbpmag.com. Retrieved in a) March 2011 b) April 2015

When this technological choice was made in Spain, it was sought as it could lead to none *Bandwidth* increases per user. In an FTTH deployment, the use of concentrators to link fibers originating from different consumers allows for the aggregation of capacity and makes the service more efficient. The equipment used for this purpose is called a *splitter*, which is a passive (i.e., unplugged) device that is required in the G-PON infrastructure – Gigabit Passive Optical Network. This device is a basic element to facilitate the construction of tree-based architectures and to concentrate all links coming from households in a manageable reduced set of fibers to the PoP – Point of Presence. The splitter thus reduces the duct occupancy problem. In technical terms, the splitter divides the optical signal into numerous paths, or it may combine many paths into one optical signal. It is noted as 1:X (one to X), where X is the number of separate fibers gathered into one.

The number of splitters is different according to the choice of decoupled fibers (households/users) that have been assigned in each of the fibers that depart from the PoP. A common aspirational value used in NGAN deployment is 64 households sharing the same fiber at the same concentrating points. Fibers are grouped into a range of 16 to 256 fibers depending on the density and distance from the household. A study of household’s density may place the maximum tree topology allowed by splitters between 1:2 and 1:16.

On the other hand, active networks implement connected to energy power (active) elements. This technology combines fiber on different trams and implements copper or cable technologies at the last meters of it. In this case, it is seen at not completely evolving all the network, but at the same time it may allow to achieve a quick increase in speed without expending to much money on the last and expensive meters to reach the final users (their street and home).

4.3. Fiber-based deployment Types

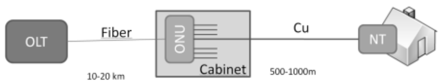
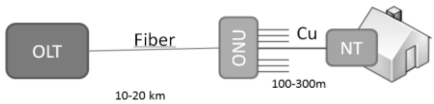
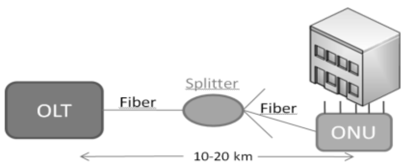
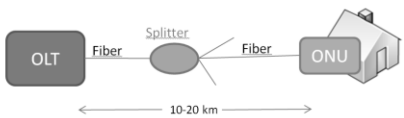
Fiber-based deployment types are first classified by its main topology that will be highly dependent on the number of cables deployed. Two clear topologies erased from this first type of classification. Point-to-Point – P2P – or Point-to-Multi-Point – P2MP – networks. Those are only differentiated by the use they tend to indicate in their names. The P2P deploys one cable per user connected. The P2MP aggregates a number of users over the same fiber at the carriers’ offices, mainly by using the already explained splitters.

In this thesis we are going to take into account all the deployment models that are implemented with fiber. They can also be classified as Active or Passive technologies according to the Equipment installed at both ends of the optical fiber, and mainly the equipment placed between those two places. The Active, as it have been already said, needs nergy to some of their network components, not only at both ends of the network. On the other hand, the Passive ones, only need power for the communications equipment at both sides of the fiber.

Moreover, the most common way to classify fiber-based NGAN architectures that cover the last mile is by naming the place where the fiber ends. FTTX solutions are said all the fiber on the last/first mile, which are broadband optical access networks that are following ITU-T Rec. G.938.1 recommendations and G.983.x. from November 2001, and updates until 2006 (ITU-T, 2005) and PON recommendations in ITU-T. Rec G.984.1 recommendations (2008) with recent updates until 2012.

Each of the FTTX acronyms gives us a selected deployment type. This last “X” is the one that defines some parameters like distance, the place where fiber ends, and speed. In Table 2 are described the more common ones. The fiber end is the one that defines the fiber deployment type. So, close to the home, or inside the home itself, allows us to call those deployments to the Cabinet or to the Home with the next different definitions: FTTH, or Fiber to the Home; FTTB, or Fiber to the Building/Basement, which utilizes an in-building copper-cable network; FTTC, or Fiber to the Curb, where fiber is deployed until the last possible point between user’s home and the carrier’s central office; and FTTCAB or Fiber to the Cabinet, where fiber extends to the last street cabinet and copper cable reaches the end users in their buildings.

Table 2. Types of Fiber deployments.

	Technology	Description	Deployment
Active Technologies	**FTTCAB, Fiber to the Cabinet**	- Copper from the ONU to the NT - Fiber covers from 10 to 20 km between the OLT and the ONU (inside the cabinet) - 8Mbps downstream and 1Mbps upstream	
	FTTC, Fiber to the Curb	- Copper between user NT and ONU - Symmetric 100Mbps, but this speed depends on the state of the copper material.	
Passive Technologies	**FTTB, Fiber to the Base /Building**	- Nearly all Fiber. It finishes at the base of the building. From there it may go with another type of cable to user's homes. - Distance from 10 to 20 km between the OLT and the Base of the building	
	FTTH, Fiber to the Home	- Entirely implemented with optical fiber cables. - One ONU is inside each home. - Distance from OLT to the inside home goes from 10 to 20 km.	

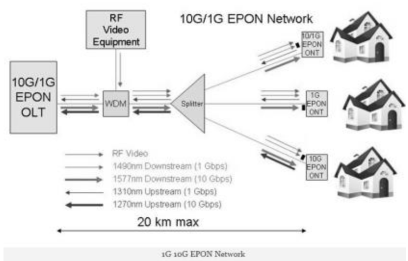
As this Thesis selects FTTH, we provide the possible implementations and evolutions of it. Each implementation technology offers different broadband access and different splitter ratio. As they are all implemented with FTTH, all of them are passive technologies and are identified as X-PON.

Nowadays, the implemented and deployed technologies are based in EPON, Ethernet PON, and GPON, Gigabit PON reaching the 1Gbps offers – some of them are later analyzed in the following chapters like the offers from Google, AT&T or Adamo.

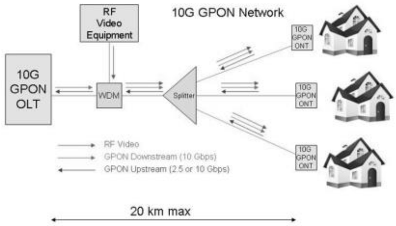
In the next table, we introduce the 10GEPON, 10GPON, and WDMPON; standing for 10 Gigabit EPON10, 10 Gigabit PON, and Wave Division Multiplexing PON respectively, see Table 3. Note that 10GEPON is an Ethernet technology that becomes passive as it eliminates the active elements of its distribution network by implementing fiber for transporting data in this 20Km distance.

Arrived to this point, it is mandatory to include why policymakers should be adamant to request the implementation of WDM technology in the current PON networks when they want to unbundle it, see the achievable speed over one fiber in Bozinovic and Yue et al. (2013). We know that it is a company's choice, but Governments should promote and spur that operators implement it. As we understand the WDM allows separating a wavelength per user over a PON and it creates a real communication link between the PoP and the user's home emulating a Point to Point deployment. Thus, every user carried over a single fiber has one different wavelength, or at least, it is shared between fewer users, thus bringing a new type of connection and the possibility to separate users individually.

Table 3. Types of all PON deployments.

	Technology	Description	Deployment
Passive Technologies Passive Technologies	**10GEPON**	- IEEE P802.3av standard[15] - 3 different types of connections - 1Gbps/1Gbps (EPON) - 10Gbps/1Gbps - 10Gbps/10Gbps (both 10G EPON) - It allows to use of ONT 1GEPON and 10GEPON	

[15] IEEE P802.3av standard http://grouper.ieee.org/groups/802/3/av/index.html

<table>
<tr>
<td>10GPON</td>
<td>- ITU-T G.987-X[16]
- 3 different types of connections:
a) 10Gbps/1,25Gbps (GPON)
b) 10Gbps/2,5Gbps
c) 10Gbps/10Gbps
- Cost of ONT is nowadays the biggest issue on this technology</td>
<td>


</td>
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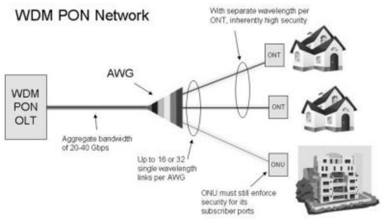
<tr>
<td>WDMP ON</td>
<td>- It is a further employment of X_GPON / X_EPON standards
- It is based on assigning a different wavelength per user
- Expected users are 32 and their speed should equal to one fiber per user using one laser per user.</td>
<td>


[17]
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4.4. Thesis FTTH model

In this thesis the common FTTH model implemented is the ITU-T recommendations G.938.1, G.983.x, and G.984.x with their most recent release in 2012 (ITU, 2008). Communication's speeds of 2,5 Gbps downstream and 1,5Gbps upstream are obtained over one fiber with G-PON, meaning that each single user among the 64 households (maximum division over one fiber implementing this standard) can achieve a download and upload speed of 39Mbps/23Mbps respectively. Figure 10 depicts the deployment of a G-PON network.

The G-PON network selected as the common deployment in this Thesis is composed by different sections:

- First, we have the PoP of the operator, sometimes also called "telecom central office" as these buildings where usually a place where telephonic lines where interconnected. In here, it is still placed the equipment that can control a big number of users called OLT – Optical Line Terminal. This OLT is composed by Optical cards that can be bought separately and extended as much as spaces as it has when bought, with

[16] Select G.987, G.987.1, G.987.2, G.987.3 standards http://www.itu.int/rec/T-REC-G/en
[17] Pictures available from < www.fttxtra.com >.

some thousands of users to 100.000 users operated from the same equipment.

- The first fiber tram is the usually deployed with a single-mode fiber between the OLT and the first point of division. This is usually a large path of fiber. It can also be known as the Feeder network.
- First splitter and cabinet. Usually it is installed into a buried cabinet that has space enough to allow the operation of a man, as it needs to fuse fibers in it. A splitter carries out this first point of division. In this case, as our objective is to provide fiber to buildings, or small streets, the 1:4 division helps to understand that from one port of the OLT card are controlled (with the next 1:16 splicing) 64 homes. For less dense areas, it is also possible to use in here a 1:32 splitter, and forget about the next splitter as a way to reduce the light signal attenuation introduced by each splitter.
- The second fiber tram interconnects the two splitters and can be deployed with a multi-mode fiber – more attenuation, but cheaper than a single-mode fiber. This tram connects the cabinet to the base of the building (or the curve of a short street if is made of semidetached houses in not so populated dense areas). Although it is a path shorter than the first tram, the number of fibers increases in the conduits or poles where it is deployed. This tram can also be known as the distribution network.
- The second point of splitting can be placed at the base of the building. As explained, in this thesis this will be of 1:16, so one fiber arrives to the building and it can connect 16 homes.
- The last, but not for that easier, is the in-building deployment and it includes another active equipment called Optical Network Terminal – ONT.

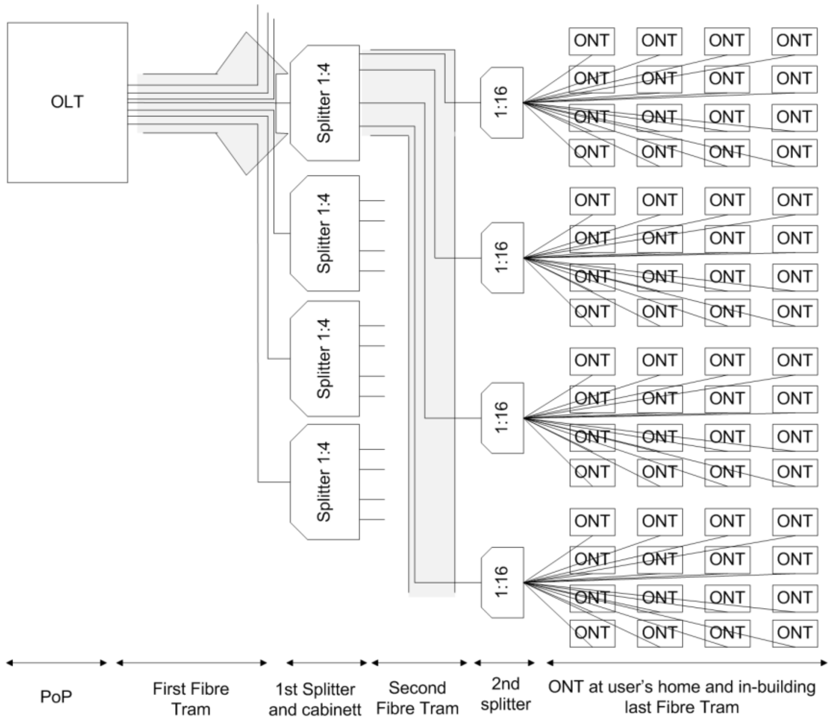

Figure 10. G-PON implementation followed in this thesis, with one fiber serving 64 homes.

Chapter 5

LEARNING FROM REAL FIBER CASES

"Learning
never exhausts the mind."
- Leonardo da Vinci

In Chapter 4 we have introduced the different deployment types according to their network topology and fiber-based technology selected. This chapter provides real fiber deployment cases and classifies them corresponding to their business model and main stakeholders.

To deal with the complexity of classifying a real case, we follow to variables: selecting the main stakeholder that provisions the network and the deployed area. The area of control of those cases can be a National network (interconnecting all different municipalities across the country), a Municipal/Regional network (a network that connects all the villages and cities inside the Region under its control), and a Local Loop/Access Network (a network that connects one or more homes in the same street).

Under the same category, the stakeholder that provisions the network can allow to identify different motivations on how to deploy and select the fiber technology. There are three main possible stakeholders, which are also classified by the money source: Private (firm or carrier), Public (the Government or any public administration statement), and the User (people).

After observing and studying fiber cases from around the Globe, we included some of the more representative cases, and most of them pioneers in their fiber deployments ways, creating from one point or another a singularity. We classified them according to possible areas where most of the fiber deployments are taking place according to the type of stakeholder. Figure 11 shows the first type of classification, depending on the area of control and the network-provisioning stakeholder.

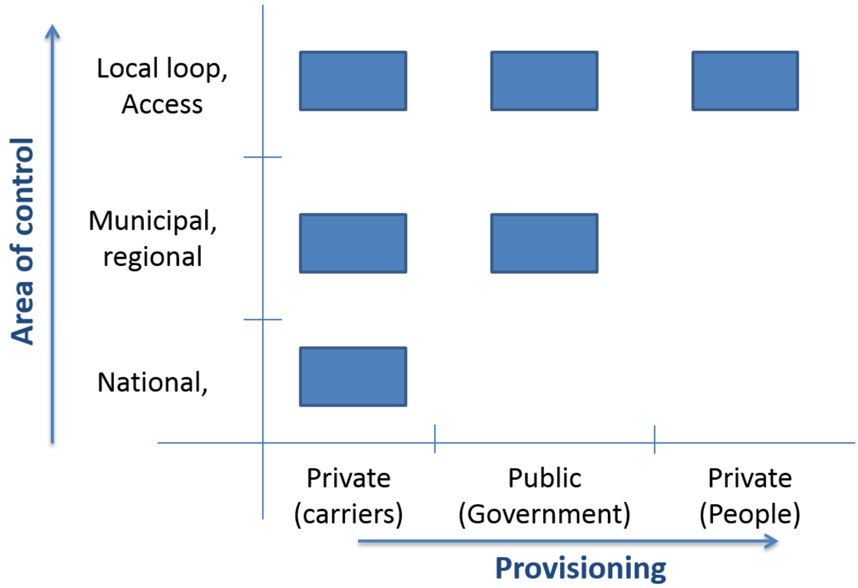

Figure 11. Network classification according to their point of control (Area) and provisioning (Stakeholder).

Another angle of analysis of the Fiber deployment outcomes is the business case and principles that are followed in each scenario. Figure 12. includes the main variables and its extreme cases: source of capital, governmental involvement, ROI goal in time of achieving it, the area of deployment and the purpose of the deployment. This last concept – a profit or benefit project – is one of the variables that may have a direct effect over all the others as it defines the purpose of the network. Fiber deployments are complex and they can be categorized by the next variables, we acknowledge that they may limit the understanding of the scenario and we provide an explanation of the case and the motives to set one variable more close to one of the extremes.

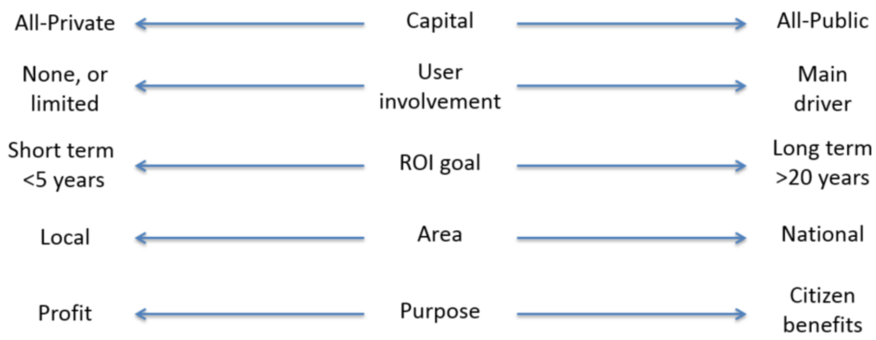

Figure 12. Business case variables for any fiber project with its extreme values.

For capital, we define this variable as the source of the money devoted to the fiber project. An all-public project would include public administration as the main stakeholder of the project, and an all-private one, would include carries or users as the main stakeholders. To identify if the user is the source of the capital, we need to focus on the next variable, user involvement.

User Involvement defines the committed involvement inside the project of the final user as a stakeholder and it helps to understands on a first basis how it helps to decrease the fiber deployment. In case to be the main driver it implies that users are also investing more than time to the project and this type of investment falls into the economic side.

The ROI – Return Of Investment – goal is set between to time variables. We choose time variables in each of the extremes because provides a better idea of the income searched by deploying the project. The ROI variable is included with the percentage rate of the invested money is going to come back when the project generates benefits. We use 10% in all the cases included in this project, a quick project (less than 5 years for obtaining the desired return) is generally obtained by a cheap deployment and a big number of customers (also the retail offer can be high), conditions that are well established in the cities. On the other hand, scattered users in rural areas may provide a costly deployment that may lead to a more than 20 years project.

The area variable helps to define the fiber network coverage, and it allows comparing the business cases among the deployed area. A local project answers to a small village, whether if the variable is set at the national side means that is reaching all the main cities and villages of a country.

The purpose of deploying a fiber network is also an important variable, as it may help to define and understand the other choices. If a project seeks only citizen benefits, it may not search to be profitable in less than 5 years and it may be a local project. On the other hand, a project with a profit purpose is going to search the way of giving back a good percentage rate to the investors to attract the money needed before starting to deploy the project.

5.1. Private stakeholders (Carriers)

Firms or private operators are seen as big interconnection carriers that own Nation-wide networks and have the power to sustain them and get profit from them. These ways, firms poses the core networks and have a key role in the way that the Internet infrastructure has been build – since the Arpanet project, see Waldrop (2009), of interconnecting a few nodes to today's Internet with nearly one connection per home. This point explains some cases that may bring a better idea of what it is to have a national network that also arrives to nearly all municipal regions and usually controls the Local Loop access.

Japan and Korea are two interesting Asian cases where the incumbent operators – the ones inheriting the public state network operators – lead the fiber deployments and catapult those countries to the leading fiber group in adoption and deployment.[18] We are particularly interested in the NTT Japanese case that provides interesting results on how a fiber-based network reaches 70% of adoption among its passed homes – a home is considered *passed* when it is deployed a distribution fiber cable to its premises. On the other hand, we also include Verizon as one of the private firms inheriting part of the Bell Company, once the only operator in the US. Verizon continues its work by deploying and passing more homes every year in the USA, although the result is that only

[18] Usage remains as a variable difficult to study because carriers are the ones in possession of this data. In several conferences those Asian countries have evoked some solutions to incentivize the usage of such a powerful network, thus, spreading the sense that they are underusing those national fiber networks..

around 26% connects to it. Last, there is Telefónica de España business case. This European firm is reaching more than half of the homes in the country after a quick deployment during the last two years with a favorable and stable regulatory framework.

5.1.a) NTT, a Japanese private operator that reaches 70% of take-up rate in fiber solutions

The NTT, which stands for Nippon Telegraph and Telephone Corporation, is the incumbent of Japan. Since 1985, it was gradually privatized as a way to promote competition in the telecom market; mainly by introducing the mandate of unbundling obligations into the copper networks. We want to enlighten that the Japanese state still holds more than a third of the shares, and thus still has a significant influence on the company's strategy. Organized as a holding in 1999, it keeps three branches in the fixed telecom market: NTT Communications, NTT East and NTT West.

With the unbundling of copper lines in place, competitors emerged (e.g. Softbank BB[19]), rapidly reaching a similar market share as NTT. Driven by this threat, and encouraged by "favorable Government tax and interest treatments", see Akematsu et al. (2012), NTT announced, in 2004, that it would start to deploy fiber by replacing the copper lines to their customers' homes, see MacMillan (2014). That way, every upgrade to a fiber line was removed from the legacy network. Soon, however, unbundling of the fiber lines became mandated as well, although not much alternative operators have succeeded to gain significant market share on the fiber network (e.g. Softbank reached 237.000 subscribers over the NTT's unbundled fiber in 2010). All of this has made Japan to be one of the leading countries in all the fiber rankings, and to become one of the countries with nearly 30% of the entire world fiber deployed. Currently Japan has more than 25 million homes connected with fiber solutions, on a total coverage of more than 36 million homes passed with FTTB and FTTH solutions.

[19] Owner of Sprint in the US broadband market since 2012, and Vodafone in Japan since 2006.

NTT thus still is the dominant operator on the fiber network, reaching a combined (East and West) fiber market share of over 70% of take-up in December 2009, MIC(2014). When investigating the reasons for this low competitive entry in the fiber market compared to the DSL market, there are two that should be stressed. First, NTT offered a 100Mbps connection on fiber for the same price as the comparable, yet lower-speed, xDSL offers – disrupting the market with a differenced offer in peak-speed. Secondly, the unbundling price for fiber was set at nearly five times the price for the copper unbundling as a way to increase facility-based competition[20].

In general, the business case for FTTH deployment in Japan currently has a positive outlook, as uptake is very high (all DSL customers migrate to fiber) and so thus is ROI. The threat of lowering the fiber unbundling price is however imminent, and might drastically impact the business case outcome for NTT. To sum up the Japanese Business case, Figure 13 is showing how we categorize this project.

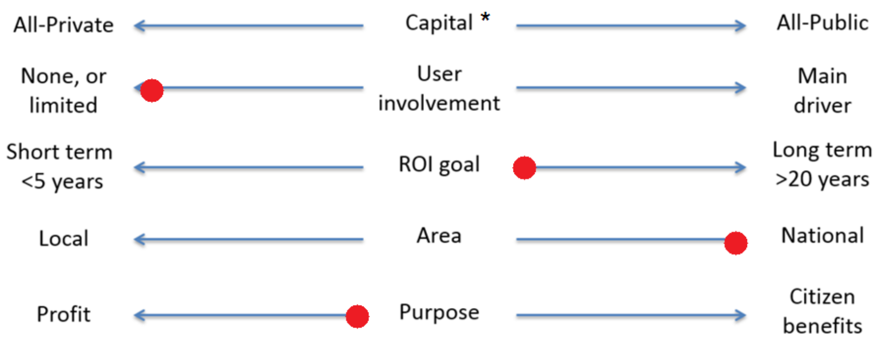

Figure 13. NTT business case, Japan. *capital cannot be graphically set.

We explain the selection of the variables in this paragraph. The reason for seeing such a singular result is that the project implementation budget comes from a mixture of public and private capital. The source of this money is difficult to track, as some comes directly as state involvement and other parts may come as

[20] Monthly unbundling price for copper was set as an average at YJP 1,367 (USD 13,1) on September 2000, and monthly Fiber unbundling was set at a minimum of YJP 5,186 (USD 49,8) on April 2001, Katagiri (2005); the current price has decreased to 40 USD based in costs from 2001 to 2007, Katagiri (2008).

state aid for rural areas, thus, making no possible to set the parameter, although we would set it to the right extreme, as an all-public as the main source of money for this private company. The user involvement is merely the one of a user that buys or not a new product, so in the technical deployment it would be said as none involvement. The ROI answers to the mixture of capital sources. A public project would tend to a long-term period to recover the investment, but, as the private company is also in the project, it urges to achieve a high penetration level to decrease this time to approximately 10 to 12 years to recover it. The way to do it is by offering a very different product from cable and copper offers at nearly the same price than the other technologies had. Subscribers then only have to compare speed and price to realize that for the same price or even lower, they can obtain a better product. The purpose from the Government is to reach all Japanese citizens, so it is a nationwide project, and it will help its citizens by having an already implemented fiber network. The purpose of both, the Government and NTT, was to recover the invested money as it was seen as way of a Public shared investment and not an all public project. To achieve this mid-term goal, regulation was set to difficult the entry of other players to the fiber market without deploying their own fiber network. More or less, what happened in Europe on 2009 when the view was that parallel networks were incentivated as a way to switch off the copper legacy ones. The wholesale though, is the issue that continues giving to live the operators that provide service over unbundled lines from the incumbent operators. Regulatory may affect this transition, as it did in Japan. The unbundling price for copper was as expensive as the price for getting a fiber connection, making that way, feasible the return for the only company deploying area in the region, which was NTT. Currently, in 2015, the project is nearly to reach a positive net profit and the regulation may now seek to lower the entry barrier to the fiber market by decreasing the price of fiber unbundling. This product will set again competition, and it will be done over the NGAN and not the copper networks like in most of the countries that already had a communication network.

5.1.b) Verizon, going nationwide can be difficult, state by state option

Other large carriers like Verizon in the USA have been leading the deployment of fiber against many difficulties – to describe some: strong cable carriers, content battle, state and county laws, unbundling of copper networks at a very cheap price, mobile battle based on full coverage of LTE deployments, and a long tail of local and regional operator.

Verizon is one of the first operators/carriers, although its name was coined in 2000. It is the result of the merge from the former Bell Atlantic[21] and GTE carriers. The case of Verizon is attractive as it deploys one of the first successful fiber solutions in the US. The FiOS service (which stands for Fiber Optic Services) started in 2005 and currently covers more than 18 Million homes and connects more than 5 Million according to Vodafone Webpage. Again, accounting fiber homes passed and connected is difficult because most of the homes are covered with FTTP or FTTB – to the premises or to the building. Verizon solutions are available to most of the states where it had already Bell operations in place. Their fiber solutions in 2015 provide a wide range of options that goes from the 25/25 MBps to 500/500 Mbps (download/upload speeds). In 2015, and after they bought Vodafone shares, their network covers all the US with mobile and wireless solutions which seems a big step to go fiber national in the future.

Some of the problems that Verizon and other operators are facing in the US are about content. Contents are one of the key points to launch and attract a new customer to contract a fiber offer. TV is the premium service to be offered over it, thus making content the current driver to pay a little bit more. Comcast, a cable based company, is currently one of the best-positioned content carriers, see Wallsten (2014).

About this case, we observed that it is a firm with a clear view on how to differentiate from the market. The selected time for Verizon

[21] Bell Atlantic was one of the seven branches into what was divided Bell Telephone Co. Most of them merged into AT&T, but NYNEX and Bell Atlantic divisions joined with GTE to form what is known as Verizon Company.

to launch their FTTH product challenged the cable-market players – connected with Hybrid Fiber-Coaxial cable that was mainly used to distribute TV content. In this case, Verizon wants to go National with wireless, although with fiber is more a region-by-region expansion scheme. The ROI for them is important, as the capital source is private (it has to be attractive to investors and one way to do it is that the ROI has to provide returns as fast as possible), something that limits is expansion to a nation-wide project and the budget for the future expansion.

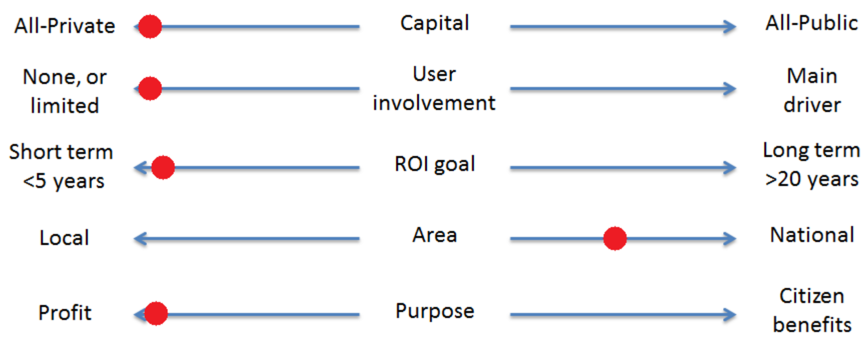

Figure 14. Verizon business case, USA.

This project answers to a private company pattern that depends only on its private investors to deploy the network, see Figure 14. Thus, the user is not involved in the network as a stakeholder and the main purpose of the network is to obtain profit. This purpose leads to fast deployments in cities and dense villages (not small towns) were they could get a quick return of the deployed fiber network. The area is not reaching a national goal because Verizon, and the source of its capital, search mainly to connect with fiber users that are not very expensive to be connected because to its home distance from the main network (rural areas), and that will make positive the project in less time. One of the things that allowed quick returns to Verizon is that AT&T and Comcast continued to ignore the offer of broadband speed as a possible contender to network deployments. Now, they both are improving their networks and offer speeds. The move from Verizon, by acquiring Vodafone has somehow stopped the fiber deployment and the promotion of bundling fixed connection with mobile connectivity. It allows to classify them as a private company that is bringing a NGAN to all the USA, as now they have good coverage by combining fixed and mobile solutions, note that the figure refers only to the fixed network. The definition of the FCC has made that Verizon erects as one of the main pillars of the US number of subscribers that are considered as broadband users – the minimum FiOS speed offer is 25/25Mbps.[22] It is said that they have covered more that 41Million people in the USA.[23] However, we include Figure 15 that shows a FiOS map that supports that with their fiber solution they are only going to quick return areas and that are high dense populated areas.

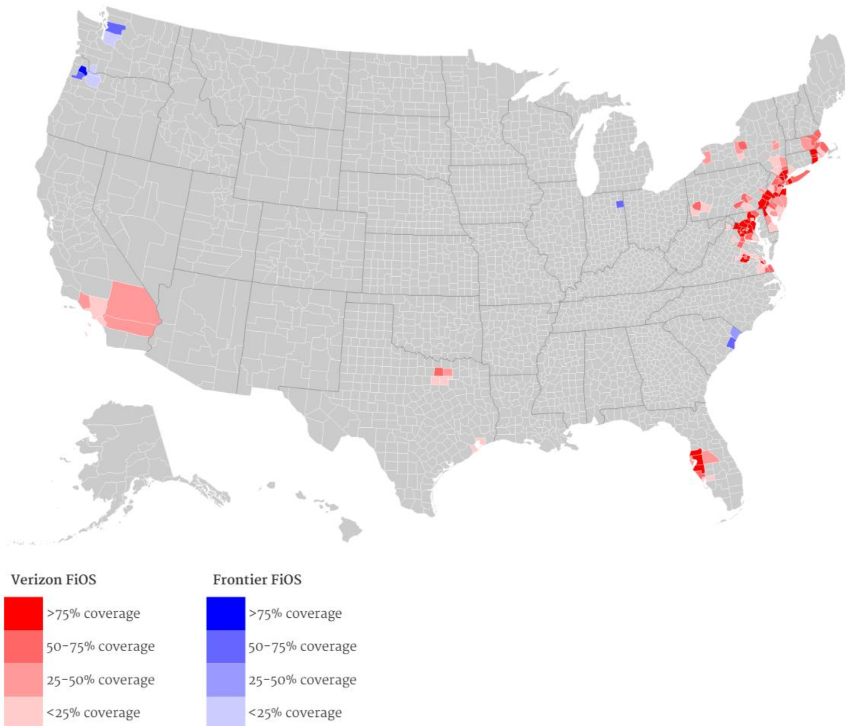

Figure 15. Verizon FiOS coverage map in red colored areas. It also includes the Frontier map coverage in blue color, case not analyzed in this dissertation. Map and legend retrieved from < http://fiberforall.org/fios-map/ > in June 2015, including data from May the same year.

[22] Verizon FiOS solution is one product that gives the user a broadband connection following the broadband FCC definition 25/3Mbps. See FIoS internet speeds to find solutions from 25/25, 50/50, 75/75, 150/150, 300/300, 500/500 Mbps (download/upload speed) < http://fios.verizon.com/fios-internet.html >.

[23] Data available on May the 15th, 2015. Retreived from < http://broadbandnow.com/Verizon-FiOS >.

5.1.c) Telefónica, a quick deployment under favorable fiber regulation in Spain

Since 1924, when CTNE – Compañía Telefónica Nacional de España – was established, it has been evolving to the giant that we know today. That time though, it was an American participated company by the International Telephone and Telegraph Corporation NYc. It became a State participated – owned – company under the dictatorship period, where the State was the owner of 79.6% of the company by 1945. Since 1978 it reached the 10 Million figure for telephone fixed connections and it has not gone below that number; currently, at the end of 2014, it has 10.6 Million homes connected with its fixed network, and 4.1Million homes served in wholesale service to other operators. After that day, it continuously has being designated as SMP – Significant market position – in the fix market in nearly all regions of Spain. The main reason is because it possesses the last mile copper-line connection for nearly all homes in Spain, at the end of 2014 it had 76.87% of the total fix market (directly connected with retail or wholesale services), data extracted from CNMC (2015).

The full competency in Spain was introduced in a long transition period, that for some goes from 1987 until 1996 and even all agree that until 2003 it could not be considered a full competitive market between different firms in Spain, see Guarnido & Jaén (2005).

Currently, regulation in Spain is coming back to its strong surveillance of the market, but during the period from 2012 to 2014 the former regulator CMT was integrated to the supraregulator CNMC – Comisión Nacional de los Mercados y la Competencia. This new regulatory body was formed from five existing ones: energy CNE, telecommunications CMT, competency CNC, postal services CNSP, and Railways & airports CRFA.[24] During this two years period, Telecom policies have not being changed, not even a comma. Thus, it provided a stable framework for carriers operating in Spain. Telefónica lead the change to FTTH deployment in Spain

[24] Comisión Nacional de la Energía (CNE) + Comisión del Mercado de las Telecomunicaciones (CMT) + Comisión Nacional de la Competencia (CNC) + Comisión Nacional del Servicio Postal (CNSP) + Comisión de Regulación Ferroviaria y Aeroportuaria (CRFA) = CNMC

during the last year, 2014. One of the reasons can be that the unbundling of fiber was not mandated and this product differentiation allowed the firm to grow in subscribers with a product that cannot be matched by the other carriers, as they do not deploy fiber networks. The result is that Spain had 1.60 Million homes passed with fiber at the end of 2011, and now, it has more than 15.04 Million homes passed with an FTTH solution. Cable has experienced a slow increase during the same period, but not at the same pace that fiber was increasing, and has now 10.01 Millon homes covered. Figure 16 provides a visual interpretation of the NGAN fix broadband market. FTTN is not considered as a solution to high dense areas, while, FTTH is leading now the implementation and the market.

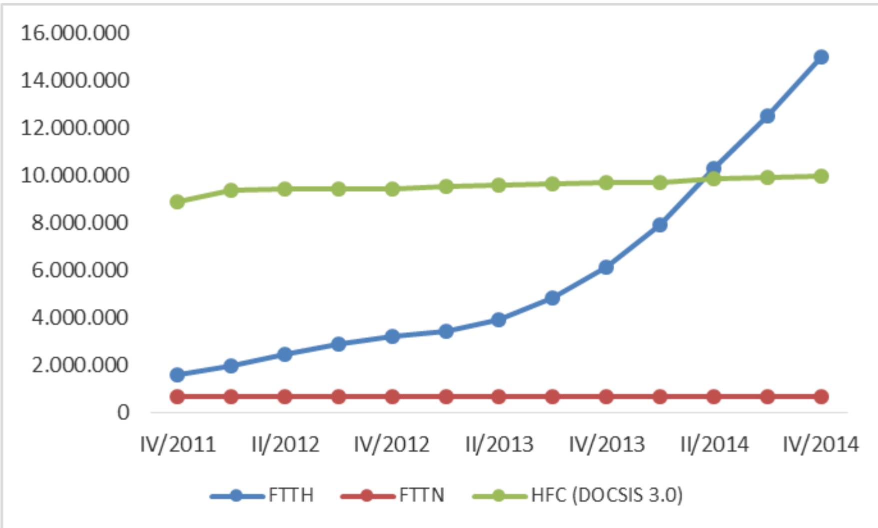

Figure 16. Fix NGAN broadband market evolution during the last three years in Spain analyzed every six months and including the number of homes passed with each of the fix NGAN technologies. Data source is from CNMC (2015).

The penetration number in the FTTH passed homes remains low (10.4%), reaching 1.56 Million homes with an FTTH solution. On the other hand, cable still leads the market with 2.20 Million homes connected. This leaves Spain with a fiber-based solutions take-up rate of 10.4% and a 21.9% for cable. The positive trend points out that fiber, with a nearly 200% increase per year, and the launch of some solutions that will motivate the change to fiber[25] will bring the fiber fix market to lead the number of connections in a brief period of time (two or three years).

This business case shows how a firm can take profit of a stable period for developing and installing its FTTH network. Telefónica is now leading the FTTH connections in Spain and is leading the number of fiber subscribers in Spain (more than 84% of the fiber subscribers are with Telefónica) as it has 1.3Million subscribers with this technology. Figure 17 shows the summary for this business case.

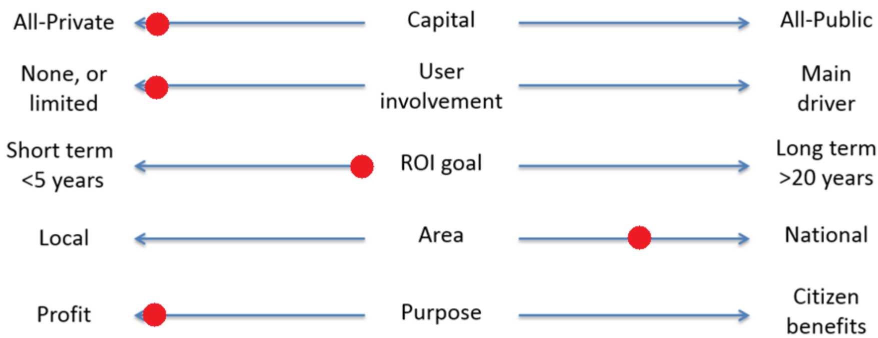

Figure 17. Telefónica business case, Spain.

This Business case answers to a private investor that has no rush and that believes in the project. The ROI goal points out that the take-up rate strategy is not the one to grow fast the incomes for the project, but to deploy as fast as they can in the silver lining found during the transition of the Spanish telecommunications regulator takes place. For instance, Telefónica has connected more than 10 Million homes in two years, although the rural areas are still outside of the quick deploying plans. The main purpose of its actions, as a private operator running a big network and offering many services over it, is to increase their profit. The tactile followed in this business case is about bundling the final users offers. Telefónica

[25] Fusión from Telefónica, and One from Vodafone are quadruple offers, including fix and Mobile telephone + data + TV at a lower price than taking separately three of the included services. Fusión available from < http://www.movistar.es/particulares/oferta-combinada/fusion/ >, and One available from < http://www.vodafone.es/particulares/es/descubre-vodafone/te-ofrecemos/one-todo-en-uno/ >.

was decreasing their take-up rate since the entry of copeer unbundling and the easy “portability” – change from mobile company – that helped users to seek their best offer options. So, we can confirm that bundling is one of the best options they have followed, they offered fixed telephone calls at flat rates + broadband data without data caps + TV channels + one mobile telephone including mobile broadband data with 2GB cap. The point is they decreased the number of users that were leaving Telefónica for other promotions or better options for the consume pattern and price. In talks with the CNMC we discussed that it is difficult to disentangle how much does it costs a single service now as you can get fixed telephone + 300/300Mbps + Mobile flat rate calls and 2GB data cap (in 4G network) + TV just paying € 63.6 per month (+VAT). One important point of those Telefónica offers is that to be competitive they always need TV on them, if you want no IPTV the offered price of the service rises. Because of that, we would say they are also offering a cheap offer to attract users to their new services like TV. A content strategy that is making Telefónica one, or the main, content provider in Spain. In 2016 it will be the only way of watching all Footbal matches, Formule 1 and GP motorways, along with other exclusive content they are pushing for. After knowing so many cases, we believe that they are following the same strategy that Comcast is following in the USA, where owning the content, makes the only possible provider to choose for many users – although they can get poorer connections than other available broadband companies.

5.2. Public Stakeholders (Municipalities and Government)

As explained in Chapter 3, there is a European classification that depending on the area type, it allows or not to include the government with a Key role in deploying a new fiber roll out. In this Thesis, we include to different examples of Public involvement. In the first one, Google Fiber, in the USA, where the Public municipality collaborates by helping the promotion of the project and allowing Google to install their network on the already public existing infrastructure. The second project is a National Public fiber deployment-taking place in Australia. As a political project, more than a carrier strategy, the project has been modified within its implementation years depending on the budget devoted to it.

5.2.a) Municipalities in the US can help the roll out of fiber, the Google Fiber case

This case is a more recent one. Back in 2010, Google announced that they were starting a new business branch called Google Fiber[26]. The main purpose of this department was to find an area to deploy a fiber access network under the best possible conditions: maximizing the value of every dollar spent on the new network and to provide an outstanding broadband symmetric offer (a symmetric 1Gbps connection). Municipalities from all around USA answered to a public contest launched by Google and provided as much data as possible about their already existing facilities and some proof of engagement of their population to the project. After the first contest in 2010, Google received data from over 1,100 communities and local governments, endorsed by more than 194,000 individuals, see Rao (2010), all of them applying to get fiber deployed in their towns and cities.

From these applications, Google selected Kansas City. There, Google divided the city into fiber-hoods (smaller than neighborhoods) that allowed them to set some goals of pre-engagement before starting any deployment. If a fiber-hood does not reach the minimum level of pre-engagement, Google does not deploy fiber there – proof that only deploys for benefit. Having those levels of pre-subscribed users allows a better planning to deploy the new fiber network (passing and connecting houses at once) while it reduces the risk of investment. Google's model seems to be reaching more than the minimum pre-subscription goal per fiber-hood. According to Sanford C. Bernstein it could reach 50 to 60% of possible subscribers in two years after deployment, see Baumgartner (2014), Richmond (2014) and Reardon (2014).

The model, although not being a true Public Private Partnership, has a strong commitment from the public administration. The latter

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[26] 1Gbps experiment was announced before having the idea of becoming the operator Google Fiber. Retrieved from <http://googleblog.blogspot.com.es/2010/02/think-big-with-gig-our-experimental.html>.

provides access to any existing telecom infrastructure, if available (poles, dark fiber, conduits), and eases as much as possible the provision of rights of way needed to deploy the network. On the other hand, the city council gets involved in the demand aggregation process by stimulating residents to subscribe, thereby reaching the minimum pre-subscription level, and in return gets a fiber connection to schools, churches, hospitals or other public buildings in the fiber-hood from Google for free. The Google Fiber model seems to be working as after Kansas, Google now is expanding into other cities along the US like Austin and Provo (in the states of Texas and Utah respectively) and has also another active contest to expand the network to some other 14 locations, presumably Salt Lake City.

The keys to obtain such a quick revenue project are not only obtained from applying a pre-engagement of end users, as Domingo & Lehr (2013). The cost-effective deployment is obtained by having the pre-engagement of public administration to support this private firm network. The combination of both commitments – user and public administration – leads to seek new deployment areas by a public contest methodology that inquires for specific details about already existing infrastructure and actions that will give support to participate and contract the new network services of Google Fiber. Figure 18 allows us to realize that although the investment is private, and the time to recover is less than 5 years, the involvement of the Public administration helps to mark the purpose of the network for searching the citizen benefits, rather than making profit with the fiber network itself. Note that Google can also obtain other profits from being the local operator, like traffic inspection, improvement of its OTT services and billing them more easily to the final user.

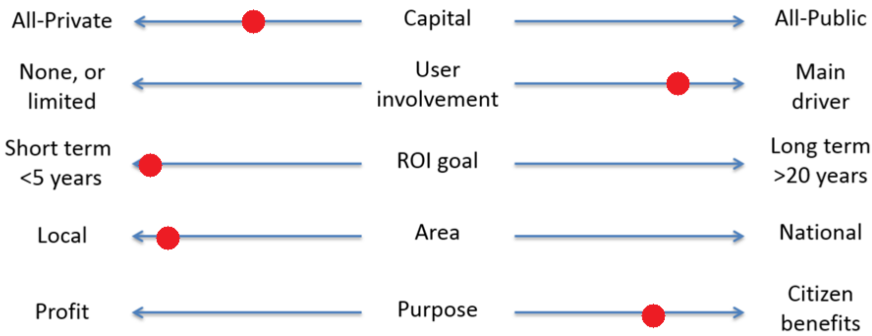

Figure 18. Google Fiber business case, USA.

The selection of the variables of the Business case brings us to an All-private money source, Google, but with a component of Public municipalities taking part in the project deployment. For instance, the allowance of deploying the network in the public owned infrastructure is something that helps to ease the upfront investment of the project and gets a faster rollout. The user involvement in the project is higher than a common carrier, as it even leads to users organizing events to recruit other users to the network. The user, may even pay the deployment of the fiber and get a free connection during 5 years of a Today Internet connection (5Mbps). The project is deployed in the areas where the percentage of presubscribed users reaches the point of ensuring a quick return of the investment (if it does not reach this minimum number of pre-subscriptions, the project is not deployed in that area). On the other hand, the purpose of the project is not to make profit, as it connects all the public buildings in the deployed area for free (churches, schools, etc.) and it gives 1Gbps connectivity at cheaper prices than any other operator offering 50Mbps in the area are doing. The problem of this Business case is that it cannot go national, and has to find the right place to be sustainable. Local projects are deployed in cities or villages that will give support to the project, Kansas, Provo, Austin, and futures Atlanta, Salt Lake City, Nashville, with an increasing list of possible places[27] that must show how they can help to decrease the budget figure for deploying fiber in their city. As a fiber to the home project, the Business case looks strange when thinking that it comes from a private firm with private investors holding it. We think that other factors may need to be included in

[27] The list of possible new cities is available from < https://fiber.google.com/newcities/ >.

future research, like the number of services that Google will be able to launch on 1Gbps connection. Moreover, Google, as a new carrier, will also benefit of learning how its users interact with the network and build new usage patterns that can help its main business, the search and OTT services.

5.2.b) Australian Case, a modified public open access network

Australia Government started in the early 2003 to design the plans of deploying an FTTH network that could reach the entire country,[28] see Broadband Advisory Group (2003). In 2009, they created the public governmental company called National Broadband Network Company – NBN Co. This company should deploy FFTP all across the country to reach the home's premises of the 21.5 Million of Australians citizens. Their main statement to stakeholders was set clear in NBN Co (2012): "NBN Co's goals are simple – to deliver Australia's first national wholesale-only, open access broadband network to all Australians, regardless of where they live."

In 2014, and after reaching more than 300.000 homes with the fiber solution, there was a change in the government, which took place in 2013. The first thing they did was to review the National Broadband plan, which lead to a new strategy that include all type of NGAN (including wireless solutions) calling them "optimised multi-technology mix". The NBNco should determine which technology fits better in each area to decrease the peak investment and making sustainable the state-owned-open-access-infrastructure operator. The government opted to a 90% coverage at 50Mbps download speed and reaching all the inhabitants with a speed of 25Mbps as a minimum. As they are the main shareholders, the Minister for Communication and Minister for Finance (2014) sent the new strategic government expectations to the NBN Company.

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[28] The NBN Co map coverage is available from < http://www.nbnco.com.au/sell-nbn-services/rollout-map.html >.

The project currently has reached the 1 Million-figure coverage with the different NGAN technologies. From those, 607 thousand homes are covered with a fiber solution. The serviceable ones are 554 thousand because 53 thousand are still in need for short fiber deployments (in-building). The take-up of the project is very positive, as an open access network where all the service operators have to use the network, is something that one could expect. The number of connected homes in May 2015 is 263 thousand with fiber-based solutions meaning a 47.5% of take-up. Combining all the solutions – fiber, satellite and wireless – there are 437 thousand homes connected (43.7% of take-up rate). Data extracted from NBN weekly report in May 2015, NBN co (2015).

Figure 19 provides the general Business Case of this Open Acces network that is evolving through the years. Take it as an analysis of 2015 that may evolve to a worse or better case in the future.

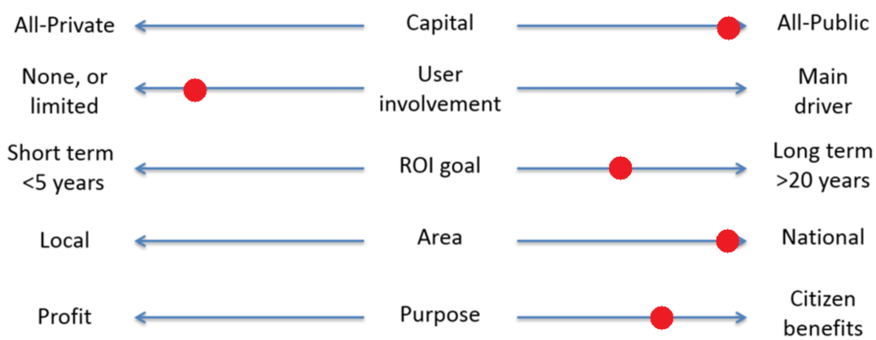


Figure 19. NBN Co business case, Australia.

The capital of the project was primarily public, although private operators and general-public can invest in the company. The Government of Australia has limited its involvement to a 29.1 Billion AUDollars – approximately 20 Billion Euros. This limit was set after the users vote the political party change, mainly lead by the proposal of reviewing this plan and lower the investment in the fiber network. A solution that has been possible by not deploying an all fiber based project. The ROI goal was first a long-term investment, but with the new government, it has become more important to obtain profit in a shorter period. It has also decreased all the possible benefits from a fiber project to different solutions (including wireless ones) that only seek to obtain more profit by covering the same number of homes, but with less current and future-capable speed. The area value is set at National because in its network definition says that it is a Natioanl open-access network and it is a good example of how Public Administration is involved in deploying broadband networks, but also how political decisions can affect the outcome of the project. We observe it as a way of waving the operators from the dilemma of investing or not in infrastructure, as the State will do it. On the other hand, there will no be infrastructure competition when the state covers one area, as they have signed expensive agreements with the existing operators that they will use the Open access network once it covers a served area. By doing this, the State is also ensuring to recover in a mid-long-term the infrastructure investment. There exists also one threat, and is that with public money, a State will deploy now the fiber network, but in the future may incur to some other technology that can become a failure and a waste of citizens money.

5.3. People Networks

People can really affect directly the Local loop Access – also known as the last mile access. As individuals can have less effect than when cooperating together in community. The two examples exposed in this Thesis answer to final users being involved in the deployment of the network with a more active position, as a Stakeholder, as a take-up enabler, or as a work force deploying and installing the fiber.

5.3.a) Community-built fiber project, the Guifi.net Case

In 2009 a group of neighbors in a small rural community in Catalonia (Gurb), Spain, decided to deploy a fiber network by themselves. The first issue came before starting as they realized that they did not know about the deployment methods and associated costs. As they were in Touch with the Guifi.net Foundation, they ask for some help into the fiber deployment. The Guifi.net was active in deploying community wireless networks, currently with more than 25.000 wireless active nodes; see Vega et al. (2012). This neutral operator calculated the costs of deploying the fiber infrastructure and also recommended to reach more than 60% of take-up before deploying if each household wanted to pay € 1000 or less for the network installation and connection, see Beltran (2013).

According to Barcelo et al. (2012) this case follows a "Bottom-up Broadband Network" scheme - BuB. The main principle of the network is that is follows a bottom-up scheme, deploying the network from the user to the core, but in this case, the network deployment and operation is fully paid by the final user. The fiber network itself belongs to the Guifi.net community, where the user becomes one of the associates of the Guifi.net operator after paying for his own deployment. Volunteers carry out the installation, thereby significantly decreasing the overall project installation costs. The pre-subscribers pay all the equipment and material to be connected, see Roca (2011).

The deployment has been named *Fiber From the Home/Farm*, giving special attention in the direction of its construction *From* the Home/Farm as the deployment starts from there following the BuB deployment scheme. While Guifi.net runs the maintenance of the network and active equipment connected to the network, it does not interact with the final client. Data, TV and OTT services in Gurb village are offered through a separate service provider operator; Gurbtec was the first to offer broadband services of symmetric 1Gbps over the open and neutral network of Guifi.net.

Currently Guifi.net is exporting this model to other communities, such as Calldetenes or Mataró, which are also aiming to entry the Gigabit connection era and want to mirror their future deployment to the one done in Gurb. They have already illuminated more than 120 buildings reaching around 80% of take-up rate in the deployed areas, with plans of reaching 240 buildings (120 new ones) during 2015. Currently, there are two service providers competing over this free network, Gurbtec and Gaufix, offering a range of services (telephony, television, Video on Demand, etc.) with price differentiation. Gurbtec offers the service for € 24 per month to each connected household, VAT included. From this monthly payment Gurbtec pays € 8 to Guifi.net as it runs over its open and neutral network. The ARPU to the Service provider (Gurbtec) is kept around € 8 to 10. This separation in different layers helps to analyze why Guifi.net, as infrastructure operator, can obtain a quick profit that is kept to repair, maintain and upgrade the network if needed. The two main positive effects of the applied bottom-up broadband deployment strategy are the pre-engagement of the final user (thereby having certainty of the uptake rate to expect) and a lower deployment cost by the help of volunteers. Finally, the competing service providers are also key as they are necessary to get services over the network.

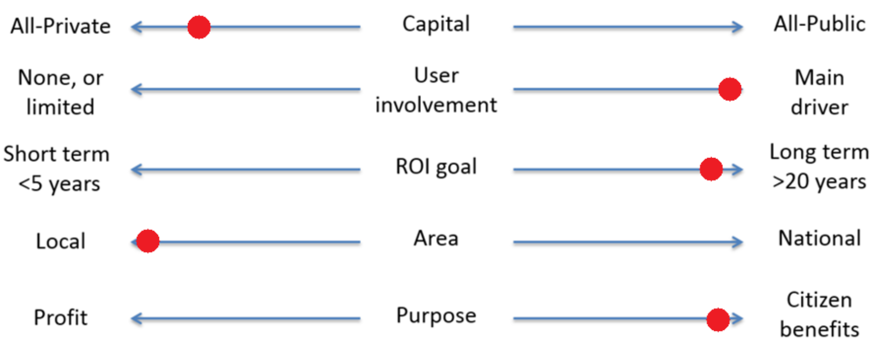


Figure 20. Guifi.net business case, Spain.

The Business case shown in Figure 20 shows how the User involvement is the main driver of the project, although not 100% of the money is set as private. The reason is that the Interconnection network that connects the village to the local Interexchange point – Catnix – is done over a public owned operator that agreed a lower price for offering the data transport from the village to the IX. The ROI is set as a long-term return, as the user gets a cheap retail offer after investing in the deployment of the network, so, in the long run, the monthly savings equal to the initial investment. The area of the network is reduced to a local project that may involve a neighborhood or a small village. The purpose of the users involved in deploying the project is to obtain the maximum number of benefits from their investment. Because of that, local TV can transmit their signal over it, or they can allow any future project, like telecare-hospital services to be implemented over their network without a cost for the health services. One point that remains as difficult to understand, is why the service provider is paying a monthly fee to the infrastructure operator, without being committed to the possible future upgraded of the network, or if that cost will suffice in case of a major disaster in the area. The feel of being part of a community that deploys their project, a project that challenges the big firms and carriers to come and cover what they already have done, is something to be taken into account for any existing carrier. It also shows a path to other communities. Moreover it gives a new statement, communities may have the key of the network that can allow freedom of service choice, but it will also increase the todays cost, so a way to fund this upfront cost is the main drawback of the entire project. Although the investment is recovered in the global figure and in a long term period, one thousand euros was the bone found in the project. It was solved with some credit funds that will have to be able to replicate if the model wants to be implemented elsewhere with more than a possible 120 homes, and the difficulty of granting those credits will be proportional to the network implementation and project success – meaning for success a project feasible and sustainable.

5.3.b) The Netherlands, a leading fiber country started on the people shoulders

The Netherlands started to develop its FTTH initiatives over the involvement of municipalities deploying fiber-based networks. Currently, in 2015, Reggefiber drives the fiber networks. Reggefiber (2014.a), founded in 2005, is a subsidiary of the private investment company Reggeborgh. When it started, Reggefiber was involved as a merely investor in certain municipality networks (e.g. Glasvezelnet Amsterdam, OnsNet Nuenen, etc.). Since the Reggefiber acquired the backbone provider Eurofiber, Reggefiber linked the various isolated municipal initiatives and became a carrier.

In 2015, Reggefiber is 40% owned by KPN, the DSL incumbent in the Netherlands. This joint venture was granted by the ACM (2014) – Autoriteit Consument en Markt, former national regulatory authority OPTA. One condition was imposed, and it was that Reggefiber only operates on the passive infrastructure level, leaving the installation of active equipment and offering of services to other, competing providers on a non-discriminatory basis – this way the integrated vertical service that KPN should provide was replicable by other operators and kept competition in the areas.

Reggefiber uses a demand aggregating strategy to ensure itself from enough revenues from the start of each deployment. The company determines the next deployment area based on a pre-subscription level: once a certain level (30%- 40%, depending on the area) is achieved, the company is assured of sufficient revenues to make a viable business case in that area, and start deployment. Their online platform allows households to check how close their area is to reaching this subscription level, thereby stimulating convinced families to persuade their neighbors. Following the latest update, 1.82 million households in the Netherlands are covered, while 586,000 are connected to a service provider on FTTH, thus showing the positive effect of the demand aggregation strategy on the uptake, see Telecompaper (2014).

On the cost side, Reggefiber also uses several measures to ensure a positive business case. First, they try to reduce the cost of trenching by searching cheaper ways of laying the fiber into the streets. In here, micro-trecnhing was set in place as a cheaper and faster method for fiber deployment, see Reggefiber (2014.b). Furthermore, they set a maximum of €1000 per home passed for private investment (Reggefiber only). In areas where the costs exceed this €1000, they communicated the need for a different source of aid, frequently getting support of the local residents or the municipality, see Reggefiber (2014.c).

Reggefiber can be considered an example of a successful private-user supported model deployment. In this case, the company business case was secured by assured revenues upfront (demand aggregation) and the limit on the cost per home passed made realize the users of the deploying cost and gave more value to the network connection. Having the incumbent KPN as a shareholder furthermore limits infrastructure-based competition and helps to secure the revenues of the fiber infrastructure network.

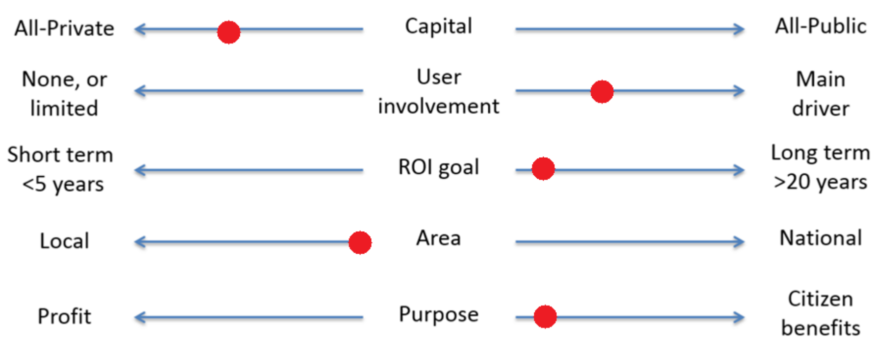


Figure 21. Reggefiber business case, The Netherlands.

The capital source of the Reggefiber case is mainly private, but, as said in the case, when homes are difficult or expensive to be connected (more than € 1000 per home) it asks for public funding to cover the area – involving municipalities in its deployed network. The user in here is one of the main drivers for the network, it can be helping in different ways, but usually supporting with its money to cover the exceeding cost over € 1000 per connected user, and also helping to deploy the network by opening the street or giving pass through private soil. The ROI in this project ensured to sustain the network but it do not seeks a profit purpose. Thus, the variable is set at the citizen benefit side, as the ACM regulated the entry of KPN as one of the main stakeholders of the deployed network, ensuring fairness on the wholesale services and leaving the network as an open access network to Service providers' operators. The *area* variable is not set at the local point because when the project quickly grew it was extended to buy the interconnecting network between deployed villages, something that confirmed its regional status.

5.4. Commonalities and differences in fiber-business cases

The different business cases shown in this chapter allow describing general commonalities and differences among them. We are going to compare some of the variables described in the different deployed fiber projects.

From the capital point of view, it confirms the relation of company private capital (carrier project) to look for a quick return of its investment, the case of Verizon. The Telefónica's case points out that when there is an opportunity to ease the network deployment the investors take the risk to become the first movers in the new technology area. Those projects have in common that they cover first the main cities, where the number of inhabitants' density is higher and the deployment goes nearly national as they already have an interconnecting core network, so they are upgrading the last mile network (not paying the high cost of data transport). These carriers consider the user in those projects at the end of the network, and the one who will subscribed to the offered services. Thus, the purpose of the carriers' deployment is to generate profit.

On the other hand, if a carrier is designed incumbent in a legacy network (mainly copper) – like Telefónica, France Telecom, Telia Sonera, British Telecom, etc. – it has not been a bad idea the Japanese solution. A state, Japan, helps with an investment and policies to deploy one fiber network from the designed with Significant Market Power – SMP – including one clause: once the majority of subscribers, in this case 70% of the market, are opting for that fiber-based network you change the policy to regulate the unbundling fiber price to allow competition. By doing this, the nation is covered with one fiber network; the state obtains competition in the new network and recovers the investment. Nevertheless, there is always a big but, during the transition, most of the market players have been moved to mobile solutions or service solutions, and the ones that remained deploying a parallel network will create isolated areas where they may not recover the invested money and some sort of compensation should be ready.

Going further on the Japanese solution, Australia, another country in the Pacific areas, has developed and all public open access network. This means that the capital source was all public and that the existing operators should stop using their networks when the country fiber network arrived to an area. The second part was obtained after agreeing with Telstra that they will stop using their copper lines after 18 months of the NBNco network arrives to an area, and that they will not compete with wireless solutions to it. They also agreed that Telstra would allow to deploy NBNco network inside their existing infrastructure. Those agreements added a 9Billion AUD – 6.3 Billion euros – to the network implementation cost, NBN (2011). Thus, it clearly differentiates from the Japanese case, as in here the resulting NBNco is a government-owned company that is supposed to ensure equal access to all the operators that will not be allowed to compete by deploying parallel infrastructure networks. However, as a non-private company was behind the deployment, politics took the network as an electoral tool to provide another solution from the initial one. Currently, in 2015, the network is not anymore an FTTH network to all homes but instead, a myriad of solutions that can provide 50Mbps download solution – which includes cable, mobile and satellite solutions.

Just in 180 degrees turn, when a municipality is going mad to obtain a fiber deployment network to its citizens, it has now one solution, entry the Google's fiber contest of desirable cities that want fiber. To do so, they will provide access to all public infrastructure in place and will give the audience the opportunity to hear what Google plans to do if they aim to be a fiber city. People will also have to push for it, as the number of presubscriptions are basic to deploy or not the network in an area. Once, they selected as a Google Fiber city, if the deployment happens in one neighborhood, then, it not only connects homes for a monthly price, but also connects the public administration buildings in place, like schools, university, churches, sports centers, with 1Gbps for free. So, the community in here upgrades not only their speed at home, but also the neighborhood spaces that benefits the citizens living there. This project has quite things in common with the user deployment projects, but differs on the Service provider, as in here, Google deploys an vertically-integrated solution, which makes Google services the only provider running on that network.

People has different motivations to implement a network, but, as Google does, the first thing they need is to achieve a minimum demand threshold. Reggefiber, whith a capital group supporting the initiative, needs a 30 to 40% of pre subscriptions to start deploying the network, where Guifi.net, a user driven deployment with the support of a neutral and open operator needs to reach 60% of pre-subscription to make the project feasible. The funds in those projects is the main bone that blocks its quick adoption through other cities and villages. The result is in form of open access network that allows the user over one fiber to choose the service provider they want, so, clearly showing proof that the users want to access content and services of their choice and not to be locked on a carrier's integral solution like the ones explained in this chapter from Google, Verizon, Telefónica. Reggefiber and Guifi.net have one thing in common and is to show the € 1000 as threshold. In the case of Reggefiber, the user has to pay the exceeding cost over € 1000 to connect his home. Gifi.net instead, says that € 1000 is the maximum you can expect from a user, so, if the cost exceeds that figure, you should find more people to share the distribution network cost and decrease the upfront investment. Doing this, Guifi.net reaches a higher penetration rate and a lower money demand from final subscribers.

Chapter 6

A FIBER-BASED COMMUNITY-SHARING MODEL

“Sharing is good,
and with digital technology,
sharing is easy.”
- Richard Stallman

Most FTTH models consist of integrated vertical operators deploying the whole networking infrastructure, from carrier’s premises to customers’ households – HH. Verizon and Telefónica examples introduced in Chapter 5 provide some insights on how those deployments require an upfront investment that must guarantee its return in a short-term basis, less than 5 years. Two main drivers are the ones that trigger a fiber deployment in the different public and private deployments introduced in this Thesis:

- a private deployment model aiming to maximize profits and revenues and trying to get an increasing market share
- a public deployment model aiming to provide universal broadband/Internet coverage in less-profitable – mostly rural – areas.

Users, after the irruption of Web 2.0, have been understood as a key partner and stakeholder for new product development. In here, with communications’ networks, the user is the final product and the consumer at the same time, something that is related to content products – e.g.: Facebook, Twitter, Instagram, Whatsapp. The network is getting the consideration of the medium – like water – where all those contents travel from user to user. We believe that the time where users were only getting Internet to access a Digital

Encyclopedia are over, and proof of it is that some of them collaborate to build a wiki encyclopedia.

Some motivations commonly seen in Wireless communities that could be understood as fair motivations for users aiming to deploy a community-sharing project are:

- Underserved areas
- A cheaper way to connect in areas where there is already a Broadband solution
- Aim of learning technological deployments (after plenty of DIY videos)
- The will and proud to be part of a community
- A way to control the network (considering that ISPs are the only controller)

De Filippi et al. (2014) and Sadowski (2014) describe in detail the motivations of the Bottom-up initiatives mentioned in this Thesis. We describe a "Community" in our model as the trigger of the fiber deployment; it is the start of any initiative lead by the users. The community-sharing model described in this Thesis is placed in a hypothetical scenario based on real projects that are providing data to explore what may happen if this model is applied to today implementation model or how it may have an effect in the close future.

A techno-economic model, which follows the methodology described in Chapter 1 and with some examples in Chapter 2, is one of the tools that will help us to build the fiber-based community-sharing model. As we have seen in the current situation, Chapter 3, there is a will to deploy broadband networks from most of the countries. Digital Agendas and broadband definition are tools that governments and policymakers are using to encourage the fiber deployment. However, a fiber-based community-sharing model is something that comes from a Bottom-up perspective. More related to the grounds of society building a network that connects to the Internet. This chapter will introduce first the concept of top-down and bottom-up with communities involved in the deployment. Afterwards, it will describe all the model variables of the fiber-based community-sharing model and provide examples of its effects.

6.1. Top-down or Bottom up?

Chapter 5 has introduced two examples that can be extended to exemplify this characteristic of the model in community-sharing. A top-down project that requires users to extend and join for the final drop with a business-sharing model included, NTT in Japan. A Bottom-up project carried by users and with the help of Guifi.net in Gurb, Spain, will also approximate the different views of those projects.

6.1.a) Top-down

Japan has been in the top group of leading fiber-deployed-and-connected countries for several years. In the Background point of Chapter 1 we have included the FTTH Council ranking that shows it is placed in the top 4 countries in fiber deployments.

It is a Top-down initiative, as it is a company, the Japanese NTT, helped by state capital budeget deploys and renews its copper access network to a fiber-based one. As we have shown in Chapter 5, the take-up rate in this model is quite high, but as we are involving communities in a Top-down project, we focus on their play in the deployment.

Japan realized of the in-building problem of deploying fiber to each of the homes inside of the buildings. In some high-dense areas, it was difficult to deploy the fiber cables to all the users' homes. To reach a better take-up rate figure, especially in big condominiums in Japan, they decided to approach with FTTB discounts on multi-dwelling units, see NTT East (2015) retail offer. This NTT's target of joining a building-community to rise the take-up shoot to one of the known community motivations to share something: A cheaper way to connect in areas where there is already a Broadband solution. Following this approach, NTT accounts that a 30% of their connected homes is through an FTTB solution.

Communities joined to obtain the maximum discount as possible, but also to deploy themselves the in-building network. It could be fiber-based, over the existing network in the building or Wi-Fi. Depending on that, NTT would deliver one or another type of

Router-ONT at the user's home. They recognize three types of user connectivity: Optical fiber, VDSL and LAN systems. The solution is called FLET'S Hikari service and allows sharing 100Mbps access of a single optical fiber among multiple customers. Now, in 2015 NTT East (2015) is also launching 1Gbps to be shared among the FTTB solution.

The basic novelty is the discounts they offer. The monthly price discount follows a Top-down approach, thus, it is billed separately to each subscriber. The control of the number of subscribers that a top-down model demands made unavailable the one community payment as they share their connection. Figure 22 shows the three types of price that depend on the number of contracts that can be expected in the multi-dwelling unit. Thus, by aggregating more HH from your community, all benefit from a monthly discount. It starts with aggregating 4 contracts/subscribers in the same building, plan called "Mini" and has a monthly costs to each subscriber of Yen 3,950 (€ 28.5 per month). Maximum discount is reached with "Plan 2", where there can be 16 or more contracts, and the monthly offer per subscriber is Yen 2,950 (€ 21.3).

Contracts expected in the same building	When 16 or more contracts can be expected **Plan 2**	When 8 or more contracts can be expected **Plan 1**	When 4 or more contracts can be expected **Mini**
FLET'S HIKARI Normal charge	3,350 yen	3,750 yen	4,350 yen
Go Giga! Promotion (30 months discount)	-200 yen		
にねん割 Ninen-wari 2-year contract (cancellation fee applies)	-100 yen		
FLET'S 光 メンバーズクラブ FLET'S HIKARI Members Club Monthly Points	Use monthly points to pay NTT EAST service charge 1st year equivalent to -100 yen * To use points to pay NTT EAST charges, application for exchange is required each time. * **The menu to award points such as monthly points may be changed. In case the change takes place, it will be notified in advance through our website, etc.**		
FLET'S HIKARI monthly charges after applying discounts, etc. (1st year)	**Effectively** 2,950 yen	**Effectively** 3,350 yen	**Effectively** 3,950 yen

Figure 22. NTT east FLET'S HIKARI monthly offer reduction when community buildings are joined.

As users are sharing a single fiber in the FTTB model, they were asking for some sort of unbundling of NTT as content provider. Since February 2015, NTT West has moved faster than the adoption of the new possible unbundling fiber regulation that the Japanese regulator MIC may approve. They have offered the “Hikari collaboration model” that properly allows the subscriber, for an extra Yen 500 cost (€ 3.6) is able to choose the service provider that he wants to receive over the top of the NTT network. Figure 23 shows the different providers over the NTT FTTB solution. Because of that, NTT Group (2015) is offering as wholesale its data to other providers that also offer their services on top; they have reached 270,000 subscribers in two months that wanted that solution.

Figure 23. NTT west Hikari collaboration model. Service providers on top of NTT fiber.

Figure 24 provides a general scheme for Top-Down operators’ deployments where the user is the main source of income. In this case the Operator decision of deploying the network needs an accurate design, but also a Budget to be covered. Therefore, the need for investors can put more pressure on the need for increasing the revenues. We can imagine the Japanese strategy of increasing the take-up rate as a way to increase the income. On the other hand, this top-down approach shows that when users are involved in the project, they may introduce some changes in the way that a vertically integrated operator works, and it may reached a nearly-open access network shared with their building neighbors. Once the users are sharing and investing in the in-building network they took more decisions on what products they wanted through it.

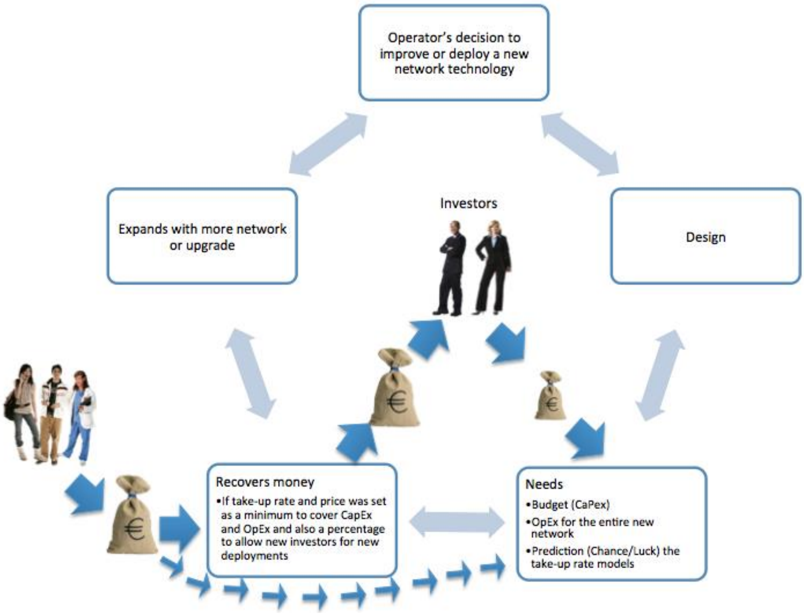


Figure 24. Top-down deployment initiative phases description.

6.1.b) Bottom-up

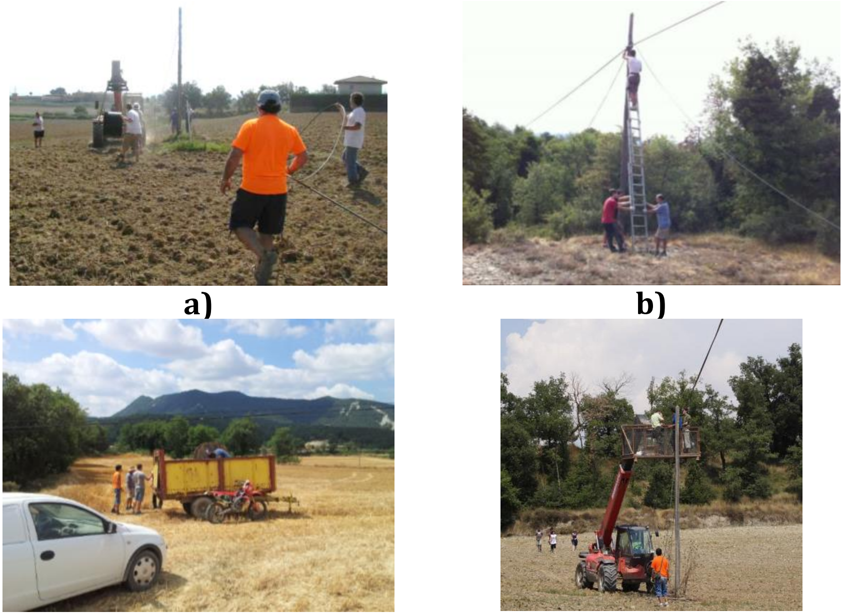
One example of a community fiber-network scenario is the one introduced in Chapter 5 from Gurb, Spain. The "Fiber From the Home" project – FFTH – has been pioneer in its kind. The first thing the community has to share is the need for a faster or reliable network, in this case a fiber network. Once they share this will with many users in the community, it may happen that they have to search a way of deploying it under the current legal framework. Regulation in Spain says that if someone wants to construct a new network into the public domain it must be an operator. With this Spanish law, people cannot start to deploy or construct things on public property and they need to find a legal way to do it – although we guess that this law it is implemented across the countries. We can compare it to the Airb&b portal and the need to obtain a hotel-category (apartment) license for the flats posted on their website, or asking the drivers to pay their self-employee fees if they want to operate as Uber taxi drivers in some countries. As it happens with laws, in this case, for fiber deployments they need to constitute as an operator if they want to roll out and deploy a network. In Gurb – a small village in the Catalan region – what they did was to find an operator willing to run the deployment at the lowest cost as possible and to operate the infrastructure once deployed. As we have already introduced they were in touch with the Guifi.net Foundation operator in the wireless deployment domain, and they ask for some help into the fiber deployment.

The deployment in 2009 started being as much collaborative as it can be, and as far as we know, it continues in the same way until today with Guifi.net as the legal operator– 2015. Some citizens from the village started to deploy the first distribution network tram by helping to roll the fiber on posts, but also doing trenches when needed. This main fiber connection allowed interconnecting Gurb village with the Catalan Open Network – XOC, Xarxa Oberta de Catalunya[29] – that gives transport data to the Catalan IX, called CATNIX.

As Figure 25 a, b, c, and d are showing that the deployment was mainly aerial through all the posts installed on crops. The vehicles and workforce was mainly lead by people from the village that helped the volunteers of the Guifi.net Foundation to deploy the fiber-cable. The splitter installation was carried out with help of some technological tools, like a fusion machine, and the guidance of the Guifi.net operator's volunteers.

In this Bottom-up case, we can identify three motivations to deploy and be part of the network. First, it is an underserved area, mostly rural, with scattered farms and far from the city, but close to the motorway that had already fiber. Secondly, once someone started to claim for fiber there existed the will and proud to be part of a community. Third, and as the pictures have shown, there is an aim of learning technological deployments.

[29] XOC is operated by the Imagina Group that runs and operates the network by connecting different public buildings and offering the network as wholesale transport data to communicate all the Catalan region; Available information at http://www.xarxaoberta.cat/



a) b)

c) d)

Figure 25. Pictures taken in 2009 and 2012 of the Gurb network. Pictures: a) users helping to deploy the fiber cable; b) attached fiber to the postsr; c) a tractor trailer to transport the fiber-roll arrived; d) one of the user's construction machines that helped in the deployment. Pictures main source from Guifi.net (2009) and (2012).

Figure 26 provides a general scheme for Bottom-up initiative deployments where the user is the main driver and again, the main source of income. In this case, the Operator decision of deploying the network is requested by the operators, although some caveats are the same than Top-down approach. They need to reach a minimum Budget to start deploying a fiber network. In this case, users are investing the money for the project that will be recovered in some years as they are only going to pay for OpEx after the deployment is done.

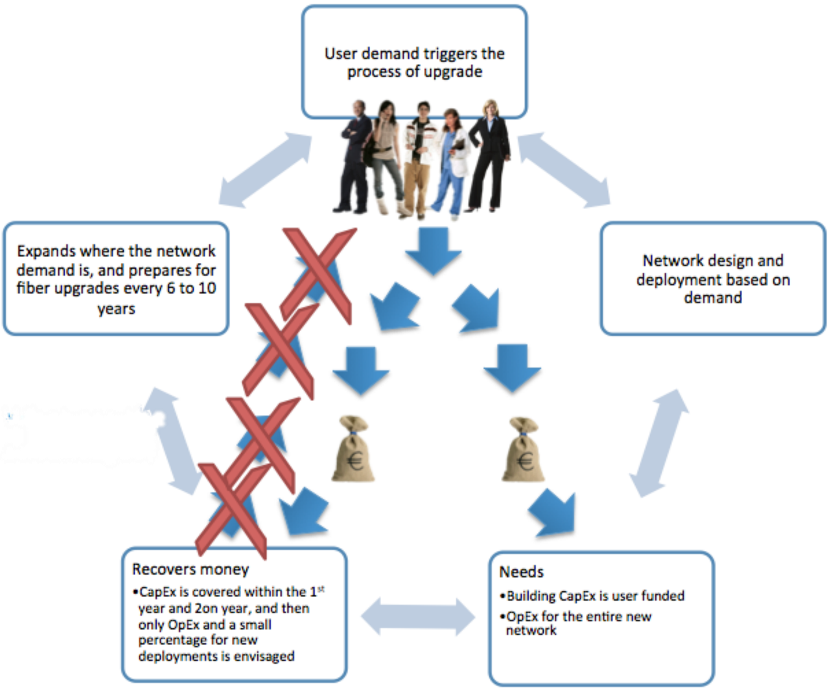


Figure 26. Bottom-up deployment initiative phases description.

6.2. A sharing solution: Statistical multiplexing

The Top-down and Bottom-up selected fiber network approaches that provides some insights of how the network functions have a sharing commonality. From a technological solution perspective there is the share of 1 optical fiber among 8, 16, 32, or even 64 HH in a GPON solution. Because of that, operators or users take the advantage of sharing. Moreover, the OLT aggregates all those fibers to one backbone-link that connects it to the Internet, thus, sharing one line for all the area covered by 1 OLT.

The principle that makes the user-aggregation model feasible is known as statistical multiplexing. It provides a link utilization improvement – or gain – when several uncorrelated user random flows merge over a shared trunk. Carriers use the statistical multiplexing gain to save costs in the high-capacity trunks by increasing its utilization – increasing the throughput. Thus, the rule of thumb used by carriers allows multiplexing several flows requiring less than a 5% of the sum up of the individual speeds.

Operators are using statistical multiplexing metrics to design the trunks where customer's flows are converging in, see Andersson (2000) and Cao et al. (2002). Each individual traffic flow follows a random pattern depending on the type of contents, the user habits and the type of access network used. When each of those individual flows, assumed independent, merge over the same trunk, the statistical properties tend to be markovian where traffic peaks are smoothed due to the overall utilization increased.

Basically, it groups randomly packets sent from multiple users. These packets are grouped into the backbone network, the order would be something like this: first, it entries one packet from the first user, then a packet from a second user, now three packets from a third added to a new packet of the first, and it continues like this as long as the network is active. Individually it would have seemed that the third user flow is sending a burst when he sent three packets, but it is smoothed when aggregated to all the traffic. Legacy networks controlled this capacity sharing through the implementation of buffers that collected each flow and merged them to one flow at a known speed rate. Currently it is the overprovision of the backbone the first rule, as the less conversions than a packet suffers from optical to electrical the better, so old solutions like buffering are less and less common, see Popescu & Constantinescu (2011).

The result of applying this methodology is that the statistical multiplexing accommodates a high number of customer's traffic flows over the same trunk at higher speed rate, but at much lower speed than the sum up of all individual flow rates.

The drawback of this methodology consists of balancing the savings on the common trunk and the individual quality of service perceived by each customer. Carriers tend to use heuristic metrics and their own experience to balance the equation. As we have said, most carriers apply a rule based on selecting a variable value between 2% and 5% to seize the bandwidth needed for the common trunk depending on the number of users. Once the network is delivering customer's traffic, a continuous monitoring of the network traffic allows a finer measurement to adjust the speed needed depending on the quality of service offered to the users, the cost of the trunk, and traffic consumption pattern changes as well as the number of individual users' flows aggregated on each trunk.

6.2.a) Real Data input

To implement the techno-economic model in this Thesis, we were in need of real data that could help to improve the result of the model, and not just selecting a 2- 5% rule of thumb. After asking permission to different operators, we were granted access to the management system of one deployed fiber network. Therefore, we use empirical measurements obtained from one niche operator that helps us to analyze how the statistical multiplexing may apply for smaller sets of users.

The measurements were taken from a trunk collecting traffic from 572 fiber subscribers with a symmetric contracted service of 20/20 or 10/10 Mbps (download/upload). For such number of subscribers, applying the 2-5% rule mentioned above and assuming that half of the customers' contract one or another speed rate, the maximum speed contracted for the common trunk would be placed between 171.6Mbps and 429Mpbs for 2% and 5% gain values, respectively. Without applying multiplexing gain the nominal speed rate would have been of 8.6 Gbps, thus, needing a much more expensive interconnection trunk.

Figure 27 provides the aggregation of flows from the 572 subscribers. We observe that it follows a regular daily pattern. This pattern is pointing out a busy hour approximately between 20:00 and 21:00 – we define the busy hour as the sliding 60minutes period of the day where the trunk is carrying more traffic. The observed peaks of traffic allows designing the suitable network trunk capacity that must be close to 140Mbps to carry the maximum peak observed during that week. It is worth to notice that this maximum speed is close to the lower heuristic value for this trunk – 171.6Mbps at a 2% approximation. The traffic pattern seems quite stationary during the whole week, highlighting Sunday's traffic (March the 23rd, 2014) where it reaches a slightly higher consumption compared to the rest of the week.

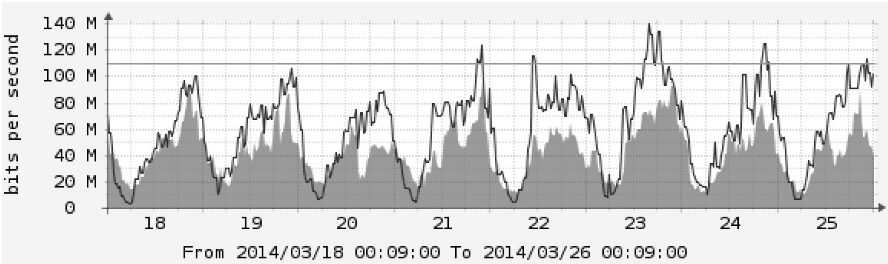


Figure 27. Aggregated traffic for a 572 subscriptions single flows. Week from March 18th to 25th. Upload (full colored grey) and Download (dark line).

Figure 28 shows a zoom of the aggregated measurements along one single day. Download and upload peak traffics are balanced during the whole day, being 133Mbps (at 22:30 approx.) and 102Mbps (at 20:15 approx.), respectively.

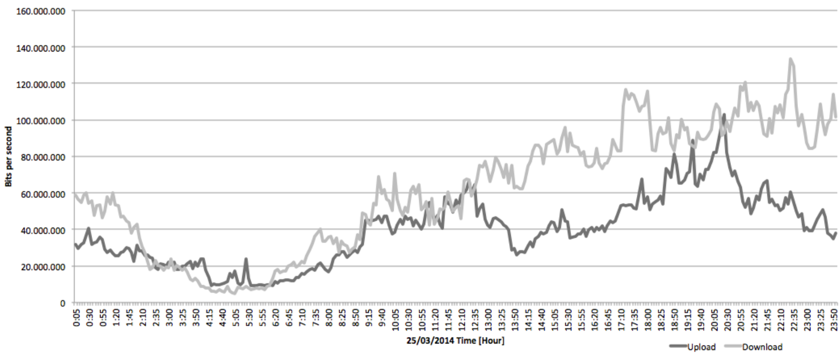


Figure 28. March 25th, 2014, Upload (darker grey) and Download (light grey) measures taken every 5 minutes. Time is shown in the horizontal axis and speed in the vertical one.

6.2.b) User pattern

When going into more detail on the analysis of the traffic flows, we observed that not all subscribers were active during the busy hour. A fraction of users just had the router on, generating a very light signaling traffic to keep the connection alive with no contribution with the user-generated traffic analyzed on the common trunk. Other subscribers got the router device simply not plugged, thus, they are showing no traffic activity on the network. Finally, the rest of subscribers were effectively active and generating most of the traffic carried out during the busy hour.

User measurements and observations allowed us to obtain averaged speed traffics per connection along the whole day and during the busy hour. Table 4 shows that each active subscriber had an average usage speed along the day of 0.99/0.67Mbps (download/upload). The maximum peak speed per user reached a maximum value of 1.33/1.01 Mbps (download/upload) measured during the busy hour.

Table 4 Averaged traffic per active user measured on March 2014

	Daily Average	Peak Rate
Download	0.99 Mbps	1.33 Mbps
Upload	0.67 Mbps	1.01 Mbps
Total	1.66 Mbps	2.34 Mbps

Comparing those values with other measurements found in the literature such as the ones done in Japan in 2009 and published by Sato et al. (2013) we observe that they are lower because they included other narrowband technologies still dominant at that moment. Sato et al. measured average speeds of 43.2/29.9 Kbps and the peak rate 63.9/41.6 Kbps (download/upload) during the busy hour and they keep similar proportions as the values measured shown in Table 4.

The number of simultaneous active subscribers during the busy hour reached 118 from 572 users, representing a fraction of 20.6%[30] subscribers. Although national carriers work with larger figures, we have observed that noticeable gains may also apply in much smaller scenarios, as the user-aggregated model presented in this paper.

An FCC (2013) report measured the current speed rates offered by US ISPs to compare the real to the offered speeds. An interesting result from Figure 29 shows how the average amount of data traffic consumed by users in each speed tier is positively correlated with the speed that each tier is offering. Then, higher speeds tiers means higher data consumption by the average user.

Just to note, the users that have a 50Mbps and makes a usage of 9% of their available Mbps consumption, means that they would be

[30] Real measure equals to "0,206293" and this is the number implemented into the model.

using a 5Mbps all the time at 100%, something that correlates that the more you have the more you use it. Those users will have a problem when they change to a home with 5 or 10Mbps. The main problem will be to guarantee a 100% or 50% sustained connection during all day by any operator, something that will be difficult in a Best Effort Internet – BE in case of traffic, BE packets are discarded on the first router to not add more traffic and avoid congestion problems in the core network.

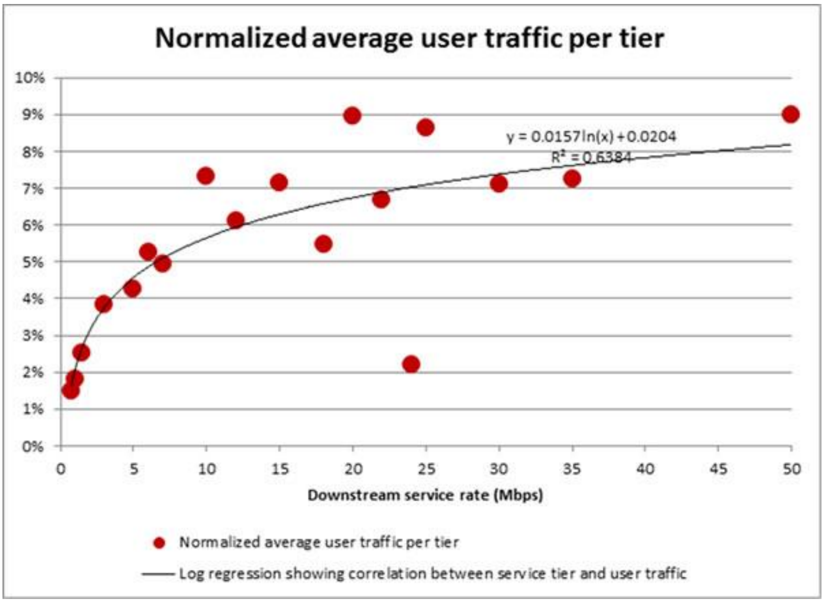


Figure 29. Normalized average user traffic per tier. Image source: FCC (2013).

Concentration of users matters, and because of that, it is important to classify them into different areas types.

6.3. Area density

The area variable defines plenty of times how the model can be implemented and the policies that may apply to one area type can be different from other area's classifications. Primarily are classified according to their population's density or to the possible investments that can be done in each area. Second, they can be classified according to the allowance of public administration involvement in the project. Third, we define the selected area in techno-economic model of this Thesis.

6.3.a) Inhabitants classification

Inhabitants' density is one of the key parameters that is directly linked with demand in every area. Some classifications are using the rural and urban words to classify areas into a business category type for future fiber planning. We will avoid using them to describe the dimension of the city or the classification as a village for their user density links. According to Satterthwaite and Tacoli (2003) there are no clear variables that allow comparing urban and rural because each country uses different criteria that fit for their population and economy. Using user density, we have more granularity in estimating the investments and the potential demand on it.

In this thesis the term *urban area* refers to areas that have more than 4,000 inhabitants per squared kilometer, and as 'rural' ones with less than 800 sq. km. To compare this classification with others like the one done by WIK (2008) we describe in Table 5 the eight geotypes of inhabitant’s density and how they are classified as one of three possible categories: urban and rural, and suburban. Defining suburban as an area with densities that range from 800 inhabitants per sq. km to 4,000. This classification is done according to different GPON deployments and based on their density helps to assert the number of building concentration and potential HH that will subscribe the service.

Table 5. Geotype classification according to household density per square kilometer.

<table>
<tr><th>Wik Consult</th><th>inhabitants density per km²</th><th>Thesis</th></tr>
<tr><td rowspan="3">Urban</td><td>x ≥ 10.000</td><td rowspan="2">Urban</td></tr>
<tr><td>10.000 > x ≥ 6.000</td></tr>
<tr><td>6.000 > x ≥ 2.000</td><td rowspan="3">Suburban</td></tr>
<tr><td rowspan="3">Suburban</td><td>2.000 > x ≥ 1.500</td></tr>
<tr><td>1.500 > x ≥ 1000</td></tr>
<tr><td>1.000 > x ≥ 500</td><td rowspan="3">Rural</td></tr>
<tr><td rowspan="2">Rural</td><td>500 > x > 100</td></tr>
<tr><td>x ≤ 100</td></tr>
</table>

The analysis of vast areas loses details but allows obtaining global results for countries or larger areas. For example, the EU uses a classification called NUTS – Nomenclature of territorial units for statistics – that defines a hierarchical system for dividing up the territory for the purpose of collecting statistics, socio-economic analysis and framing regional policies. The cost of achieving universal service goals in Europe or the USA are approximated by this last classification in its smallest division called NUTS 3. Even the Eurostat Regional Book uses another classification to better model the overall distribution map of the inhabitants in EU defining three types of areas. It defines the rural type as an area of one sq. km with at least 300 inhabitants, and where at least one half -150- of them is distributed on both sides of an imaginary line that splits the area in two parts. A second type of area, defined as Intermediate Urban, uses also one sq. km with densities between 300 and 5,000 inhabitants. The third type is Urban and is for areas with a density of 5,000 or more inhabitants in the same area of one sq. km and where less than 20% of the population density in the area can be defined as rural (Eurostat, 2010).

6.3.b) Three color classification: Black, Grey and White

Another way to classify an area is depending on the availability of broadband offer from more than one provider. The color identifies the allowance to public administration institutions to invest in the area by providing infrastructure or giving funds to an operator to promote and implement a NGAN deployment. The colors are described from the most restrictive on public intervention – black – to some areas where the only possible way to improve the network is to seek public involvement – white.

- The black-areas concept is linked to dense urban areas where it is expected to have more than one NGAN deployment and competition in infrastructure becomes a reality without any investment or aid from public administration.
- Grey areas, are the ones that allow to public investment or aid to deploy fiber NGAN, although, there is some regulatory attention and budget is supervised by each state or the EC – European Commission. A unique provider

usually covers the Grey areas and competition may suggest introducing a new player in the area.

- White areas are regions where there is no clear business plan that project a suitable profit project if an NGAN is deployed in the area. In this case, it is required public intervention to cover its broadband demand. The most common way can be a State aid call or a municipality deployment.

Table 6 synthesizes all three areas regarding broadband-offer and the possibility of Public Administration to invest or not in NGAN in those areas:

Table 6. Area classification type according to existing broadband-offer and future possibilities.

Area	Public-State Aid allowance	Broadband providers
Black	Not allowed if it acts as a private investor*	Two providers (including cable)
Grey	Allowed in some conditions	One provider of basic broadband
White	Allowed if there is not any private investment in the area	No broadband infrastructures

* As a private investor is understood when a Public entity invests money in equivalent quantity as a private investor at the same time and competes to it with a business plan.

6.3.c) Techno-economic model's area

To analyze the impact of the user's sharing-model it is better to implement it in a dense populated area where the effect can be more noticeable than in rural areas where it would be more difficult to extract conclusions of its direct effect. On the other hand, the effect in a dense population will provide the effect that it may have in rural areas too.

We choose the city of Barcelona because we could ask about the real data from the city council itself. 70,676 buildings and 812,044 HH are the figures for Barcelona city, also available now from Barcelona City Council (2010). We assume broadband end-users living in apartments that are grouped in the same building as a single community. According to the Spanish official data sources, Idescat (2011) and INE (2011), buildings are classified into seven categories based on their size that is measured in number of HH per building

We have simplified the number of categories to three: Plan A, Plan B and Plan C, which have an average of 3, 12 and 19 HH respectively. The reason to call them "Plan" is that, like NTT, we will define different tariffs for each community type.

Table 7. Buildings classified according to the number of homes.

Building Plan	Number of Buildings	Number of HH	Averaged HH per building
A	26,498	73,084	3
B	19,808	235,493	12
C	24,361	503,467	19

The sum of the second column in Table 7 results in 70.667 buildings. The difference from the official data, 70.676 buildings, is a deviation of 0.000124299 and it is caused by percentage approximations and decimals truncation. We consider that these deviations will not affect the research answers to the proposed questions of this Thesis[31].

6.4. Classifying operators

Operators are mainly classified according to the business layer where they are focused on. The three layers on the network domain and where operator's business happens are:

- *Content and service Provider.* An operator that offers contents, services and applications to final users, using other operators' communications services.
- *Communications Provider*: an operator that operates the active elements to allow communication inside the fiber network. It provides these services to content/service providers.
- *Infrastructures Provider*: an operator that rolls out the fiber and arrives to the user home or building. It owns the ducts

[31] We want to advise that although they are going to answer the questions proposed, the resultant figures should not be taken as precise and truly accurate. Approximation or tendency will be more correct than to cite data as precise numbers.

and fiber network. It rents these facilities to the communications providers.

Although those are the main types of operators, it exist the possibility that an operator has more than one business network, and it has a role in more parts of the supplying data services chain. Therefore, we include the different operators' classification:

- *Neutral FTTH Operator:* when an operator possesses the infrastructure and the active elements, the ones that enable communication layer. It needs a service provider that contracts its service to sell services to final users.
- *Neutral FTTH Infrastructure Operator:* when an operator only rolls out the fiber and makes connections to the homes, but without connecting anything to both sides of the fiber cables. To fulfill a complete service, it needs a Telecom operator that can use its infrastructures, or a combination of a network operator and a service provider. Depending on the network, it can allow several Telecom operators or a Network operator and several service providers.
- *Network Operator:* it is an operator that only places and maintains the active equipment to allow communications. To understand this classification can be summarized as an operator that only installs and maintain ONUs and OLTs.
- *Service Operator:* when only gives contents and services to final users, so it only takes the upper layer of the chain. It needs the network implemented, but is the one that can sign new users.
- *Telecom Operator:* an operator that provides communications and contents by renting the network infrastructure of some other operator.
- *Integrated Vertical Operator:* it is an operator that plays all the roles: infrastructures, communications, and contents and services. It connects the user, and is paid directly by him, as he is the only provider he can get.

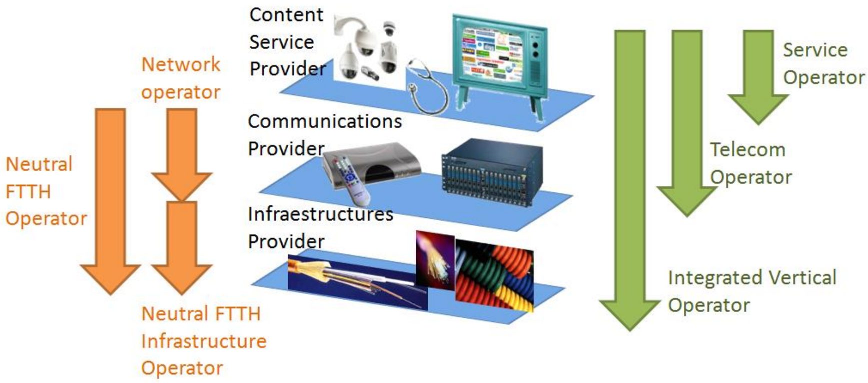


Figure 30. Operator's types according to their business layers.

In figure 1 orange operators, left, are operators that are offering the network to Service providers as a way to reach the user. We could include in here the Australian case, Guifi.net case or other open Access operators. The green ones, right, are operators that are reaching the user. Those operators are usually seeking profit, like Telefónica, Verizon, AT&T, France Telecom, Adamo, Gurbtec and a long etc. The scenario where an operator is controlling all the network and builds some difficulties for the entry of other operators is the case of Integrated Vertical Operators. Those operators are usually imposed by regulatory bodies a way to offer their Infrastructure or communications in a wholesale basis to their competitors.

6.5. Costs

The model described in this article takes into account a very simplified model for the deployment costs. After calculating different possibilities for Barcelona to reach a building can cost from € 260 to € 890 and depends on many variables such trenching costs when necessary, area of deployment, rights of way, etc. After agreeing a price of € 500 as a general price to reach a building in Barcelona we check it with some local operators. The answer is that they are deploying it first in cheaper areas where aerial and façade deployments are allowed. Thus, they are avoiding the costly homes. Table 8 shows the costs associated to deployments into aggregated homes and traditional deployments.

Table 8. Main deployment model's variables.

CapEx and OpEx	Deployment Cost		
	Building	*Single HH*	*Community HH*
Infrastructure (paid once)	€ 500	€ 120	€ 70+
Equipment (paid once)	€ 300	€ 100	€ 50+
O&M (paid yearly)	€ 19	€ 90	€ 45

+This cost can be paid by the user himself if the community deploys the infrastructure and buys cheaper routers or materials.

The model implements three different deployment approaches. As it is shown in Figure 31. , there is an aggressive deployment that reaches 90% of the homes before the end of the second year. There is also shown a moderate deployment model that rolls out the network to 90% of homes before the first decade of the project. The third type is a slow deployment that can provide a project where more difficulties are found when deploying in the city as it takes over 10 years to reach 80% of the homes with fiber.

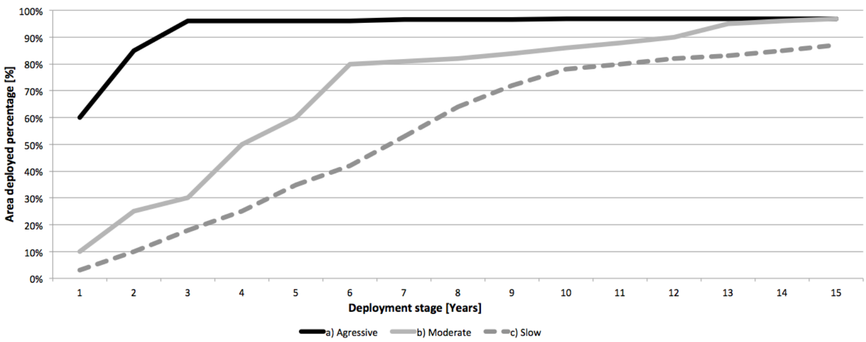


Figure 31. Deployment types implemented by the model. Color lines for deployment types: bold black for aggressive, grey for moderate, and dotted grey for slow.

6.6. Pricing

Pricing is a key element in the analysis of a sustainable project. For that, we first introduce a brief analysis of how the price is set, by doing the reverse calculation.

6.6.a) Real offers unwrapped

Table 9 compares data for a panel of European and U.S. broadband providers with offers above the 100Mbps. They are representing a mix of operators from incumbents to new entrants using a mix of technologies and business models. The first column averages data for large incumbent providers, including Comcast (U.S. cable broadband provider), Verizon (U.S. telephone broadband provider), Telefónica (Spanish telephone broadband provider), and France Telecom (French telephone broadband provider). The second column averages data for European-based broadband entrants, including Numericable and Free-Illiad from France, and Adamo[32] from Spain. The third and last column, includes Google's broadband service in Kansas City. These companies differ significantly in size, market share, choice of technology, and business models, and so hopefully, span the feasible space of revenue models.

Table 9 averages the ultrafast broadband offers of the providers in order to identify the range of revenue contribution available to recover the CapEx costs of deploying a fiber-based deployment.

The following assumptions were relied on in constructing Table 6:

- The retail offer prices are the average of the advertised tariffs of each provider published on their websites as of March 2013. The average prices for incumbents and Google are for retail services offering "triple play" service bundles that include television programming, telephony, and broadband services, whereas the new entrant services exclude TV.

[32] Thomson One database accessed on 2013, February the 25th. Company overview of: Google Inc., Telefónica S.A., France Telecom S.A., Comcast Corporation, Verizon Communications Inc., Iliad S.A. About Adamo, information retrieved from < https://www.adamo.es >. Numericable information retrieved from < http://www.numericable.fr >.

- IPTV, or cable television, costs are estimated as € 26.25[33] per subscriber. This value is from Comcast's (2013) annual report.
- Customer management costs include sales, marketing, and customer service expenditures. These are estimated as a percentage of operating costs. Based on operator annual reports, this ranges from 19.99% to 39.95%, with an average of 21.42% for incumbents and Google. A lower estimate of 17% of operating costs is used for new entrants.
- Telephone expenses are conservatively estimated to be $ 4/line for legacy telephone, and $1/line for newer VoIP-based services.
- Network operating expenses are estimated to be 9% of operating expenses. A review of operator annual reports suggests this range from 5-10% of operating expenses.

Table 9 . Unwrapping different type of operator's retail offers (all table is expressed in €).

	Incumbent/SMP Operator 100Mbps including TV and telephony	New entrant 200Mbps including telephony	Google Kansas, 1Gbps, including TV and telephony
Average retail offer as of March 2013	148.38	54.97	113.39
TV programming cost	26.29	0.00	26.29
Customer management	31.82	9.35	24.54
Telephony and Voice	3.57	4.5	4.5
Network OpEx	13.36	4.95	10.21
Margin before Taxes	73.35	36.16	47.84
Taxes	8.40	9,.4	6.42
NET Margin per subscriber	64.95	26.62	41.42

[33] All the conversions are done at a change rate of €1 = $1.12, on June 2015

With these assumptions, the above analysis suggests that ultrafast broadband operators have something like € 26 to € 65 per month per subscriber to recover the costs of providing ultrafast broadband services (representing a net margin of between 45 to 55%).

6.6.b) Averaging pricing by download speed offered

To determine the price we should be setting, it is important first to examine how retail broadband pricing offers are targeted in the market. We use the data published by the FCC (2012) on broadband pricing offers in 38 countries available during August 2011 to February 2012, reported both in $USD and Purchasing Power Parity (PPP) deflated $USD (PPP deflators are commonly used for international price comparisons).[34] We converted this data using the conversion of €1 to $1.12 as of June 2015. The FCC data includes 565 plans offering speeds above 30Mbps. The average price for these plans was € 49.29, or when PPP deflated, €-PPP 64.13. Table 10 presents the data broken out by speed tiers.

Table 10. Worldwide retail offer's prices categorized by speed type.

Monthly Offer Type	Average PPP €	Average €	# OBS[+]
Equal or Above 1Gbps*	157.16	112.03	16.96
Between 75 Mbps to 1Gbps	73.02	56.08	251.79
Between 50 to 75 Mbps	46.43	35.44	130.36
Between 30 to 50 Mbps	62.91	48.76	105.36
All offers over 30 Mbps	64.13	49.29	504.46

*Excludes Slovenia, with an offer from T2 operator of 1Gbps priced at USD-PPP €1,478 that is a clear outlier

+Number of Observations

[34] Whether it is better to focus on USD or PPP-adjusted USD prices is open to debate; we report both here and leave it to the reader to determine which is more interesting. The source of the PPP deflators is identified in the FCC (2012) source documents.

6.6.c) Setting the Thesis prices for a community-sharing building

To compare the impact of user aggregation we will first use exactly the same pricing scheme whether the final user is a single HH or a community. In this case, the operator has not realized of the opportunity of deploying FTTB and users take advantage of it by sharing their in-building connection and get individual subscribers for a lower monthly offer price. This model offers to both, community and individuals, the same price and connection. It consists of a basic Internet access at a maximum symmetric speed of 1Gbps, but in the case of the community they share the 1Gbps at the entrance of the building. The techno-economic model only assumes the broadband Internet access and does not include any kind of content (TV, video on demand) neither voice nor mobile service. We assume that end-users may contract those services separately to the Internet access to third parties or service providers, also known as services Over The Top (OTT).

To set the price we base the operator's retail offer on the market it is targeting. In this case a 1Gbps market should be marketed around € 100, something we have seen in Table 11. On the other hand, we know that some countries are still surcharging the 1Gbps service. Because of that, we include an updated table for the Spanish 1Gbps market as we are implementing this model in the city of Barcelona.

Table 11. Barcelona's province 1Gbps retail offer's prices.

Operator	Speed	Vat included
Adamo	1Gbps	34.99
Telefónica (+fixed telephone)	300 Mbps	55.4
Fibracat	1Gbps	99.99
Gurbtec (Guifi.net)	1Gbps	24.2 stakeholder 48.4 new neighbor

As we can see, in Barcelona province there are four main operators offering 1Gbps. Telefónica says that for € 5 more (VAT included in all prices) one user will get the upgrade to 1Gbps, but this offer is still not available. Telefónica includes the fix telephone, a service that should decrease the cost for serving only data. Adamo is the most aggressive of the three private providers, and it offers for € 35 a 1Gbps in Barcelona. On the other hand, in a more rural environment and far from the city there is Fibracat offering a 1Gbps at € 100 per month – one cent discount provides the € 99.99. There is also the explained case of Gurbtec – selling its data service over the Guifi.net fiber network - that provides the data service over the users deployed network. Gurbtec pays to Guifi.net the OpEx, upgrades of the network, and acts as the Service provider to the user/stakeholder/owner of the network. The cost is € 24.2 per month, something that may seem cheap to the rest of the users for getting a symmetric 1Gbps. Moreover, if a neighbor also wants to be connected, and he did not collaborated with € 1,000 to the network deployment, it will cost him € 48.4 per month to get the same service and connection – risk in this project helps to obtain a lower monthly offer, and maybe recover the investment in 4 years. This 50% discount in the deployed network is quite important, as after 4 years, the difference is about € 1161.6, something that helps to promote the investment in the project form the first moment. Not having taken the risk of investing money at the beginning is positive too for the new neighbor. He has no deploying fee for the same service, so it is also a way of paying Guifi.net and Gurbtec the cost of deploying the necessary last meters fiber and making the network more sustainable in time.

On the other hand, if they get the Adamo, Telefónica, Gurbtec or Fibracat connection in Barcelona, all options priced without the user involved in the network deployment, the retail's monthly price would be set between € 35 to 99 per connected building. Thus, if the users were joint to deploy the in-building to share one connection, the price among the building's HH would be nonsense compared to a single connection. Although this option has to find a regulatory framework where it can fit in, we think that it is possible to be implemented from the operator side by lowering the monthly offer's price to incentivize the users to deploy the in-building network. The operator can go further and even deploying the street network in cooperation or partnership with users acting as stakeholders, this operator would follow an FTTC deployment approach.

6.6.d) Setting price differentiation for a community-sharing building

As we can appreciate, the profit-margin for Gurbtec when users are a stakeholder are reduced to the minimum, as they are the owners of the network and benefit of being the stakeholders of the network.

Thus, a user could deploy himself part of the network. In a dense area, they only would deploy the in-building and a small tram in the street network – FTTC or FTTB solutions. This action could decrease the margin of the operator to a 20% – from the original calculated percentages of 45% to 55% provided in point 6.6.a. Again, the user should become an operator, or ask to an existing one to deploy the network in public domain, as people cannot deploy staff in the public space.

Taking the fiber-sharing-solution of Guifi.net as the main reference, and adding to it the 20% profit margin, the price would be set at € 29 per connected HH. This price would reflect an operator that has a low-profit objective profile and it is providing a 1Gbps connection over the sharing-network built by the final user. As in the point 6.6.c the cost model only assumes the broadband Internet access and does not include any kind of content, neither voice nor mobile service.

A second scenario foresees a pricing scheme split to differentiate single HH from community access services. The monthly price is proportional to the number of HH engaged in the sharing-community project. Thus, we can approximate the real number of active users that will be connected to the FTTB or FTTC provided solution. Based on Table 4 in point 6.2.b the average number of users suggests that for Plan A we can approximate it to one active user, for Plan B to three active users, and for Plan C to four active users.

Table 12. Number of active households (HH) per building plan.

Building Plan	Average HH per Building	Average number of active subscribers [a]
Plan A	3	0.62
Plan B	12	2.45
Plan C	19	3.92

[a] Number of active users in the Busy hour, not an all-day measurement

Single HH will have a standard monthly fee that will be independent of the number of HH engaged on each community. Thus, Table 13 points out the benefits of a community-sharing network and calculates the monthly offer per HH according to its proportionate usage of the network. If we share a fiber among 19 HH from the FTTC cabinet where the operator's network arrives, we could be getting a monthly price per HH 5 times cheaper than what can be obtained as a single HH connected with operator's fiber.

Table 13. Number of active households (HH) per building plan.

Building Plan	Average HH per Building	Price per Building that the operator targets based on usage	HH montly price based on HH number and operator Building price
Single HH	1	A	A
Plan A	3	1 x A	$\frac{A}{3}$
Plan B	12	3 x A	$\frac{3 \cdot A}{12} = \frac{A}{4}$
Plan C	19	4 x A	$\frac{4 \cdot A}{19} \cong \frac{A}{5}$

The approximation of A as a single user can be the user that wants to be connected by the operator that has a low-profit objective profile and offers a 1Gbps connection by a monthly offer price of € 29. From a consumer perspective, one may think directly on price, but we should remember the available speed per user is also going to be better than most people may think. In a single HH served by the fiber-operator's network a user will enjoy from a 1Gbps. As we have shown, sharing the network among three HH, Plan A, a user will even notice that there is someone else connected, so, he will have a close to 1Gbps available. Plan B considers a traffic generated pattern equal to three active users connected, so, on average, and granting fair mechanisms implemented, a Plan B user will get a minimum of 333Mbps available. Plan C, with 19 HH sharing a fiber, and 4 active users generating traffic to the trunk in average, makes that the minimum a user can get here is a 250Mbps connection.[35] We want to remember that the only price where the user do not deploys part of the network is the case of a single HH at € 48.4 price per month.

Table 14 . Monthly offer price per households (HH) in a shared deployment.

	Building Plan			
	Single HH	*Plan A*	*Plan B*	*Plan C*
Monthly retail's offer price per HH	€ 29 € 48.4*	€ 16.13	€ 12.1	€ 9.68
Operator income per building plan	€ 29 € 48.4*	€ 48.4	€ 145.2	€ 193.6

*The user in this case connects to the network after being deployed; the only way to do it is as a single HH.

[35] Of course, the maximum a user can get in a Shared network is 1Gbps, when we say the minimum, we understand that the maximum is the same that one user can get if he is the only active user in the Shared-network.

Chapter 7

SHARING COMMUNITY IMPACT

"The true delight
is in the finding out
rather than in the knowing."
-Isaac Asimov

The impact results are the consequence of asking why something happens after observing and studying it. The images and figures included in this chapter are part of the work done to solve the hypothesis proposed some years ago. As Isaac Asimov said, it has been interesting to learn all the way round here, and the bad results not included in this Thesis have always being a proof of working hours, and detecting small mistakes or big errors in our hypothesis. These results allow enriching the conclusions exposed in the following chapter.

7.1. Sharing variables model

We describe some of the most model variables settings that are part of the results itself.

7.1.a) Access network, a matter of distance

A different combination of types of trenching techniques – e.g., in-road, under pavement, field – depends directly to the civil works cost required to deploy the fiber-cable. Every scenario involves barriers to deploy the ducts to reach the PoP and households. The model accounts for this combination of techniques depending on the described rural suburban urban areas.

The length from the PoP to the home is different between high-density areas and rural areas. As Figure 32 shows, the European market has a high percentage of its subscribers – around 80% – at a loop length distance of 3 kilometers.

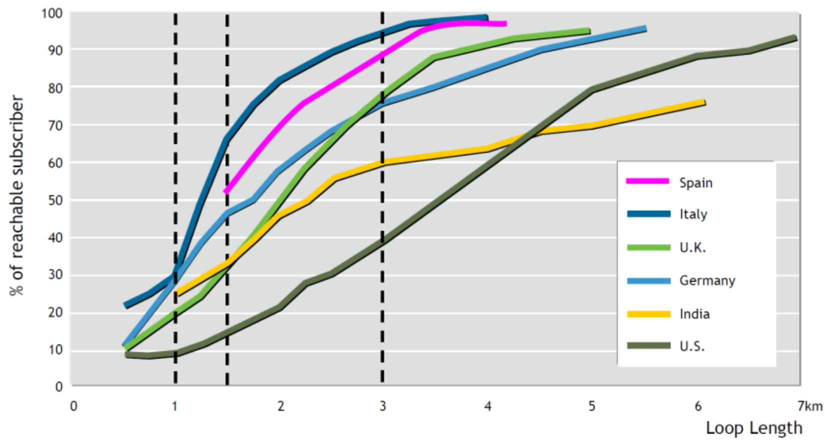


Figure 32. Cumulative loop length distribution in various markets. Source: Alcatel (2007).

We have studied the distances from the PoP to the first splitter or cabinet. Model assumptions are shown in Table 15. The value of 1600 meters is approximately a mile distance given in meters. It is also one of the first distance measure available for Spain; area where we based our model variables. US deployments are difficult to compare, as they are approximately 2 Km further for any percentage of reachable subscribers than any European analyzed country – Span, Italy, U.K. and Germany. Something that gives a hint on the possible explanation on why Verizon Model or Google Model, as both American companies, is targeting high dense populated areas.

Table 15. Distance assumption for every defined area.

	Area Type		
	Urban	*Suburban*	*Rural*
Average length of the first tram: PoP to first splitter	1600 m	2400 m	3800 m

7.1.b) Take-up variables

Demand estimation or take-up rate models are crucial to make fiber deployments sustainable and profitable. Like in the referenced techno-economic models, we will assume a common targeted market of 45%. We think it is reasonable to do so as a second mover can deploy in the same area along the fifteen-year investment.

The model analyzed in this paper needs to differentiate between the take-up rates per targeted segment: single HH and communities. In both cases, the new entrant operator expects to reach the 45% of the whole market. Figure 33 provides the Take-up rate curves implemented in the model.

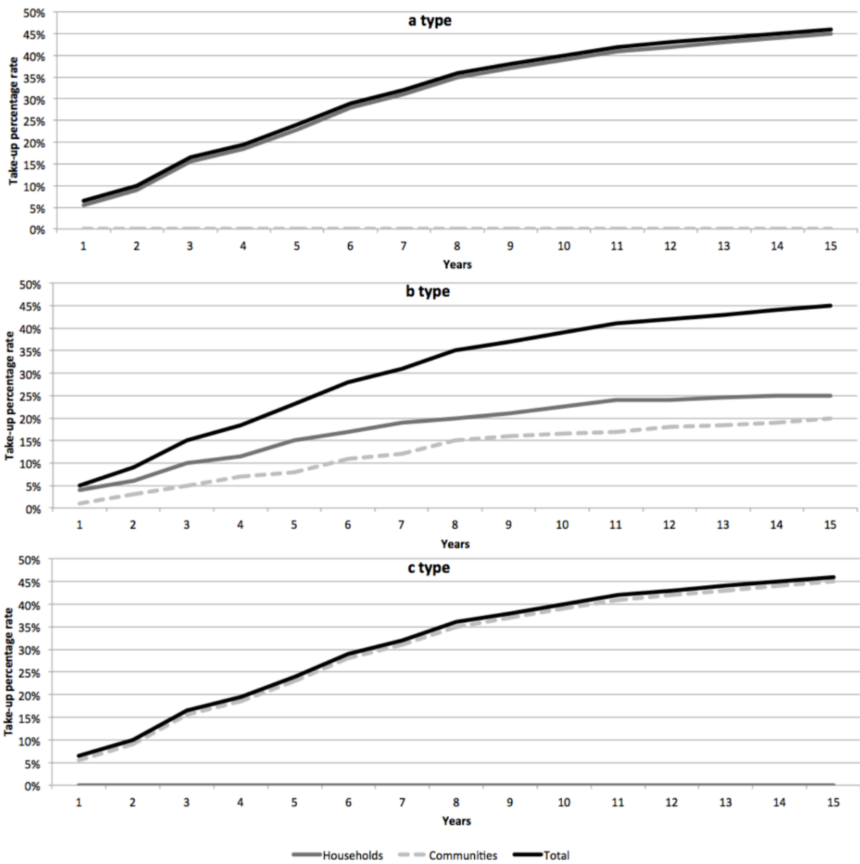


Figure 33. Take-up rates included in the community-sharing model.

7.2. ROI, NPV and PB results for the community-sharing model

The techno-economic model evaluates the investment targeting three main variables: the net present value (NVP), the return of investments (ROI) and the payback period (PB).

Table 16 shows for each combination of deployment model, take-up scenario and pricing scheme, the number of years needed to achieve a positive NPV, or to get a ROI at an interest rate of 10%, and the payback period.

The aggregation of users is clearly affecting all three variables, becoming the whole investment non-sustainable in some scenarios where the operator ignores price differentiation, and therefore the community model.

An operator that ignores the community take-up model has an approximate 10 years delay impact of the investment economic variables when compared to an operator that applies a differentiation model. Differentiation of pricing makes the investment less risky and all investment lengths become closer.

The mixed take-up rate scenario, that considers a mix of targeted demand with 25% of households and 20% of communities, is quite consistent reaching positive returns in no more than one year over the traditional scenario. This fact presents a new problem, which is the one of detecting the sharing community model by the operator that is ignoring the case by taking into account economic parameters only.[36]

Based on the model results, the aggressive model provides better ROI periods at equal take-up scenarios for the different deployment strategies.

[36] We know that technologically the number of equipments connected to the same ONT can be limited by setting the maximum number of allowed concurrent equipments. Thus, the operator could limit that, but it also would prevent some home advances, like Internet Of Things – IOT – implementation. Otherwise, traffic inspection per each ONT would expose any operator to a detailed analysis issue difficult to sustain in front of users privacy.

Comparing the overall project cost when covering the reference scenario (only single households) and a user-aggregated one (only communities), the model estimates from both the total costs for the operator's investments in €132.8M and €73.2M, respectively. The reduction in costs is noticeable, becoming a 45% less that represents an interesting strategy to lower the investment barrier for new entrants.

Table 16. Results of the Techno-economic model. ".25" answers to the first quarter, ".5" to the second quarter, and ".75" to the third quarter of a year. Colored are marked the projects that have a long-term return that is over what private investors seek.

Model		**Operator model**					
		Differentiates Single HH from Com.			*Ignores Com. Case*		
Deploy	**Take-up**	*NPV*	*ROI**	*PB*	*NPV*	*ROI**	*PB*
Aggressive	Single HH	5,25	4,25	3,0	5,25	4,25	3,0
	mixed	5,75	4,75	4,5	6,75	6,0	5,75
	Community-sharing	6,5	5,25	5,0	15,0	14,5	13,75
Moderate	Single HH	6,5	5,0	4,5	6,5	5,0	4,5
	mixed	6,75	5,5	5,25	7,5	6,5	5,75
	Community-sharing	7,25	6,25	6,0	NS	19,75	18,5
Slow	Single HH	6,75	5,25	4,75	6,75	5,25	4,75
	mixed	7,0	5,75	5,5	8,0	6,25	5,75
	Community-sharing	7,5	6,5	6,25	NS	NS	19,5

NS = Not sustainable; * ROI considering a 10% interest rate

Chapter 8

CONCLUSIONS

"I am turned into a sort of machine
for observing facts
and grinding out conclusions."
-Charles Darwin

This chapter exposes the main conclusions from this dissertation. We proof in this Thesis that there exists a feasible way for users to achieve a fiber-deployment to their homes. This conclusions chapter is split into different points about the different role played by each network actor: *user*, *operator* and *public administration*. It also includes some future research points that could help to deep in come interesting points that this Thesis has merely explored.

This dissertation has provided a fiber-sharing network model and its analysis. From Telephony to Data, operators have searched the same business conditions and provided a fix infrastructure change, in this case: copper by fiber – unless in some places where TV had bad coverage signal and cable was deployed first, providing an unexpected competitor in fix access networks, the cable companies.

One of the keys on planning any network deployment is to estimate the number of users that will opt-in for our product as we prepare a business plan. This number becomes the foundation to obtain the revenues projection figure that will lead to explain its positive future results. It also forms the pillar to obtain the necessary budget that covers the fiber network upfront investment, compound most of it by CapEx. The OpEx is calculated after obtaining the number of fiber-service adopters. The community-sharing model distorts those plans, and it may affect the final output of the project, as it has a direct effect on the number of users' estimates.

Consequently, ignoring the sharing model will carry some unexpected delays to the scheduled times and planning for the fiber-based project. Not only that, it will also have a negative effect on the projected revenues expectations, as the possible number of fixed lines is severely reduced in the areas where sharing happens. Thus, the community-sharing model introduces a time uncertainty variable to all those business model's plans and their odds to succeed in the implementation of a fiber network.

Otherwise, when the community-sharing model is taken into account, a possible top-down approach model can also be set in place. A first example could be by reducing the monthly retail offer price when the connection is shared, see the NTT explained model as an example. This example allows users to join in a shared connection way, where the operator controls the home-equipment and part of the network. The fiber network reaches the curb or to the building and users connect themselves to the last drop of the operator. Hence, it is deployed and shared by the users themselves, although the operator carries out the point-to-point control by having its own equipment at the users' home.

Nevertheless, the bottom-up model brings more possibilities to any new operator, unless the operator is only devoted to the infrastructure layer and plans obtaining a high margin with it – in this case, a high margin of the installed optical fiber cable can derive in parallel networks to avoid this toll or expensive service offers to run on it. One of the possibilities that the community-sharing model brings is a way of promoting the Horizon 2020 and the different Digital Agendas exposed in this Thesis. The model of an economical digital layer that goes on top of a network is clearly the way that matches with the bottom-up model. A fiber-network is considered the gate to the content and goods, and this door has to be as open as possible, in this case with a fair price (we don't need five guys holding the same door), faster as it can be (we don't want a revolving door that has such a slow spin that we have to leave by the time we are inside), and secure (we don't want a false entry, or a backdoor entry to the same closet were we are in private).

The model exposed in this Thesis guarantees a fast fiber connection, albeit shared among some neighbors that will not diminish our speed connection; statistical multiplexing applied from the user perspective allows obtaining such big speed per user even when sharing the same connection fiber cable.

Moreover, it is possible to set a price that allows sustaining the network and making the deployment feasible. At the same time, it will provide transparency on the charges applied to each user; remember the user is now a stakeholder. Thus, each user will choose his OTT service providers that are offering different contents, services and goods. The security point remains as a future research goal after analyzing different open and shared implemented networks. Instead of not seeing some possible secure implementations, like implement an IP-VPN differentiation per user, or ciphered and keys communications, etc., we observe that users are controlling part of the network in a shared way, and they must be capable of trusting each other, or at least, trespass this responsibility to the installer that sets a security method in place. Another more advanced solution would be to give advance knowledge about the equipment they are installing to configure them in a secure mode. As we have met with security researchers, we decided this point should deserve another research line and it has not been properly deep explored in this thesis, something that will remain as future work.

8.1. User's network role: the main player

As the Thesis shows, users can make a big impact on the current fiber access network deployment models. User has been considered the key element from the business perspective since the start of the telephonic system. Now, after running a data interexchange network called the Internet, users can trigger and implement a fiber-based network deployment.

The main reason is that users are playing a new role in the access networks: a stakeholder of the broadband network. The Guifi.net model has been a good source to improve the techno-economics methodology applied in this Thesis. Having implemented a bottom-up broadband model approach has been a first iteration of the techno-economic model. Although the Guifi.net model has been implemented in a rural scenario, Gurb, the inhabitants (lead by the knowledge of Guifi.net) managed to make the investment feasible and sustainable based on two main points. First, because users provided the fiber-network upfront investment; approximately they invested € 1000 per connected home. Second, because they managed to involve as many neighbors as to decrease the interconnection's price, something that provides a sustainable 1Gbps connection per user. We acknowledge that the trust and confidence users are granting to Guifi.net may come form the sharing Wi-Fi networks where they created one of the biggest wireless networks worldwide with more than 25.000 nodes across the world, but mainly in Spain.

The fiber-sharing model allows sharing the capacity by many, always based in one big hypothesis: no data caps are applied. See that no offers included in this thesis are applying data caps; only the ones given by 3G and 4G routers to the residential sector are doing so as a common practice. Nevertheless, this could prevent implementing the community-sharing model with one operator that applies them. Except, that this could also have a reverse effect of pushing users to implement and adopt a complete sharing model and avoid operators that are applying caps.

As we have explained, statistical multiplexing allows sharing a Today's capacity of 1Gbps among 16 to 20 neighbors without noticing a great impact on the user experience. Measuring real data has brought to the analysis a better usage approximation figure and strength to the argument that with the current usage it can be unnoticed to the user experience when they share or not their community-access network.

Even in the case that a top-down operator adopts the community-sharing model, it results in a higher speed access connection offered at same or cheaper price than today single *broadband* connections. Remember than according to chapter 6 two of the main motivations to change to a top-down or shared infrastructure are to be in an underserved area or get a cheaper way to connect where there is already a Broadband solution. Taking the latter as a motivation for change, it would help operators to seek this shared solution as a way to promote the rollout of a new fiber-network.

However, the current deployed fiber-networks are in need of an operator that includes the community-sharing model as a business model. If all the telecom market agrees that the take-up rate is the variable that we all must take into account, we also agree that fiber is having a slow adoption curve. Except some countries like Japan, or Andorra, that deployed fiber to all the country HH and replaced whenever was possible the existing copper by fiber, or at least, lowered the fiber price to make the change happen. To offer a fiber solution ten times the speed than a copper one, and at the same price, helped in cases like Japan or Andorra. The result of doing this with state aid is that to obtain profits of this huge investment in less than 15 years infrastructure network competition in those countries lowered to one fiber-network provider.

One of the points that the model also solves, is the FTTH access deployment. To reach all HH, fiber must be deployed in the in-building. A Top-down player like NTT solved this problem, as we have referred many times, by acknowledging the role and power of the users and giving them some reasons to act as network access investors.

Policies promoting this community-sharing model will increase the take-up rate in the areas where they are allowed. We base our conclusion on the example followed by the US government launching the One Gigabit Nation program – after the Google Fiber model was launched in Kansas and Austin. The program aims to connect at least one city in each US state at 1Gbps home-connection speed. We have seen also that Google involves the users since the beginning of the project planning. First, on selecting the city, where users can interfere to their mayor and public servants to help Google to come to their city. Secondly, and more important, by defining different areas (fiberhoods) and making a pre-subscription list of users to the Google Fiber project before being deployed. Moreover, it is not deployed in some city areas where it is not reached the goal of a pre-set number of pre-subscription level. This Google model, could also be improved if users could share their street cable and make themselves the work of connecting to it.

8.2. Operator's network role: the bridge

Operator's role has been considered as the one of transporting data or voice from one place to another since the start of the Internet, and previously from the Telephonic system. The so-called carrier or operator carries the signal from user A to user B, something that has already happened for data exchange for more than 40 years. From there to the conclusion of becoming the bridge between different users, and the ones implementing the proposed community-sharing model.

This Thesis concludes that any operator needs to take into account the community-sharing model; making special attention to Chapter 7 results. Of course, when it is only an isolate case in thousands of homes it can have no effect over a large operator. However, when the community-sharing model reaches a noticeable amount of buildings in town, above 10%, it makes the case a first priority to be tackled by the operator that was not taking into account this model and its impact on the economic side to keep its OpEx and revenues balanced.

Like Uber or AirB&B at its starts, it seemed that they could not affect a well-established role like taxi drivers or hotel. The results are that if many people values the sharing model as a valid and good one, it may generate a conflict with the already established ones. Moreover, it becomes an unexpected business competitor that uses already existing goods, like a fiber network that was not meant to be shared among users, that where constructed with usage patterns and their according revenues projections. For instance, Uber numbers in New York City are above the yellow taxi drivers in number of cars, but still remains a 10% of the taxi economic Pie in the Empire State city.[37] Operators have now the opportunity to become the bridge of the community-sharing model and their current top-down model.

[37] Number of taxi cabs is higher for the Uber than NYc yellow cabs with a medallion http://money.cnn.com/2015/07/21/news/companies/nyc-yellow-taxi-uber/
The regulated Taxi business has decreased a 10% in NYc since Uber irruption http://www.businessinsider.com/taxi-trips-down-10-percent-new-york-uber-2015-8

One possibility to become that bridge is the one followed by the NTT Company. This example may be the easiest to be implemented and controlled. It provides a monthly price offer reduction according to the number of homes shared over the same access fiber. This measure minimizes the economic impact of user community-sharing solution and, as we have already explained, it helps to reach each user's home by placing some hardware there. By doing this, operators can deploy solutions that work to all the service adopters as they can control the hardware configuration end to end.

Otherwise, when users are the ones deploying their fiber section of the access network, they are in need of an operator figure that maintain and deploy the network. As the example from Guifi.net and Google, users were willing to have fiber at home, but they lack of the knowledge and trust to become a local operator and deploy the entire community. Therefore, operators can become the enabler of the community-sharing model in areas where the will of this model is already in place and can help to minimize the deployment cost and maximize the take-up rate.

Although the two explained options, there is a third possibility: to form or become an operator that implements the community-sharing solution. In this case, we can conclude that the model allows covering a large area without the need of making a huge upfront investment. As the operator is the one implementing the model, it can keep each user paying a monthly subscription, which remains at the same time as an entry channel to each user's home for new products.

We found that when the community-sharing model is in place, the price is set at 1/5 (20%) of the total monthly current price to be paid by each user (when compared to a top-down deployment). This can be seen as a handicap from the revenues side, rather than the high ARPU it could be obtained with a non-sharing model per each user. The sustainability of the model is set as the sharing model obtains a higher number of take-up rate per building covered. The example of Guifi and Google show that they reached in both cases more than 50% of the market in the area, leading to better number of fiber take-up rates than traditional operators do (20 to 30%).

Although we have focused on the residential segment, with the results of this Thesis, we can also conclude that the sharing model would have even a bigger impact on the business segment if implemented. The possibility to share a fiber connection among the business segment is not far from reality if we admit that business-offices, shops, factories, and other retail businesses are commonly clustered in the same building, area or street, just creating a hub in some areas. Thus, the sharing model would be even easier to implement in this segment.

8.3. Public Administration's role: facilitator

One of the points observed as a barrier for the sharing model is to obtain a competitive price per connected home. Consequently, the price of deploying FTTH solutions through the streets and motorways is the main variable to study. Infrastructure sharing is one of the options studied in this dissertation as it can lower the upfront investment necessary to deploy the new fiber.

So, what have to do the public administration with operator's rights of way or their high deploying costs? They have several options. An easy one is renting the public/municipal owned infrastructure, not only conduits, but also dark fiber, or active equipment. Allowing aerial deployments in areas where there are aerial cables in place, or at least providing the rights of way to operators is also a possibility that help to decrease the fiber rollout. Mandate to join the trenching between operators that are asking permission to deploy their optical fibers (only digging once), and even between different utility providers that open streets (like water, gas, energy) is more difficult as it needs coordination between different actors, but the results are better for the citizens and the cost of deploying the infrastructure is shared among the different actors implementing their networks. Policymakers are also allowing service providers to compete on top, but they also have to grant fairness in buying the content to provide, as users want to have access to the OTT services, not only to have a better connection.

A possible way, but still unsaid possibility, is to devote part of the public budget to investing in the new fiber network. Although there exists in Europe the three-color area rule (black, grey and white), any possible dime injected to the fiber deployment will be recovered by the public administration is a short period; 5 to 8 years after doing so.

We can conclude that public/municipal owned infrastructure end with a lower rental price for their infrastructure, they can even collaborate by offering it free to the new operator. On the other hand, incumbent operators sees the infrastructure ownership as a way of generating a barrier, and to support this statement, the rental price for ducts and posts are more expensive and difficult to deal with than the public ones (some NRAs, like the Spanish one, helps to set some regulated prices when they can designate a SMP). For instance, some states in the US do not propose to allow a rental for a path between A and B points, and operators have to deal in a one-by-one post rental agreement. That way, the new entrant operator is forced to deploy a parallel infrastructure network to obtain a similar speed offer and services into the same area, or delay its fiber-network rollout due this bureaucratic allowance.

As explained in the second chapter, this Thesis introduces a new sharing model that can be another solution to take into account by the different Digital Agendas if they want to achieve their goals in the expected time. The year 2020 seems the year where most of them have a confluence, and specially to cover all European HH with 30Mbps and half of the European HH at 100Mbps download speed.

Above all the Public Administration, there are the national regulatory bodies like CNMC, FFC, MIC, etc. that have to preserve competition, but also should allow new policies that may allow to accomplish the Digital Agendas. Sharing is now somehow included in all new regulatory policies that those NRAs are issuing. There is the last step of allowing to share not only between operators, but also to share the network with user communities.

Just to give a clear example of how policy can have a big impact over the fiber market we have the US broadband definition. One single definition from the policymakers is changing the game scenario for operators, as they cannot offer anymore a broadband labeled connection if they do not offer more than 25Mbps. It has also given awareness to users about what type of connection they are already getting. Today, 2015, about a 16% of the US HH are not ready to obtain a broadband connection, instead of the 3% they had with the old definition a few months ago. This measure is seen as a way to increase the demand side for fiber, but it also helps the public administration to better identify the lack of real broadband access and the lack of competition on broadband. The US was acknowledge to have a good competition broadband fix infrastructure level with 88% of users that could choice between two or more broadband providers, currently the percentage has lowered to a 39%.

8.4. Future work

After studying and observing the fiber network deployments in this Thesis, future work should focus on extending the community-sharing model to its policy ruling and explore its implementation in other market target rather than the residential one.

One of the possible extensions of the model would be to include the business sector by building a sharing network among them, but including the same services that they can currently get from a dedicated and guaranteed traffic, signed on their QoS agreement.

User decision-making is also a very interesting point to understand why he collaborates or not in a sharing model. It would bring better understanding and improvement to the sharing-model adoption projection. We believe that Game Theory could be one good methodology to study that. We started implementing it for observing the adoption results, but we only got the basic results as we do not had real data to include in all the variables that produced an effect. Some of the variables are the number of friends/family/neighbors adopting the new operator product, its possible price reduction, operators retention cost and effect, and plenty of more variables that would come up from the relations set between the triangle user/operator/public administration.

TV content and its effect over retail pricing offers has been something difficult to analyze. What we have concluded is that in the US has a bigger impact than in EU. However, the way the content market is regulated and how OTT services are starting to be regulated would provide far better approximations on how to include costs on these model variables. We have now started to experience the TV content battle in Spain after the operators realized that users do not see fiber as one of the reasons to change.

Security issue is something trendy in the news, although we recognize the need for deploying a secure model when the network is shared and ran by the neighbors' community. This point would give more confidence to the users that put their privacy in their number one position of their top-list of reasoning to adopt a new product.

The policymakers should learn and study the effects of this community-sharing model and start to do some drafts about proposals including the community-sharing model as a possible one and the one that brings benefits to all the network players. At least, they should apply new policies against the barriers and agents that want to block this type of implementation. As it happened in Kansas after Google took its agreement to deploy their network, the Court was close to pass a bill against public administration allowing the pass of fiber cables through their conduits and posts (luckily people brought it at the center of the media and it stop that the bill was passed).

The model can also be explored form only the technological side, which would provide plenty of new research to ease its implementation. Even some protocols could be able to be modified if the sharing model is placed as the model to be implemented. Thinking on WDM and its implementation, it would bring special cases where sharing a wavelength could be done over different communities that also share a fiber, bringing new possibilities to the OLT and the capacity transport they can support.

We expect to have given enough ideas to allow a new student to get the necessary inspiration to start working on a research specialized area, and specially the one to Bottom-up networks deployments.

ACRONYMS

ADSL	Asymmetric Digital Subscriber Line
ARCEP	Autorité de Régulation des Communications Electroniques et des Postes
ARPU	Average Revenue per User
BEREC	Body of European Regulators for Electronic Communications
CapEx	Capital Expenditures
CMT	Comisión del Mercado de las Comunicaciones
CNMC	Comisión Nacional de los Mercados y la Competencia
DWDM	Dense Wavelenght Division Multiplexing
ECTA	European Competitive Telecommunications Association
ERG	European Regulators Group
FCC	Federal Communications Commission
FFTF	Fiber From The Farm
FFTH	Fiber From The Home
FTTB	Fiber To The Base
FTTC	Fiber To The Curb
FTTCAB	Fiber To The Cabinet
FTTH	Fiber To The Home
FTTP	Fiber To The Premises
FU	Fiber Unbundling
HFC	Hybrid Fiber Coaxial
HH	Households
IBS	Internet Business Solutions
IPTV	Internet protocol Television
IRG	Independent Regulators Group
ISP	Internet Service Provider
ITU	International Telecommunication Union
LDSI	Large Screen Display Imagery
LLU	Local Loop Unbundling

MIC	Ministry of Internal Affairs and Communications
MPEG	Moving Picture Experts Group
NGA	Next Generation Access
NGAN	Next Generation Access Networks
NPV	Net Present Value
NRA	National Regulatory Authorities
NTT	Nippon Telegraph and Telephone
ODF	Optical Distribution Frames
OECD	Organisation for Economic Co-operation and Development
OFCOM	Office of Communication
OLT	Optical Line Termination
OMDF	Optical Multiplexing Distribution Frames
ONU	Optical Network Unit
ONT	Optical Network Termination
OpEx	Operational Expenditures
OTT	Over The Top
P2P	Point to Point
P2MP	Point to Multipoint
PON	Passive Optical Network
QoS	Quality of Service
SDV	Switched Digital Video
SMP	Significant Market Power
TCI	Telecommunication Common Infrastructures
TESA	Telefónica de España S. A.
VDSL	Very High Bitrate Digital Subscriber Line
VOD	Video On Demand
WDMPON	Wavelenght Division Multiplexing PON

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ANNEX I: DIGITAL AGENDAS

The following digital plans were among those considered in preparing this Thesis. Order comes as Country order, not by the name of the Plan:

- Argentina, El Poder Ejecutivo Nacional; "Estrategia de Agenda Digital de la República Argentina"; Spanish written, Buenos Aires, May 7th, 2009.
- Australia, Department of Broadband, Communications and the Digital Economy "National Broadband Network corporation Plan 2012-2015"; prepared for the consideration of the Shareholder Ministers, August the 6th, 2012.
- Austria, Ministry of Transport, Innovation und Technology; "Broadband-Strategy 2020", 2012.
- Belgium, Ministre pour l'Économie et la Simplification administrative; "La Belgique – Coeur de l'Europe numérique 2010-2015"; Quickonomie.be, 2009
- Cyprus adopted the broadband targets of the Digital Agenda for Europe. By 2013 all households will have access to the Internet with at least 2Mbps, by 2020 they will accomplish the EU targets. Information extracted from European Commission, Information Society, and Implementation of the Digital Agenda. 2012.
- Czech Republic, Ministersiva Prúmyslu a Obchodu; "State Policy in Electronic Communications – Digital Czech Republic"; 2011.
- Denmark, Erhvervs – OG Vaekstministeriet; "Bredbaandskortlaegning-2011"; Danish written; March the 8th, 2012.
- Estonia, Estonian Association of Information Technology and Telecommunications (ITL); "Development vision of next-generation Broadband network in Estonia"; Tallin, April 2009.
- Europe, "Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions, A Digital Agenda for Europe", Brussels 2010.
- Finland Digital Agenda, Liikenne- ja viestintäministeriö (Ministry of Transport and Communications); "Digital Agenda for the years 2011-2020"; Suomi written, Government report to the Parliament, 2011.
- France, "National Broadband Programme",French written, April 27th, 2011.
- Germany, it has been read the goals and terms from Germany from different documents and we cite some of the ones we have read to help understand the country: "Shaping Ideas to Shape the Future – Competence, security and new business areas" Edited by different partners in conjuction: Münchner Kreis,

EICC, T-mobile, Tnsinfratest, Siemens, Vodafone, SAP, O2, ZDF. Really important to consult directly data from the Future broadband portal: www.zukunft-breitband.de

- Greece, Information Technology Committee; “Digital Strategy 2006-2013”; Greek written; November the 17th, 2006
- Hong Kong, The Government of the Hong Kong Special Administrative Region; “2008 Digital 21 Strategy”; First published in 1998 but evolved until 2008 as a living document. Last review date December 30th, 2011.
- Hungary, They have a strategic document called “Broadband Development Concept” but it has not been updated for a long period, best explanations are given in: Government of Hungary, “National Reform Programme 2012 of Hungary”; Hungarian written, April 2012.
- Ireland, Department of Public Expenditure Reform; “Supporting Public Service Reform – eGovernment 2012-2015”; April 12th 2012; This release is based on a previous document: “eGovernment Strategy 2010”;
- Italy, Italian Government; “Italian Digital Agenda”; Italian written, March the 1st, 2012. They also added some urgent measures to help the implementation of their goals in a second document called “Misure urgentu per l’innovazione e la crescita: agenda digitale e startup” October the 4th, 2012.
- Latvia, Latvian Cabinet of Ministers; “The next generation of broadband electronic communications network development concept project 2013 to 2020”; Latvian written, Draft concept submitted by the Ministry of Transport2012
- Lithuania; Government of the Republic of Lithuania “Approving the Lithuanian Information Society Development Programme 2011-2019 and Repealing certain Resolutions of the Government of the Republic of Lithuania”; Vilnius, March the 16th, 2011.
- Luxembourg, Gouvernment du Grand-Duché de Luxembourg; “Stratégie nationale pour les résaux à <<ultra-haut>> débit”; L’<<ultra-haut>> débit pour tous; French written, Luxembourg, April 2010.
- Netherlands, Rijksoverheid; “Digitale Agenda.nl – ICT voor innovatie en economische” Dutch written, May the 5th, 2011
- Norway, Norwegian Ministry of Government Administration, Reform and Church Affairs; “Digital Agenda for Norway”; ICT for Growth and Value Creation, March 2013
- Perú, Presidencia del consejo de Ministros, Comisión Multisectorial para el Desarrollo de la Sociedad de la Información; “Plan de Desarrollo de la Sociedad de la Información en el Perú”; Spanish written, Lima, 2005.
- Poland, Departament Telekomunikacji MI; “Naradowy Plan Szerokopasmowy (projekt)”, Polish written, March the 8th, 2011
- Portugal, Presidência do Conselho de Ministros; “Agenda Portugal Digital”; Resoluçao do Conselho de Ministros n.º 112/2012, Agenda Portugal Digital is

on Annex of the resolution, Portuguese written; Diário da República; December 31st 2012

- Romania, Ministry of Communications and Information Society, “Concept paper – State aid memorandum – Development of broadband infrastructure in Romania (RoNet Project)”; July 2011.
- Slovakia, Ministry of Transport, Construction and Regional Development of the Slovak Republic, “National Strategy for Broadband Access in the Slovak Republic”, Government Resolution number: 136 / 2011. Bratislava 2011.
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- Sweden Digital Agenda, Näringsdepartementet (Ministry of Enterprise, Energy and Communications), “Guidelines for state secretaries and inter-departmental working group for coordination of work with a Digital Agenda for Sweden”; Swedish written, Stockholm, December 16th 2010.
- Swiss Federal Council, “Ordinance on Telecommunications Services (OTS)”; 784.101.1, German written, March the 9th of 2007, status as on January the 1st 2010.

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- United Kingdom, Department for Culture, Media & Sport; “Britain’s Superfast Broadband Future”; Stimulating private sector investment to achieve transformation in broadband in the UK by 2015, December 2010, Published May the 16th 2011.
- United States, FCC, “Connecting America: The National Broadband Plan”; Washington, 2010.

ANNEX II: EUROPEAN TV MARKET

As this is not the main goal of this Thesis, we have taken into account the cost of broadcasting TV offers over fixed networks, but we found it really interesting to know, we can categorize some European examples based on their TV payment fees.

Some countries have as an only income for TVs the television license taxes; those are France, Denmark, Norway and Sweden. Others have a television license tax and also allow the display of commercials on TV like Greece, Ireland, Italy, Polonia, and plenty of other European countries follow that model, a cost example for Ireland is €160 per television at home[38]. Then, some regulated countries with license per TV at home, commercials shown on TV and government grants are Germany and UK. For Germany you can consult the current fees for a combined TV & Radio license and obtain that a yearly fee is set at €215,76 per obtaining both at home[39]. Another example of this is United Kingdom. There, according to Ofcom, you must yearly pay a fee of £145 per color TV at home or £49 per a black and white TV[40]. This allows you to watch TV in computers or mobile, but you have to live on an address that pays this fee. Then, you have some countries with no license on TV and that are funded basically by governmental funds and may include or not commercials on their broadcasting programs. This last example occurs in Finland, Netherlands, Portugal, Spain or Turkey, although some other taxes are imposed to obtain the amounts of the public grants like Turkey obtaining them from a small percentage over light consumption or Spain with a percentage applied to telecommunication operators.

In Europe most of the TV channels have been always broadcasted in the UHF spectrum band, and not until now, some local or regional channels are debating to start broadcasting as an all IP channel. White Spaces, and the need of spectrum for 4G-LTE and future 5G connections is also lowering the number of radio broadcasted signals. See Domingo et al. (2012) that concludes that there is more availability of White Spaces in rural areas than in Urban areas, showing that radio TV broadcasting is the most common way of doing it.

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[38] See for more information https://www.anpost.ie/AnPost/tvlicence250108.htm

[39] See for more information http://www.rundfunkbeitrag.de/

[40] See for more information http://www.tvlicensing.co.uk/

Keywords