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Resum

Mentre que la tecnologia per desplegar xarxes FTTH és coneguda des de fa temps, el seu desplegament a Europa ha estat més aviat lent. La incertesa sobre la regulació futura, la baixa demanda, un model regulatori basat en l'escala d'inversió per aconseguir competència en infraestructures, i els alts costos per desplegar una xarxa fixa amb pràcticament servei universal estan entre els factors que frenen el desplegament de xarxes FTTH. Tanmateix, la necessitat de substituir la xarxa d’accés actual (basada en coure) sembla clara, malgrat la seva necessitat estigui basada més en la intuïció que en arguments econòmics o socials clars. Per tant, l’objectiu d’aquesta tesi és fer una revisió d’aquests temes, per tal de:

- Revisar la necessitat de migrar a xarxes FTTH en vistes de les experiències actuals amb el desplegament de serveis d’accés d’Internet, identificant clarament els beneficis socials i econòmics d’aquesta migració.

- Revisar les polítiques regulatòries actuals (a Europa i Espanya) per veure si són consistentes amb les conclusions del primer punt.

- Comprovar si hi pot haver altres tecnologies (bàsicament basades en ràdio) que puguin competit o complementar desplegaments FTTH, tenint en compte els beneficis socials i econòmics esperats.
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Overview

While the technology to deploy FTTH networks has been known for some time, its deployment in Europe has been rather slow. Uncertainty about future regulation, low demand, a regulatory model based on the ladder of investment to achieve infrastructure competition, and the high costs to deploy a fixed network with near universal service are among the factors that are slowing down the deployment of FTTH networks. However, the need to replace the current access network (based in copper) seems clear, but this need is based more on intuition than on sound social or economic arguments. Therefore, the objective of the current theses is to review these topics in order to:

- Reassess the need to migrate to FTTH networks in view of the current experience with the deployment of internet access services, clearly identifying the social and economic benefits of such a migration.

- Review the current regulatory environment (in Europe and in Spain) to see if it is consistent with the findings in point 1 above.

- To check whether there may be other technologies (mainly radio based) that may compete or complement FTTH deployments, taking into account the social and economic benefits expected.
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CHAPTER 1. THE NEED FOR FTTH

1.1. Current Usage of Internet

It is an obvious fact how has the Internet changed the world in the past 2 decades, and how important has it been to our modern society. It is not an intention of this work to highlight that.

However, it is important to note where and how is the Internet currently being used and how can it be used in the future. And in those places it is not being used, why. Predicting the future can’t be done blithely, but when dealing with such investments, as of those of NGAN deployments, risk needs to be minimised.

In here, broadband penetration will be studied in order to analyse the importance and incidence of broadband in our society. Also, we’ll have a look at the types of usages people give to this broadband.

1.1.1. Europe

1.1.1.1. Broadband penetration

We can define Internet penetration as the number of households which have an Internet connection, in relation to the total number of households (with at least one member in the age group between 16-74 years). When we refer to broadband Internet connections we refer to Internet connections with downstream speeds equal to, or greater than, 144 kbps.

According to Eurostat, in 2010 the percentage of broadband connections in EU27 was of 61%. If we refer to Internet access, the rate is 9 points above, and 70% of households have Internet access.

What is noticeable is the evolution of these penetration rates. In only five years, broadband connections have doubled. Internet access grows at a rate of 5 percentual points each year, as shown on Figure 1.1. This gives a glance of the importance Internet has achieved in our society in the last years.
What happens though with the remaining 30 points? When comparing with other technologies such as classic Television, which has a penetration rate in EU27 of 96%, broadband connections, or even Internet access, stay way behind.

When asked to those who don’t have Internet access at home, their main reason is the lack of either interest or skills, followed by the costs of having Internet at home.

It’s also noticeable that these percentages of reasons for not having Internet access at home have not significantly changed for the last 6 years, although penetration rates have doubled.

Finally, when observing the use of Internet by age, what is seen is that people not using
The need for FTTH

the Internet is mostly the elderly. However, all ages increase their use of Internet across years, being the most stable the age of 16 to 24 years old, which has reached the 90%.

Figure 1.3 shows the percentage of individuals using Internet at least once a day.

![Figure 1.3](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_ci_ifp_fu&lang=en)

It is important to note that the rate at which the usage of the Internet has increased among the elderly is faster than the natural growth of population’s age. Meaning that not only people using the Internet is getting older (and that is one reason why rates increase), but also more and more people from any age are more interested in accessing the Internet, and therefore its usage increases.

We can make some predictions from this data, and expect that more people will use the Internet in the near future, and that almost all the population will use it in the mid term. At least the tendency is to equiparate to television in terms of usage and penetration.

Secondly, and as a consequence, it is expected that most households will have Internet access (particulary, broadband) in the future. The tendency shows this progression could be done in few years, reaching levels of 90% penetration in less than 5 years.

For the purposes of this work, this means that the market for access networks is expected to increase. It’s difficult to predict how much or how fast is it going to increase, but the fact that for younger ages (16-24 years old) the usage is of 90% makes it easy to imagine an scenario where 80% of households have a broadband connection, in the mid term.
1.1.1.2. Types of usages

As we will see, NGAN (Next Generation Access Network, also called NGA) is a term used to describe a telecommunication access network capable of sustaining very high transmission rates and low latencies.

These NGAN allow a variety of new services to be deployed and used, and many are the possible uses of this type of Internet access. Remote care, high definition video on demand, triple-play services, realtime interactivity, eLearning, cloud computing, and so on.

Still, there is the doubt if these services will attract people enough so as to invest, and the argument that no current services exist which demand NGAN characteristics.

Therefore, it’s important to study how is the current copper network being used, in order to predict whether or not will there be demand for these services.

According to Eurostat 2010, most users use the Internet to read the e-mail and to search for information about goods and services, which are not really bandwidth-intensive activities.

Still, this data contrasts with the increase of IP traffic in Europe (and globally) at rates significantly larger than Internet access penetration rates.
During the past years and with the introduction of new DSL technologies over the copper access network (such as ADSL2 and ADSL2+), access bandwidth speeds have increased. So far the increase in bandwidth capabilities has also been followed by an increase in the usage of that bandwidth, mainly due to the emerging video broadcasting services over the web.

### 1.1.2. Spain

In general terms, the same tendencies of Europe apply in the case of Spain.

#### 1.1.2.1. Broadband penetration

When observing the number of households with broadband connections we can also see the increase in percentage of about 5 percentage points each year in the last years, just 5 points below EU27.

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**Figure 1.5** – IP traffic in Western Europe.  
**Source:** Cisco IVS 2007-2011
It is noticeable that, differently from EU27, the tendency in Spain is that as time passes broadband connections equal Internet accesses, so narrowband connections are extinguishing.

Similarly, not needing Internet access leads the reasons why Spanish inhabitants don’t have Internet access at home, with even more percentage than in the EU27 case (56% vs 40%), followed by the costs.

In the same way is shown the number of individuals regularly using the Internet, separated by age, in Figure 1.8.

Although percentages are lower than in the EU27 case, the same tendency applies, grow-
The need for FTTH is growing at rates close to 5% every year.

![Figure 1.8](image)

**Figure 1.8** – Individuals regularly using the Internet by age, Spain (%).


1.1.2.2. Mobile Internet

There is one last issue regarding broadband Internet usage, which is the emerging of mobile Internet, and whether or not these accesses are a complement or a substitute for fixed broadband access.

We don’t consider here mobile telephone lines with an Internet service associated, usually on a smartphone. This situation is very recent, and there is still few data available to compare.

The comparison starts with the evolution in the number of fixed broadband lines, be them DSL, HFC or FTTH. The evolution over the years shows these lines have increased all the years, although the rate has slowed down in the last years.
As of October 2011, the number of lines were 1,1056,266, which means an increase of 3.8% (interanual from October 2010 of 5.5%), so presumably it would slow down.

On the other side, mobile Internet accesses have also increased in the last years, as shown on the evolution of the number of datacards lines.

It should be noticed that, while most fixed lines are residential (81.20% as of 2010), there is a significant amount of datacards for the business segment (41.24% as of 2010).

Also, as of October 2011, the number of datacards were 3,549,613, which means an increase of 5.81% (interanual from October 2010 of 15.7%). This means the growth of
these access service has decreased dramatically, from 71.09% to 15.7%, and presumably even less at the end of the year.

This, along with the emerge of Internet service and smartphones, gives a glance about why datacards are used, related more in terms of mobility than as a competing service to fixed broadband accesses.

The CMT also published in November 2011 a report[^1] about to what degree mobile broadband could substitute fixed broadband accesses.

This report is based on 2248 surveys made to people directly about fixed amb mobile broadband access. Several data support the idea of complementarity instead of substitution, such as that 76.4% of people who only have mobile access never had fixed access before. Their main arguments are that datacards are enough for their needs (50.1%), not wanting a fixed line (26.8%) and mobility (24.5%).

Finally, last point regarding the report is that few users of fixed access have intention of substitution for a mobile line. Only 2.8% of surveyed were very predisposed or much predisposed, while 84.3% were not predisposed at all, or little predisposed.

1.2. FTTH deployments around the globe

There are not globally extended FTTH networks in the world, but there are local or regional iniciatives which provide these access networks. Most notably, Japan and South Korea are the main cases of study for they have reached the highest coverage and penetration rates in NGANs.

1.2.1. Europe

FTTH coverage in Europe is still at its early stages of deployment. Most advanced countries are Fenno-Scandinavian countries, specially Sweden and Norway, but also Finland and Denmark. Eastern European countries are also taking off rapidly, mostly because their lack of copper infrastructure makes that all new deployments are done using fibre.

Therefore, data is scarcely collected, and few NRAs collect them (mainly due to low relevance). Most used data comes from FTTH Council Europe, which at its last report ranks countries by the number of passed households with FTTH/B, including only those with more than 200,000 households where at least 1% of households are FTTH/B subscribers.

The same study states that the average penetration rate of FTTH/B connections in Europe is of 17.5% (as the number of households with FTTH/B installed over the number of households passed).

[^1]: Investigación sobre el grado de sustitución entre los servicios de banda ancha, fija y de banda ancha móvil de gran pantalla en el segmento residencial - [http://www.cmt.es/es/publicaciones/anexos/Informe_sustitucion_112011.pdf](http://www.cmt.es/es/publicaciones/anexos/Informe_sustitucion_112011.pdf)
1.2.2. Spain

In Spain the deployment of FTTH accesses is still very new, and it hasn’t been until late 2010 that the number of subscriptions of FTTH services has begun to increase notably. Most lines are from incumbent Telefónica, and are deployed with GPON architecture.

![Figure 1.11 – Ranking of top Europe FTTH performing countries: number of passed households](image)

**Source:** FTTH Council Europe - FTTH/B Panorama European Union (36) at December 2010, with data from IDATE Consulting and Research.

![Figure 1.12 – Number of FTTH subscribed lines in Spain.](image)

**Source:** CMT
Latest data published from the CMT\textsuperscript{[2]} states that the number of FTTH homes passed are of 524,370 in 2010, coming from 396,065 in 2009. There is no available data for previous years. Taking data from the end of 2010, the penetration rate of FTTH accesses where FTTH is available was of 9.19%.

1.2.3. United States

United States fibre deployment has not been very different from average European deployment, and way behind Japan and South Korea. While FTTH became commercially available in about 1998, it hasn’t been until the last years that it has started to deploy.

According to The FTTH Council on its document “North American FTTH Status”, in March 2011 there were approximately 20.9 million homes passed in North America (97% in the United States).

1.2.3.1. Deployment status

As stated by the same FTTH Council document, the evolution of FTTH in the last few years as been as shown below:

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{ftth_status.png}
\caption{North American FTTH Status (as of the end of the first quarter of each year).}
\end{figure}

\textbf{Source:} FTTH Council - North American FTTH Status

As suggested by the numbers, it is remarkable the penetration rate of FTTH access where

\textsuperscript{[2]}Informe Anual CMT 2010
these accesses are marketed, of 36.6%, which is way higher than the one in European countries.

The numbers also mean that, in global terms, the penetration of FTTH coverage in the U.S. is of 18%, and the penetration in terms of homes connected is of 6%.

As the type of provider of these FTTH deployments, Regional Bell Operating Companies (RBOC, the three biggest broadband operators) represent over 73% of all connection, mostly Verizon. The remaining deployments are from Incumbent Local Exchange Companies (ILECs) and Competitive Local Exchange Companies (CLECs) associated with municipal participated FTTH networks. More about the types of operators can be found in section 2.3.

1.2.4. Japan

Japan is one of the world leader in FTTH deployments. According to OECD\cite{OECD}, in 2009 it had a FTTH/B Household availability of 86.5%. As of 2010, 58% of all broadband connections in Japan were FTTH/B connections, overtaking other access technologies such as DSL or Cable.

Japan has a population of about 128 million people, an area of 380,000 km\(^2\) and 50 million households.

Japan's NGAN network is a mixture of both public and private networks. The government uses a different regulatory strategy depending on the layer of the network (from physical to application), and most of all is worried about open access and competition at physical level.

More about the regulatory framework can be found in section 2.4.

1.2.4.1. Deployment status

The deployment of FTTH networks in Japan began in 2002 by the incumbent operator NTT. The chosen technology architecture was BPON (more later on section 3.1.2.), until 2005 when NTT along with other operators started focusing on EPON.

The evolution on the usage of subscribed lines in the broadband market can be seen on Figure 1.14.

\cite{OECD}OECD Broadband statistics: 3f. FTTH/B Household availability (http://www.oecd.org/dataoecd/47/3/44435611.xls)
What stands out in the figure is the constant increase in the FTTH lines, along with the constant decrease in ADSL lines. In only 7 years, the percentages have almost reverted. ADSL lines have gone from 71.0% to 24.0%, while FTTH lines have increased from 15.0% to 59.3% of the total number of lines. Cable accesses remain very stable, increasing from 15.4% to 16.6%.

If the same tendency applies for the next years, it is likely that ADSL accesses will be minoritary, and eventually disappear, meaning that the transition from ADSL to FTTH could be done in a period of 10 to 15 years.

1.2.5. South Korea

South Korea is another world leader in FTTH deployments. According to OECD[4], in 2009 it had a FTTH/B Household availability of 67%. As of 2010, 55% of all broadband connections in Japan were LAN/FTTH connections, overtaking other access technologies such as DSL or Cable (with 44%).

South Korea has a population of about 50 million people (as of 2010), an area of 100.210 km² and 17.57 million households (as of 2010), and 94.1% of these households have broadband access.

1.2.5.1. Deployment status

The deployment of broadband began in South Korea in the late 1990s by the incumbent Korea Telecom (or KT) with cable broadband access and DSL using copper infrastructure. It wasn’t until 2006 that the first FTTH accesses were deployed, with the arrival of the National Broadband Convergence Network (BcN) program, intended by the government to bring 50-100 Mbps infrastructure to over 95% of the households.

Since 2005, the most fast growing access technology has been FTTH, which has already overcomed xDSL accesses, and has become the 20% of the total broadband accesses in just 5 years. On the other hand xDSL connections have decreased for the last years from 56% to 14% of the total lines. Also, considering that LAN and FTTH are both FTTx, 55% of the subscriptions are of this type.

Cable connections have remained very stable in these years, although the percentage has decreased. From 33% in 2005 to 30% in 2010, and the tendency in the last year is to also decrease in absolute numbers.

This behaviour is very similar to the evolution of FTTH connections in Japan, where the deployment of FTTH network is fast adopted by users, leaving behind ADSL accesses.

The broadband market in South Korea is a strong infrastructure-based competition, with 4 parallel networks (3 telecom carriers and a group of cable companies). This results in lower prices, and better bandwidth. This type of competition is possible thanks to the relatively low deployment costs due to several factors. For instance, the distribution of the
population where 76% live in the 10 largest cities, and the 50% only in the Seoul region. Also, most of the deployments are aerial in urban areas.

The same predictions made in the case of Japan can be applied here. It is expected that Fiber-based connections will replace entirely old copper network, and this could happen in a timeframe of 10-15 years from the beginning of the deployment.

1.3. Social and economic benefits

Information and Communications Technologies have driven innovation and human progress for the last decades, and it does not seem to be changing.

However, some doubts are presented when wanting to know if NGAN are another step on the evolution of ICT, on what really are the social and economic benefits of this access technologies, or if now is the right time for NGAN.

Here are presented some of the key concepts to try to figure it out.

1.3.1. Virtous Cycle of Digital Economy

The European Comission issued a document in 2002, called “A Digital Agenda for Europe” (which will be further explained in section 2.1.2.) which is introduced by the definition of the Virtous Cycle of Digital Economy. This cycle is an economic term, also called virtous circle, by which its elements reinforce each other through a positive feedback.

This circle has three separate elements: contents, users and networks. The increase in contents fosters the increase in users. The increase in users eases the increase in network investments. These investments in turn make new contents and services available, and so the cycle restarts again, more powerful.

The document also identifies seven obstacles that make the circle slow down, shown on the picture of Figure 1.16.

What this virtous circle could explain is the lack of the so-called “killer app”. The reason why current broadband users would migrate to a NGAN service is not clear, and the lack of interest by people has been argued to be an important factor why operators don’t invest in NGA networks.

However, the lack of investment in NGAN causes that no new content services will be developed, and therefore there won’t be an increase of user demand for this services, closing the circle.
1.3.2. Network effects

Another key factor to analyse the socioeconomic benefits of NGAN is what in economy is called network effects. Put it simple, is how much a product or service increases its value as more and more people use the same product or service.

This concept was specially used when the telephone service was rising, and it’s the typical example of product with high network effects. The more telephones there are, the more useful they get. On the other hand, having just one telephone makes it absolutely useless. Other examples are a tennis racket or the Internet itself.

Another factor that could foster user’s interest in NGAN is in fact other users connected to this service. Specially with NGAN, where the bandwidth available for the user to upload contents is considerably larger than the one offered by the copper-based asymmetrical connections, the increase in the number of users could accelerate the migration of users to NGAN.

An example of that (for illustrative purposes only) could be online videogames, where the upstream bandwidth is critical. Without entering into details, there is really no use to have a connection able to play a videogame which requires 5 Mbps in the upload if I am the only one among my friends to have it.

On the other hand, it may drive me to migrate to this kind of connection if all of my friends have one and play online with that game.

The same could be applied to many of the planned possible services to be developed with the use of NGAN, such as e-Health, e-Education, or e-Work.
CHAPTER 2. REGULATORY ENVIRONMENT

Telecom sector is a heavily regulated sector, and regulation has intensified since the liberalisation in the 90s. During the 20th century there was the belief that the best way to economically organise telecom was by means of technical monopolies (either public monopoly, private monopoly or publicly regulated market). Economies of scale and scope, high barriers to entry and exit due to large sunk costs and network effects were the arguments to believe that.

This situation was kept both in the US and in Europe until late 90s, when the Telecommunications Act of 1996 and Directive 96/1996 were approved seeking full competition in the telecom market.

This chapter reviews the current telecom regulatory environments around the world, looking specifically in Spain and Europe, and in the zones where NGN has an specific weight.

2.1. Regulatory environment in Europe

2.1.1. A brief history

Current regulatory environment comes from the already cited Directive 96/19, approved on March 13th of 1996. The remarkable extract of the directive is:

Article 2 1. Member States shall withdraw all those measures which grant:
(a) exclusive rights for the provision of telecommunications services, including the establishment and the provision of telecommunications networks required for the provision of such services; or
(b) special rights which limit to two or more the number of undertakings authorised to provide such telecommunications services or to establish or provide such networks, otherwise than according to objective, proportional and non-discriminatory criteria; or
(c) special rights which designate, otherwise than according to objective, proportional and non-discriminatory several competing undertakings to provide such telecommunications services or to establish or provide such networks.

hence opening to competition all telecom markets, including voice telephony, and leaves this responsability to member states, through National Regulatory Agencies (NRAs).

However, in the following years the European Comission realised that what was supposed to happen didn’t, and operators didn’t invest in the last mile network, in the local loop.

Then, on July 12th of 2000 adopted a Regulation[1] specifically dedicated to the local loop. That is, to the physical circuit between the customer’s premises and the telecommunications operator’s local switch or equivalent facility. On the same regulation develops the

different types of unbundling which should be available to operators, from full unbundling to bit stream access.

2.1.1.1. First revision of the regulatory framework

The first revision of the regulation took place in 2002, with the publication of 6 Directives\textsuperscript{2} 1 Recommendation\textsuperscript{3} and 2 Decisions.

As for the competition in the markets, the first revision doesn’t change rather than consolidate the previous framework. The same on the common regulatory framework, although it defines Significant Market Power (SMP) as having more than 25% of share in a defined telecommunications market.

What this revision newly publishes are the Relevant Markets, a list of eighteen relevant product and service markets (both at retail and wholesale level) within the electronic communications sector susceptible to \textit{ex ante} regulation, and which State members must analyse.

Finally, it also modifies the way companies are legally able to become operators, simplifying the authorisation to just a mere notification.

2.1.1.2. Second revision of the regulatory framework

In the period 2005-2010 (first presidency of Barroso) the Commission updated the electronic communications policy with two Directives in 2009\textsuperscript{4}, one Regulation in 2009\textsuperscript{5} and one Recommendation in 2007\textsuperscript{6}.

The main changes were two. From one hand the Commission established the Body of European Regulators for Electronic Communications (BEREC), substituting the old European Regulators Group (ERG). Its main role is to “develop and disseminate among NRAs regulatory best practices, such as common approaches, methodologies or guidelines on the implementation of the EU regulatory framework”.

On the other hand, the Commission narrowed the eighteen forementioned relevant markets to seven. These are listed below as a reference, since some of them will be used in other sections of this work.

\textsuperscript{2}Directives 2002/21 on common regulatory framework for electronic communications network; 2002/19 on access and interconnection; 2002/20 on authorisation of electronic communications networks and services; 2002/22 on universal service; 2002/58 on privacy and electronic communications; and 2002/77 on competition in the markets for electronic communications services
\textsuperscript{3}2003/311 on relevant product and service markets within the electronic communications sector susceptible to \textit{ex ante} regulation
\textsuperscript{4}Directives 2009/140 “Better Regulation”; 2009/136 “Citizens’ Rights”
\textsuperscript{5}Regulation 2009/1211 establishing the Body of European Regulators for Electronic Communications (BEREC)
\textsuperscript{6}Recommendation C(2007) 5406 on relevant products and service markets within the electronic communications sector susceptible to \textit{ex ante} regulation
• Market 1: Access to the public telephone network at a fixed location for residential and non-residential customers.

• Market 2: Call origination on the public telephone network provided at a fixed location.

• Market 3: Call termination on individual public telephone networks provided at a fixed location.

• Market 4: Wholesale (physical) network infrastructure access (including shared or fully unbundled access) at a fixed location.

• Market 5: Wholesale broadband access.

• Market 6: Wholesale terminating segments of leased lines, irrespective of the technology used to provide leased or dedicated capacity.

• Market 7: Voice call termination on individual mobile networks.

For the matter of NGN and broadband in general, Market 4 and Market 5 are the most relevant of them.

2.1.2. Current regulation

With the second presidency of Barroso in the European Commission, a new European strategy was published: “Europe 2020: smart, sustainable, inclusive growth”. It included five targets, which were broken down into seven flagship initiatives. One of these initiatives is a Digital Agenda for Europe[7], aimed at “speeding up the roll-out of high-speed internet and reap the benefits of a digital single market for households and firms”, adopted by the Commission on June 17th of 2010.

As long as ultra fast internet access is concerned, the strategy proposes the objectives of:

• Basic broadband coverage for 100% of EU citizens, by 2013.

• All Europeans have access to much higher speeds of above 30 Mbps, by 2020.

• 50% or more of Europeans households subscribe to internet connections above 100 Mbps, by 2020.

For that, the Commission issued a Communication[8], a Recommendation[9] and Proposal for a Decision[10].

The most important document among these three is the Recommendation, where the Commission attempts to give guidance to EU NRAs on the future design of regulatory remedies concerning NGAs. It tries to address several concerns and establish a regulatory certainty and predictability.

As always, the policy responses are aimed at fostering investment and competition. Investment to deploy NGA networks which are far from being available to 50% of the population, and competition to bring about choice and affordable prices for consumers, but also investment in the long term. This recommendation describes three possible policy responses:

- Regulatory forbearance and exclusion of remedies: in order to promote investment, optical fibre networks are excluded from the definition of markets 4 or 5.

- Imposition of full range of access and pricing remedies: i.e. continue with the same regulatory framework of regulating all potential access remedies in NGA, from duct access over unbundling to bitstream.

- Imposition of access obligations adjusted for investment risk: adding adjustments for investment risk to access obligations in NGA, aimed at driving both competition and investment.

And the Recommendation concludes the latest is the preferred option, since it favours both competition and investment favouring the imposition of access obligations adjusted for investment risk.

The Recommendation includes several guidelines, some of which are listed below:

**General principles**

- Regulators need to promote transparency about network deployment.

- Differences in competition between geographic areas resulting from the deployment of fibre should be taken into account (separate geographic markets or geographically differentiated remedies).

- Asymmetric regulation could be complemented by symmetric approaches.[11]

**Physical access products (LLU)**

- All access products should in principle be available (i.e. ducts, terminating segment, subloop, fibre loop).

- Regulated access prices should reflect investment risk, with further price flexibility attaching to high-risk projects such as some FTTH.

- Certain arrangements for co-investment by several players could result in the lifting of *ex ante* regulation.

**Wholesale bitstream access**

- Wholesale bitstream access should be imposed, as a general rule.

- Where physical access remedies suffice to create effective competition, wholesale bitstream access could be removed.

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[11] Meaning that alternative operators which deploy NGA networks could also be affected by the same regulation as Significant Market Power (SMP) operators.
2.1.2.1. **BEREC**

Along with the Commission documents, it is also worth noticing the documents the BEREC publishes, and specially the ones referring to NGANs.

One of these documents is “BoR (10) 08, BEREC Report on NGA wholesale products” where it looks at the implementation issues of relevant wholesale products in an NGA environment. On it appears the ladder of investment, an allegory used to represent how alternative operators would invest in their own infrastructures (back in the first competition-based regulatory policies), updated in the case of an FTTH operator.

![Figure 2.1 – Ladder of investment for an FTTH operator.](image)

The relevant parts of the document are slightly reviewed in section 3.1.3.4..

The second noticeable document is “Bor (11) 06 Next Generation Access – Collection of factual information and new issues of NGA roll-out”. In this, the regulator makes an extensive compilation of information on current NGA roll-out. It inspects current wholesale and access products available in every European country, and the regulatory policies issued by NRAs.

The latest document referring to NGANs is “BoR (11) 43 BEREC Report on the Implementation on the NGA Recommendation”, where BEREC continues to comment on NRAs decisions regarding regulatory policies, following the Commission NGA Recommendation.

### 2.1.3. Conclusions

Regulation in Europe has been quite consistent from the beginning, and follows the Ladder of Investment theory, by which alternative operators would invest more and more, up until having two or more full access networks, and therefore full competition between operators.
This competition would foster investment even more, since the incumbent would be forced to differentiate its services and make them better.

For that, from the beginning in late 90s the policy has been aimed at fostering competition by unbundling network elements, and the same principles have applied until now, each time adding more network elements to this unbundling (from wholesale bitstream to access to passive infrastructure such as ducts and manholes).

2.2. Regulatory environment in Spain

2.2.1. A brief history

The first regulation conducted in Spain in terms of telecommunications was the Royal Decree of August 16th of 1882, which regulated the telephone service and authorised the government to deploy a telephone network and concede to companies the operation of the service. After other Royal Decrees (1884, 1886, 1890, 1891) which took and gave exclusive rights to the government, in 1894 the “Peninsular Telephonic Company” was founded, which later on in 1914 was given the concession to operate almost all the urban telephone networks.

Finally, in 1924 the company “National Telephonic Company of Spain” (Compañía Telefónica Nacional de España) was founded with American capital, and the government hired the organisation, reform and expansion of national telephone service, effectively acting as a monopoly in private hands.

Again, in 1945 under the francoist dictatorship CTNE shares became property of the state, thus shifting the state to control 79.6% of total shares, in order to make big public investments to expand the telephone network. This situation lasted until the 1990s.

Finally, in 1995 there was the first partial sale of the Spanish government’s stake, which was fully privatised in 1999, and the telecommunications market liberalised, following the European directives.

2.2.1.1. Liberalisation

As said, following the European Directive 96/19 the government of Spain passed a Royal Decree 6/1996, which later turned into Act 12/1997 of April 24th, of Telecommunications Liberalisation.

Under this law, the national regulatory agency was created and named Telecommunications Market Commission (in Spanish Comisión del Mercado de las Telecomunicaciones or CMT), whose main function was to foster competition in the telecommunications market (for example by fixing prices of interconnection). The law also boosted a second operator, Retevisión, as a competing operator to Telefónica.

Finally, in 1998 another law was issued: 11/1998, of April 24th, Telecommunications Gen-
eral Law (in Spanish Ley General de Telecomunicaciones, or LGT), effectively creating the general framework of the Telecommunications market in Spain. This framework formerly defined the network operation and provision of electronic communications in free competition, the public service obligations, the conformity assessment of equipment and appliances, the radioelectric public domain and the paper of the public administration in telecommunications.

After the publication of this law, the first wholesale public offer of telecommunications services was also published, in 2001, called Local loop offer (in Spanish “Oferta de Bucle de Abonado” or OBA).

2.2.2. Current regulation

After 1998’s LGT, the government reviewed the law in a new Telecommunications General Law in 2003, Law 32/2003, of November 3rd. This law was issued as a consequence to adapt the Spanish legislation to new Directives issued by the European Comission (first revision of the regulatory framework), and removed the requirement of a license to operate or settle communications networks in favour of a mere notification to the regulator.

From this law also derived new obligations (in January 2009[12]) of unbundling to the incumbent, as a consequence of the obligation to study market 4 and market 5 by the European Comission Recommendation C(2007) 5406.

Regarding market 4, the CMT obligates the incumbent to publish a reference offer for access to the passive infrastructure. The incumbent did so in March 2009 and the Offer of Access to Registries and Ducts (Oferta de Acceso a Registros y Conductors or MARCO) was approved by the NRA in November 2009.

Regarding market 5, the CMT includes NGAN in the wholesale bitstream market, but only to a service of up to 30 Mbps, and therefore higher-level services offered by fibre (of 50 or 100 Mbps) are not included in the offer.

As long as NGAN is concerned, the regulator did also publish a study about the deployment of FTTH in 2009[13]. The main conclusion of the document is that in almost all municipalities of Spain (all those with a population of over 1000 inhabitants ) there could be competition in infrastructures by an alternative FTTH network operator. That is 2 operators (the incumbent and one alternative) deploying a full FTTH network, besides the passive civil works infrastructures, shared between incumbent and the alternative.

The document also states that in municipalities with 500,000 or more, there could be from 2 to 4 alternative operators with their own FTTH network competing with the incumbent.

[12] MTZ 2008/626 Resolution of markets 4 and 5
2.2.3. Conclusions

Regulation in Spain has been consistent with European regulatory framework, and has followed the same principle of the Ladder of Investment, fostering investment through competition and letting alternative operators gain market share by the use of unbundled network elements.

The approach to regulating NGAN, however, has been slightly different from the one proposed by the European Commission, and the inclusion of FTTH/GPON accesses deployed by the incumbent to the market has been restricted to a bandwidth of 30 Mbps. The argument for this measure is that if the incumbent is obligated to wholesale FTTH accesses as well, it won’t be interested in investing in the deployment of FTTH networks, since other operators would offer the same service without as much investment.

2.3. Regulatory environment in the United States

2.3.1. A brief history

The history of electronic communications started at the end of the XIX century, along with the telephone invention. In the beginning, there were thousands of local independent telephone companies (each a monopoly in its franchise territory).

Local and long distance services, though, were thought to be natural monopolies, so that they could be provided at the lowest cost by a single firm. And so a single firm, AT&T, founded by Bell in 1885, was the one to offer long communications and interconnection between the local companies. Step by step, AT&T bought all the local companies and by 1891 the AT&T group already controlled 80% of telephone communications in the United States.

After that, the need for regulating the electronic communications market emerged, and the Congress of the United States enacted the Communications Act of 1934. Under this law, the Federal Communications Commission (FCC) was created, in order to “...regulate interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States...“.

Communications remained as a natural monopoly, under the responsibility of each State of the Union, which had the authority to concede rights of exploitation in terms of monopoly. It was in the following years and following FCC initiative, that AT&T was forced by a court to split up into seven regional companies in 1984, called Regional Bell Operating Companies (RBOC), which in the following years would merge into three, AT&T Inc, Verizon Communications and CenturyLink.

Finally, on 1996 and 62 years later, the Telecommunications Act of 1996 was enacted, amending the former Communications Act of 1934. In parallel with the European homonym Directive 96/19, it included Internet regulation, and liberalised the telecommunications business opening the market to competition. Among other things, and in order to foster
competition, the Act mandated that incumbents offered competitors access to unbundled network elements at a reasonable rates, as well as interconnection, collocation and wholesale.

These incumbents were called Incument Local Exchange Carrier (ILEC), and were local telephone companies parallel to the existence of RBOCs, focused in a specified geographic area.

2.3.2. Current regulation

However, as years passed by, the alternative operators (called Competitive Local Exchange Carriers or CLECs) did not capture any substantial share of total lines, and open access provisions were still not effectively implemented due to the litigations of the incumbents after the 1999 Act. Five years later, in 2001 the FCC changed course and FCC passed a series of decisions towards focusing to competition between the owners of two different wires: copper telephony company, and coaxial cable company. The regulatory body believed that competing between each other was enough so that both would drive each other to invest, knowing that their respective investments in infrastructures won’t go to subsidise their competitors.

So in 2005 the FCC released an Order on February 2005 in which the ILECs gained considerable freedom to price network elements. It is still possible for CLECs to buy unbundled network elements, but they have to do so at market-based prices, much higher. In addition, there is no requirement to unbundle FTTH.

The big difference in regulatory responses between the United States and Europe was that cable operators were fully deployed across the country (approximately 96% of the population has at least two wireline providers), and were at that time leading the path to broadband.

Finally, on March 2005 the FCC published the document National Broadband Plan: Connecting America, in which it provides measures to ensure every American has access to broadband capability.

On it, it insists on the idea that US citizens are able to choose between two wireline, facilities-based broadband platforms with similar services, but this could be put in danger since cable operators are starting to migrate their networks to DOCSIS 3 and higher capabilities are being available.

The document issues 11 recommendations in the field of Networks, some of which are listed below:

- The federal government, including the FCC, the National Telecommunications and Information Administration (NTIA) and Congress, should make more spectrum available for existing and new wireless broadband providers in order to foster additional wireless-wireline competition at higher speed tiers.

- The FCC, in coordination with the National Institute of Standards and Technology (NIST), should establish technical broadband measurement standards and method-
ology and a process for updating them. The FCC should also encourage the formation of a partnership of industry and consumer groups to provide input on these standards and this methodology.

- The FCC should develop broadband performance standards for mobile services, multiunit buildings and small business users.
- The FCC should comprehensively review its wholesale competition regulations to develop a coherent and effective framework and take expedited action based on that framework to ensure widespread availability of inputs for broadband services provided to small businesses, mobile providers and enterprise customers.
- The FCC should ensure that special access rates, terms and conditions are just and reasonable.

The document also makes special interest in collecting more and better statistic data from broadband service providers, and making it available to the end consumer.

As seen on the recommendations, the document states that the FCC should review the wholesale regulations and the special access rates, which were left to no-regulation and resulted in abusive pricing.

### 2.3.3. Conclusions

Regarding NGAN deployments, the United States are in a situation similar to the one Europe is facing. When considering broadband, the U.S. performs in the middle of the OECD rankings and has debated which is the best way to improve that.

The approach for now has been different from the one taken in Europe (and most of the developed world countries), specifically in terms of open access policies. While Congress started adopting open access in the Telecommunications Act of 1996, the FCC abandoned this path in the early 2000s. While the leading countries in NGAN in the world have implemented open access policies, it is also true that few have the duality of infrastructures in the U.S., where practically all the country (96%) is covered by two different access networks (copper and cable).

### 2.4. Regulatory environment in Japan

The agency responsible for telecommunications regulatory policies of Japan, the Ministry of Internal Affairs and Communication (MIC), was established in 2001 and since then has issued three different national broadband strategies.

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[14]Special access circuits are high-capacity links used by CLECs as upstream components to carry both voice and data
2.4.1. e-Japan

The first one, called e-Japan (for Electronic Japan) was published on 2001 with four priority policy areas: the establishment of ultra high-speed network infrastructure and competition policies, the facilitation of electronic commerce, the creation of electronic government, and the nurturing of high-quality human resources.

The most challenging of the areas was the establishment of ultra high-speed network infrastructure, and specifically the goal was to connect at least 30 million households to high-speed access, and 10 million households to ultra high-speed access (30-100 Mbps).

But before 2001, Japan's Internet access was provided similarly as in other countries, using conventional public switched telephone networks (PSTN), exploited by a public monopoly, called NTT (Nippon Telegraph and Telephone Public Corp.). Also following the world tendency, NTT was privatised in 1985, but even in this scenario the provider has continued to be a de facto monopoly in the local telecommunications market.

Knowing that, the plan introduces competition promotion measures toward NTT, such as asymmetrical regulations or the obligation of sharing network elements. In addition, the government subsidised the deployment of FTTH with zero or low interest rate financing (for both public and private sectors), including tax incentives for the private sector, such as deferred income tax payment or a reduction of fixed asset taxes for designated network equipment.

Beside the tax incentives, municipalities also benefit from government programs, in terms of subsidy. The government payed 1/3 of construction costs of local FTTH networks in rural areas, with a total budget of MY 1627 (approximately M€15.68) in years 2004 and 2005, so that this newly created municipality-owned fibre networks could be wholesaled to all operators.

In December 2004, the MIC also set unbundled rates for FTTH unbundling. These rates were set for 1 optical line with 8 branches, since the FTTH architecture chosen by NTT was B-PON (with splitter rates of 1:8). The MIC also set rates for single star (Home Run architecture). How the unbundling is done on both cases is shown on Figure 2.2.

2.4.2. u-Japan

The goals of e-Japan were more than achieved, and instead of 30 million households with high-speed access, there were 46.3 million. And instead of 10 million households with ultra high-speed access, there were 35.9 million FTTH subscribers.

From 2006 onwards, the MIC issued the u-Japan (for Ubiquitous Japan) policy, aimed at realising the Ubiquitous Network Society. This policy packages promoted several basic points, including the transition from broadband to ubiquitous, meaning that anyone, anywhere at anytime is able to access easily anything, and obtain information over both fixed and wireless networks.

For the period 2006-2010, several measures were approved, in order to have, by 2010,
Among these measures, the continuation of the subsidy (called grant-in-aid) for the development of local telecommunications infrastructure. In total, the government spent BY 13.1 in 2006, BY 9.3 in 2007, BY 20.1 in 2008, and BY 51.7 in 2009. In the period 2005-2009 the government invested MY 95827, approximately M€924.83 ([Fujino, 2010]).

In addition, there are some other measures aimed at also creating content to achieve this Ubiquiti, such as developing Information appliances, RFID tags, or sensor networks. Empowering the ICT usage by everyone is the most important goal of this plan, while the development of network infrastructure is no longer the emphasis of this plan.

2.4.3. i-Japan

In April 2009, the next 5-year period strategy was published, named i-Japan (for inclusion and innovation Japan). It starts by stating that while the development in infrastructures was successful, many citizens still live away from that development.

Therefore, this latest strategy is focused on three priority areas: electronic government, electronic healthcare and education and human resources.
2.4.4. Conclusions

Japan is the world leader as far as FTTH is concerned. The policies the government has applied since the end of the 90s have been of heavy regulation and based on competition. The government ensured that unbundling was an option from the start, and this policy was also updated in 2009 with the introduction of NGN unbundling. It appears\(^{[15]}\) that this hasn’t diminished investment, and that prices have lowered over time.

Private investment has also been accompanied of public investment for the rural areas, so that only parts of network infrastructure were subsidised (from 1/4 to 1/2, depending on the type of deployment), but also ensuring that all the population can be connected to ultra high-speed Internet access.

2.5. Regulatory environment in South Korea

The agencies responsible for regulating telecommunications in South Korea are the Ministry of Information and Communication (MIC), the National Computerisation Agency (NCA) and recently the Korea Communications Comission (KCC).

The NCA was created by the government as a consequence to the Framework Act on Informatisation Promotion, in 1987, to oversee the construction of high-speed networks, among other objectives. In 1994, the NCA established the first initiative to foster the deployment of a nationwide optical fibre network, the Korea Information Infrastructure Initiative (KII). The government invested $ 24 billion in this phase.

After this first approach, the government issued a series of 5-year programs combining public loans with private sector contributions.


The first of these programs was issued in late 1999 with the name of Cyber Korea 21 Initiative. It was the government’s vision to facilitate a transition to a knowledge-based information society, and about 180 laws relating to e-government, e-commerce, distance learning and so forth were enacted or amended by 2001. The first key objective was to develop a safe system for using information, and ethics to sustain telecommunications.

The second objective was to increase the overall national productivity by using information infrastructure. This was to be accomplished by the use of a digital government to increase administrative efficiency in many areas, and also to improve the productivity of existing manufacturing and service industries by creating knowledge-management systems.

It was also in this period that the average backbone connection speeds were increased, to

speeds from 155 Mbps to 40 Gbps.

Finally, the third key objective was to create new job opportunities by the use of information infrastructure and the development of TI industry. All of these three objectives were further detailed in the document “The 1999 White Paper”.

### 2.5.2. e-Korea Vision (2002-2004)

Established in 2002 to strengthen the weaknesses of the previous plan, and focused on promoting national informatisation, advancing the information infrastructure, and promoting international cooperation. As for the broadband policy, the plan envisioned that all households in Korea regardless of income, age or region should have access to at least a 1 Mbps connection by 2005.

The government also invested in access technologies, and in particular in FTTH networks by funding local municipal FTTH networks. It was also in this period that the government imposed unbundling obligations to the incumbent, Korea Telecommunications (KT), after the levels of penetration of Korea had achieved the top positions in the OECD rankings.

Under these circumstances it was that DSL was introduced in the country. While the incumbent KT was focusing on ISDN, the entrants Thrunet and Hanaro introduced DSL accesses, and hence the incumbent was forced to shift its strategy to DSL connections.

### 2.5.3. IT839 Strategy and BcN (2004-2010)

Established in 2004 to present a new strategit vision for the IT industry with the aim of achieving $20,000 GDP per capita. It has three main pillars, with eight IT service, three infrastructures, and nine new growth engines (hence de “839” name).

Among the Infrastructures pillar, there is the deployment of the National Broadband Convergence Network (BcN). The aim of this deployment is to reach 50-100 Mbps services to 20 million subscribers by 2010, either with FTTH, VDSL or Cable with DOCSIS 3.

Over all these years, the investment[16] has been of over $ 70 billion in low cost loans to private providers, and over 12 billion per year from 2000 to 2006. In total (adding the KII investment), about $ 180 billion. It is not clear, however, how much of these numbers are public and how much private investment, but the most likely is that these numbers reflect a large proportion of private investment complementing the public investment.

### 2.5.4. Conclusions

It is not by chance that South Korea has became one of the world leaders in broadband deployments, in terms of both supply and demand, with the second rate of FTTH deployment,

[16]As stated by [for Internet & Society, 2010]
and the first Internet access penetration rate of the world.

Since the late 90s, the government has conducted a series of plans to foster both investment in infrastructures and demand by the population. The later, demand side programs, were not mentioned extensively, but have been as important as the infrastructures. In the published strategies, the government included elements such as extensive skills training programs (mostly to adult population), subsidised provision of personal computers, free personal computers in every school and to students with good grades, inclusion of digital literacy in college education programs, and so on.

This combined with the already mentioned investments in access network, and the particularities of the population structure of South Korea, has lead the country where it is.
CHAPTER 3. NGAN ALTERNATIVES

The technology to deploy FTTH networks has been known for some time, and offers much better technical characteristics than current access networks, including bandwidth, latency, and stability.

Only technological innovations will tell whether fibre to the home will be the best way to access broadband or not, and how many years will it keep being so.

Putting yet unknown technologies apart, there are nowadays other access methods which seem to be an alternative to FTTH in the field of NGANs. Being their cost (mainly radio-based in rural areas) their main strength, this chapter studies the possibility to compete to FTTH.

Specifically three technologies are studied and compared, FTTH, LTE (Long Term Evolution) and LTE-Advanced, and HFC (Hybrid Fibre-Coaxial).

3.1. FTTH

There are many definitions of the term FTTH, mostly regarding where the fibre ends, or how generic the term is.

In order to be consistent with the FTTH Councils, the same definition\(^1\) applies to this work, unless stated otherwise.

\[ \text{"Fiber to the Home" is defined as an access network architecture in which the final connection to the subscriber’s premises is Optical Fiber.} \]

This means that in order to be classified as FTTH, the access fibre must cross the subscriber’s premises boundary. It excludes technologies such as HFC or even VDSL, where fibre is also used.

3.1.1. Architecture

From the fibre point of view, FTTH deployments are divided into two type of architectures: point-to-multipoint and point-to-point network.

Users of point-to-multipoint topologies share a single fibre with other users, using either passive or active splitters in the field, while users of point-to-point topologies use dedicated fibres between the POP (Point of Presence) and the user.

Point-to-point (also known as Home Run or PtP) deployments require considerably more fibres and Optical Line Terminals (or OLTs, one port per home) compared to the other shared infrastructures. On the other side, it has the advantage of dedicated bandwidth.

Point-to-multipoint (PtMP) deployments reduce the total amount of fibre deployed and hence lower costs, by sharing a single fibre from the POP and the remote node by the split ratio. There are two types of point-to-multipoint architectures: active and passive.

Active point-to-multipoint (also known as Active Star) contain active devices in the remote node such as switches. The remote node has a multiplexer/demultiplexer, and switches the signal in the electrical domain and hence OEO (Optical and Electro-Optical) conversions are necessary.

Passive point-to-multipoint (also known as PON or Passive Optical Network) don’t have any active electronics at the remote node, and hence don’t need any power supply. Instead, passive splitters are used, generally enabling 4 to 64 users to share a single fibre.

### Table 3.1

<table>
<thead>
<tr>
<th>Passive Optical Network (PtMP)</th>
<th>Active Optical Network</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Home Run (PtP)</strong></td>
<td><strong>Active Star (PtMP)</strong></td>
</tr>
</tbody>
</table>

**Figure 3.1** – Overview of the different FTTH network architectures.

Notice that each of the three FTTH architectures have one point in common. Each passed home has a single fibre that goes to the remote node (concentration point, usually a street cabinet).

Each architecture differs from the others in what goes on the concentration point, and how much fibres go to the CO (Central Office).

### 3.1.2. Protocols

There are 2 standards bodies which standardise PON networks: ITU-T and IEEE. Currently used protocols are GE-PON (also known as EPON) and GPON, compared on Table 3.1.

It has been excluded from the table BPON (or APON), which was the first standard in PON network (from 1995), but is no longer used to deploy new networks.

In addition to EPON and GPON, newer protocols based on these two have recently been approved, compared on Table 3.2.
### Table 3.1 – Overview of the different competing PON protocols.

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
<th>GE-PON (EPON)</th>
<th>GPON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed - Upstream/Downstream</td>
<td>1.0/1.0 Gbps</td>
<td>2.4/1.2 Gbps</td>
</tr>
<tr>
<td>Physical reach</td>
<td>10 km</td>
<td>10 km</td>
</tr>
<tr>
<td>Splitter ratio</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>Native Protocol</td>
<td>Ethernet</td>
<td>GEM</td>
</tr>
<tr>
<td>Year of approval</td>
<td>2004</td>
<td>2003</td>
</tr>
<tr>
<td>Standards Body</td>
<td>IEEE (802.3)</td>
<td>ITU-T (G.984)</td>
</tr>
</tbody>
</table>

### Table 3.2 – Overview of the future different competing PON protocols.

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
<th>10G-EPON</th>
<th>10G-PON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed - Upstream/Downstream</td>
<td>10/10 Gbps</td>
<td>10/2.5 Gbps</td>
</tr>
<tr>
<td>Physical reach</td>
<td>20 km</td>
<td>20 km</td>
</tr>
<tr>
<td>Splitter ratio</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>Native Protocol</td>
<td>Ethernet</td>
<td>GEM</td>
</tr>
<tr>
<td>Year of approval</td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td>Standards Body</td>
<td>IEEE (802.3av-2009)</td>
<td>ITU-T (G.987)</td>
</tr>
</tbody>
</table>

There are several remarkable considerations regarding these protocols. The first one is that both protocols offer similar characteristics in terms of bandwidth, physical reach and number of users per fibre. Their characteristics are of course according to current technology availability.

Second consideration is that in a time span of 15 years there have been 3 different generation of standards, and this could well continue, according to the Shannon-Hartley theorem. However, all of these protocols use the same passive optical fibre network.

Last consideration is that both standards can coexist in practically the same passive network. This means that different operators are able to use different protocols on the same network, and each one can offer different end-user services according to that active equipment.

#### 3.1.3. Costs of deployment

The costs of deploying an FTTH network are a key element analysing the economic feasibility of such a deployment.

The modeling of these costs depend on the architecture used to deploy the network, on
the type of population density, on the current infrastructures already deployed, and so on. Models usually come with high sensitivities in the costs that make final outcome vary considerably.

Some of these models are COSTA[^2] or ISDEFE [2009][^3], both focused on the deployment of NGAN in Spain. Other studies include Mason [2008b][^4], Mason [2009][^5], Mason [2008a] [^6], Avisem [2007][^7], and WIK-Consult [2008][^8].

These models also depend on the type of electronics in the network, and whether or not this equipment is included. Usually, three parts are described and analysed in the models: the outside plant, the inside plant and the customer premises.

### 3.1.3.1. Outside Plant

The outside plant contains all passive FTTH equipment, including ducts, subducts, fibres, optical splitters, hand-holes, man-holes, street cabinets and pedestals.

These costs can be around 70% of the total cost of the deployment, depending on the type of deployment. It’s much expensive to open trenches than to use poles, or even sharing or renting already deployed and underused ducts and subducts.

![Figure 3.2 – Overview of the different Outside Plant elements.](image)

Figure 3.2 shows the different Outside Plant elements in a buried scenario. Notice that the elements appearing in the figure are common in all types of architectures described

[^3]: Ordered by the Spanish regulator
[^4]: Ordered by the Dutch regulator
[^5]: Ordered by the Belgian regulator
[^6]: Ordered by the association Broadband Stakeholder Group (UK)
[^7]: Ordered by the French regulator
[^8]: Ordered by the European Competitive Telecommunication Association, ECTA
on section 3.1.1. Differences stand in the street cabinet (Active PtMP contain powered equipment, Passive PtMP contain passive optical splitters, and in Passive PtP it is basically a registry cabinet), and in the number of fibres that come from the CO to the handhole beside the Street Cabinet.

In every scenario there is a fibre from the Street Cabinet to each subscriber or connectable household, and the costs of installing this fibre is the same in each case. This cost could also be reduced by the use of façade or aerial installations.

![Figure 3.3 – Façade and Aerial installations alternatives.](image)

However, whatever installation type is used, the cost of installing the fibre is the same for every architecture seen on this document.

3.1.3.2. *Inside Plant*

The inside plant contains all the necessary equipment to illuminate the fibre from the operator equipment to the customer premises.

The inside plant contains basically two elements: the ODF (Optical Distribution Frame) and the OLT.

The ODF is where fibres coming from the outside plant are connected. Its function is to distribute the outside fibres into the inside plant to the provider OLT. The cost of the ODF depends on the architecture of the network.

The OLT is the first active equipment found in the network, and each port can give connectivity to up to 64 users, depending on the chosen architecture.

3.1.3.3. *Customer Premises*

Finally, at the other end of the Inside Plant there is the customer premises equipment (CPE). The fibre is brought into the house from the Outside Plant and connected to the ONT (Optical Network Termination), which is the active electronics equipment needed by the subscriber.

Depending on the type of household, both the active equipment and the fibre arriving
at the home can be installed over demand by the operator, hence decreasing the initial investment on the deployment:

- Aerial or façade installation: the Outside Plant fibre ends at an aerial drop box, and the final installation is done using an optical patch-cable and a connector to this drop box.
- Buried installation: the Outside Plant fibre ends at an underground enclosure on the street, often at each two households, with enough fibres to cover every possible subscriber.

3.1.3.4. Unbundling options

Given the many options there exist to deploy an FTTx network, there are also many options to unbundling. The Body of European Regulators for Electronic Communications (BEREC) described them and their possibilities in a document issued on March 2010, called “BoR (10) 08 BEREC Report on NGA wholesale products”.

From fully deploying two separate FTTH networks, to bandwidth wholesale there are intermediate options: unbundling at the concentration point, or at the ODF. In PON scenarios, unbundling at the ODF is not possible, whereas in PtP scenarios unbundling in the concentration point makes no sense: if the operator has already deployed a fibre for each home at the ODF, it’s better to unbundle there.

![Diagram of FTTH Unbundling in the concentrator.](image)

Due to the economies of scale associated to FTTH deployments, it is of course better for the unbundler to do the unbundling at the ODF, since much of the elements such as passive splitters can be optimised. If one operator does not have 64 customers in a concentrator, it is underusing infrastructure. It is more likely to deploy more efficient infrastructure in the ODF than in the concentrator.

However, PtP deployments are more expensive for the deployer of the network, since more fibres are used and deployed.
3.1.4. Conclusion

As seen, different types of FTTH networks are basically the same at some point, which is arriving at each subscriber premises using fibre.

Beside that, there are different architectures and protocols enabling different costs and capabilities. From lowering the aggregation rate which will result in better and more expensive services, to investing and innovating in the active electronics equipment, each operator is able to offer different services and compete with other operators.

When it is more difficult to make that difference is when all operators must share the same active electronics equipment, which in turns also decreases the investment and innovation of each operator’s network.

In other words, what is desirable in order to foster both competition and investment is the implementation of the so-called Local Loop Unbundling (LLU) in FTTH networks, hard as it can be to do that for certain passive networks. Even more, the promotion of PtP deployments, where the unbundling can take place at the ODF, fosters competition (and investment in the active electronics components) by the unbundlers and the deployer.

3.2. LTE and LTE-Advanced

The ITU (Internation Telecommunication Union) is the specialised agency of the United Nations responsible for information and communication technologies.

This agency has issued requirements for mobile system standards, called International Mobile Telecommunications (IMT) specifications. The so-called 3G networks is a generation of standards fulfilling IMT-2000 specifications.

The current specifications (issued in 2008) are called IMT-Advanced, for what is marketed as 4G networks. Among all the requirements, the following are included:

- Based on all-IP packet switched network
- Nominal data rate of 100 Mbps for moving clients, and 1 Gbps for fixed clients (down-link)

3.2.1. Protocols

3.2.1.1. LTE

3GPP Long Term Evolution (LTE), also known as LTE Release 8, is a standard for wireless communication of high-speed data, standardised by the 3rd Generation Partnership Project (3GPP). The standard was approved in December 2008, and its main characteristics include:
- Peak rates of 300 Mbps in the DL and 75 Mbps in the UL, both using 20 MHz of spectrum.
- At least 200 active users in every 5 MHz cell.
- Less than 5 ms latency for small IP packets.

This type of networks is what is being started to deploy by many operators around the world[^9]. This is not to be confused with real 4G networks, although some operators label these networks as 4G LTE (VerizonWireless in the USA, or TeliaSonera in Sweden, for instance[^10]).

### 3.2.1.2. LTE-Advanced

LTE itself does not fulfill all of the 4G network and is therefore sometimes called 3G Transitional or 3.9G. Latest efforts from 3GPP to specify a 4G standard is LTE-Advanced (also known as LTE Release 10). Submitted in 2009 to the ITU-T it is expected to be released in 2012.

LTE-Advanced will provide 1 Gbps peak data rate by the use of multiple antennas and more spectrum bandwidth (as much as 70 MHz).

### 3.2.2. Costs of deployment

The costs of mass deploying an LTE network are not as well studied as are FTTH networks, and only in the last few months the first commercial LTE networks are being deployed.

In order to have enough capacity, more and smaller cells will need to be deployed, and hence the deployment is more than just an upgrade from the existing 3G base stations. Also, spectrum is physically limited, and operators claim there may not be enough spectrum to fulfill NGN needs.


Taking all this into consideration, LTE-Advanced deployments could be seen in an scenario much further in the future.

### 3.2.3. Conclusion

When comparing the investment of LTE to FTTH, it seems LTE needs much less investment than the one needed to deploy FTTH networks, although no study has been found in

[^9]: See for example: [http://ltemaps.org/](http://ltemaps.org/)
terms of deployment costs.

The technical characteristics of LTE are better than current DSL connections, but far from those offered by the fibre, in terms of bandwidth, stability and sharing of the access channel. Specially in urban and dense urban areas, the amount of base stations and spectrum needed in order to fulfill a very large share of subscribers is unreachable.

It could be a good strategy for the rural and spare rural areas, where there is no need for a lot of base stations, and where costs to deploy FTTH networks are very large. However, experience from 3G networks show that this is an unlikely scenario. The first 3G network was in Japan in 2001, and it has taken 10 years to achieve a coverage of 82% in EU27, in terms of population. When looking at the territorial coverage, only 53% of EU27 territory is covered by 3G connections, precisely the most economically feasible areas.


**Figure 3.5** – 3G coverage in EU27 (%).


Finally, there is a limitation as of who can deploy LTE networks. Only operators (and few of them) with the license to operate a certain spectrum are allowed to exploit it.

This is in contrast with FTTH networks, where any public administration, public-private partnership, or private operator can deploy NGN networks in an open network architecture, which gives much more flexibility when deploying a network.

### 3.3. HFC

Hybrid fibre-coaxial (HFC) is the technology used by cable television operators since the early 90s, and combines optical fibre with coaxial cable.

The architecture is very similar to the FTTH architecture, and in fact HFC is considered a type of «Fiber to the x» network. Fiber optic is deployed from the Headend (Central Office)
to an Optical Node (the equivalent to a Concentration Point), and from there typically 500 households are served using coaxial cable.

![HFC network diagram](image)

**Figure 3.6** – HFC network diagram.

### 3.3.1. Protocols

HFC networks were deployed by television operators, and the initial application was to broadcast TV signal. After upgrading their networks from coaxial to HFC, the operators started considering other services, including telephony or broadband.

The protocol enabling high-speed data transfer to an existing cable TV is called DOCSIS (Data Over Cable Service Interface Specification), firstly approved in 1997.

Latest version of the protocol is DOCSIS 3.0, released in 2006. This version increases the bandwidth to up to 400 Mbps in the downstream and 108 Mbps in the upstream using bonded channels. A channel is either 6 MHz or 8 MHz, depending on the specific standard (DOCSIS or EuroDOCSIS), and DOCSIS 3.0 allows to bond typically 4 or 8 channels. The total amount of bandwidth is up to 860 MHz, which is a total of at most 100 channels.

These channels are asymmetric, and according to the standard upstream can be up to 85 MHz, giving 10 channels in the upstream and 90 in the downstream. Therefore, the total amount of bandwidth to be shared among the 500 households is of 4500 Mbps and 270 Mbps in the uplink. And this is considering no TV channel at all is being broadcasted, which is not the real scenario.

It is already less capable than current PON protocols (GPON and EPON share at least 1 Gbps between 32-64 users), and future PON developments are due to supersede DOCSIS 3.0.
3.3.2. Costs of deployment

The costs of deploying an HFC network are very much similar to those of deploying an FTTH network. The elements of the network are not much different (outside plant, inside plant and customer premises), and the costliest part is the trenching of the coaxial cable to each household.

Where there is a main difference in the cost of deployment is not in the CAPEX, but in the OPEX. As seen in Figure 3.6 all the equipment between the Headend and the customer premises is active equipment, and needs power supply. It also has a shorter life cycle than passive optical elements. This means there are more failures and repairs of equipment in an HFC network than in a PON network (Bowers [2004] and John A. Brouse [2004]).

3.3.3. Conclusion

HFC networks are a valid NGAN. They are scalable, offer large bandwidths and low latencies, and are already deployed and working.

However, the main advantage of these networks over other access network was the provision of TV channels. Since the tendency is to converge into an IP world, where TV channels, video on demand, and every service will be transported using IP networks, these advantage no longer exists, and the same services can be delivered using FTTH networks.

On the other side, FTTH networks need much less maintainance, much less power supply, and are more easily upgradable than HFC.
CHAPTER 4. CONCLUSIONS

4.1. Regulatory Policies approaches

Regulatory policies in the broadband market have had (and continue to have) different approaches around the world. Many are the questions derived from broadband regulation, about how and how much regulation is good for broadband deployment. The very same definition of “good” for broadband deployment could be the first question.

Generally, regulation is able to influence markets from two points of view, either on the demand or on the supply-side. As for the supply-side, there are two main approaches towards what regulation is able to do: to foster competition, or to satisfy user needs by building up networks.

These three main areas subject to regulation have more or less influence depending on the specific characteristics of each country. Different regulatory measures explained on Chapter 2 must be contextualised with local or regional dynamics, and not every measure taken in one place can be exported world-wide with the same outcome.

For instance, it is not possible in the European Union to rely only on competition in infrastructures as is done in the United States, because there are not two widespread access networks as is the case in the U.S. with telecommunications and cable networks.

The FCC in the U.S. has left much to the market, since two different access networks exist in the country. South Korea and Japan have had a much bigger active role in broadband policies, subsidising backbone and access networks to foster this competitive market. The European Commission has historically focused its efforts mainly in the promotion of competition, unbundling network elements which, justified by the ladder of investment, would be beneficial for end users.

Differences also apply on the demand-side of regulation, where much more effort (and budget) has been put by the governments of Japan and specially South Korea, with many programs addressed to people not usually active in the adoption of broadband, such as the elderly, or the inclusion of computerisation programs in schools. These measures again could be difficult to implement to other countries due to political and historical differences between them.

4.2. Social demand

There is one thing all the players in NGAN deployments agree: investments required to make these networks available are huge.

From Chapter 1 we can extract the increasing importance of Internet access, and specifically broadband Internet. Year by year, household penetration rates of fixed Internet access increase, and so far there is no indicator this increase is slowing down, growing 5%
Assessment on the Deployment of FTTH Networks

every year. Younger layers of population already use the Internet by over 80%, showing how far can fixed Internet accesses reach.

This means networks will become more profitable: using the same access network, which already reaches every household, operators will have more subscribers.

This contrasts with the need for NGAN specifically, instead of current old copper network. It’s true that statistics show that people don’t mostly use the Internet for services which require large bandwidths, and basic uses are reading e-mail or seeking information. There is no clear demand of services requiring fibre, not even where FTTH deployments are more extended like in Japan or South Korea.

However there are also arguments from the opposite side.

First, the chicken and egg situation. Why would developers bother innovating in services requiring very large bandwidths and low latencies, if there are no such networks largely deployed? Formal way to explain that is the virtuous cycle of digital economy, or how investments enforce developing new services.

There was no video broadcasting website back in the early 90s. And as seen IP traffic has been growing around the world at rates much higher than Internet access, which means that the more bandwidth has been available to users, the more it has been used.

Second, empirical data of NGAN penetration rates in countries with significant coverage suggests people migrates from old copper accesses to new fibre-based ones. The importance of this is that it suggests there won’t be lack of demand for these networks.

In this direction, demand-side policies can improve penetration rates, and foster the emerging of new services able to maximise the capabilities of NGAN.

4.3. Technological capability

FTTH networks assure a long life expectancy for the access network, at least at the passive elements level. While copper is unlikely to to improve much, fibre still has a long way ahead. Upgrades in these fibre networks are likely to be possible for many years, and no technology performs better in terms of capacity. From currently deployed protocols giving 1 Gbps, to currently approved ones giving 10 Gbps.

There are other technological alternatives for the access network which also give high bandwidths. Mainly, LTE(-Advanced) and HFC, both described in Chapter 3. Although both are meant to offer at least 100 Mbps, they are clearly less capable than FTTH deployments.

On one side, LTE(-Advanced) offers very high rates mainly because of higher spectrum usage, and smaller cells, not by Shannon’s. The consequence is that the perspectives of increase in wireless capacity are more limited than with fibre, limited by the amount of spectrum available, and the size of the cells.

On the other side HFC networks in the end do use copper for the last mile, with its lim-
Conclusions

The main competitive advantage of old cable networks was Television, which is no longer the case with Television over IP protocols able to transmit using any IP network. Disadvantages include the sharing with many more users in HFC networks of the available bandwidth, and higher OPEX costs than FTTH networks.

The position of the European Commission from its beginning has been of technological neutrality, where it didn’t matter what technology would be used as long as it fulfilled the objectives marked by the Commission. But in practice policies have always followed technological evolution, and should in NGAN take into consideration the best technological performer in this scenario.

4.4. End conclusions

In Europe there has been from the beginning the dominant position of the ladder of investment, and competition in infrastructures, in order to foster investment.

The measures taken by State Members have actually improved competition, and therefore also services and prices, but only to a certain point. There hasn’t been any full deployment by any alternative operator at all, and the competition in infrastructures has reached only up to the local loop unbundling level, where alternative operators have invested in active equipments such as DSLAMs.

This is likely to continue at this level, and desirable in most cases. While studies ([ISDEFE, 2009]) show there may be room for multiple FTTH networks, this only does not make sense in most cases, in regards of economic efficiency. The costs of deploying one single FTTH network are huge, so as to multiply them with multiple access networks, even when some passive infrastructure could be rented.

Multiple fibre access infrastructures lightly foster innovation, since innovation merely happens at the deployment of the physical access network. There should be incentives to innovate at very dynamic processes such as the deployment of services, or active infrastructure, and not trenching fibers to each home which is an infrastructure with life expectancies of 15+ years.

Policies should reflect, emphasise the importance, promote or even obligate the local loop unbundling, since it is the best way to ensure competition at the level where innovation happens. The sharing of infrastructures up to the local loop will help reduce the risk of investment, while it would not affect investment in alternative operators (in the parts that matter).

The path to NGAN will require big investments, but is the next evolutionary stage from narrowband first and broadband later, and should improve quality of life and change the way services are thought and offered.


