Long-Term Broadband Evolution – Forecasts and Impact of New Technologies

KJELL STORDAHL

Kjell Stordahl is Senior Advisor in Telenor Networks

The paper describes the broadband evolution especially in Western Europe. The broadband penetration is separated into the business and residential markets and forecasting models are developed for both markets and also for the main broadband technologies DSL, Cable modem (Hybrid Fibre Coax), FTTx and Fixed Wireless Access. The FTTx deployment and demand in Western Europe are to a certain degree suppressed by uncertain regulatory framework for fibre accesses. The influence of mobile broadband is discussed. Finally, analyses show that the cost of Fixed Wireless Access is high, indicating that the technology only will be competitive in areas which cannot be covered by DSL and cable modem.

Introduction

The most advanced broadband areas in the world are Western Europe, North America, Australia and selected countries in Asia. It is difficult to analyse all areas and countries separately since they have different demographics and the development of broadband rollout and broadband demand are different. This paper concentrates on Western Europe, which is a rather homogeneous area and focuses on the available technologies and obtained market share. Further, long-term forecasts for the technologies and their market share will be shown and discussed. So far FTTx has captured very limited market shares. The demand for higher broadband capacity makes fibre access, FTTx, an attractive solution also for the residential market in the long run. At the same time there will be substitution effects between fixed broadband and mobile broadband and the broadband demand will be affected by bundles and N-play packages.

Huge investments have been made to roll out broadband networks in recent years. Long-term broadband demand forecasts have been and are crucial for investment decisions, rollouts and dimensioning of networks. The main broadband access technologies have been DSL and Cable modem (Hybrid Fibre Coax). Other technologies like fibre (FTTx) and fixed wireless access are also entering the market. Especially in Japan, Hong Kong, China, and Korea, the growth of FTTx has been significant in the last years. However, the fibre access evolution in Western Europe has been quite modest. To cover the residual broadband market, technologies like WiMAX and mobile broadband are needed.

Specific attention is paid to FTTx, which is the long-term ultimate broadband solution. The long-term FTTx forecasts for Western Europe are dependent on a set of assumptions like time delay, regulatory aspects, degree of densely populated areas, etc. *The access forecasts for Western Europe show that the dominating technology, DSL, soon will start to lose market shares.*

Broadband Potentials for Western Europe

The Western European countries analysed comprise EU15 and Iceland, Switzerland and Norway. EU15 consists of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Luxembourg, Portugal, Spain, Sweden, and UK. The broadband potential will be a function of the number of households and the number of business units in EU15+3 – Western Europe.

The total population of Western Europe (EU15+3) is about 400 million and the number of households about 170 million. The number of individuals per family is close to 2.5 persons. The number of households is estimated to grow by 1.5 million per year, while the total number of inhabitants is estimated to grow by 0.8 million per year. So far the number of households is the driver for residential broadband access demand contrary to the mobile market where the individuals are the driver. However, there are some limits. One barrier is older people who need time to adopt the new broadband technology. Another barrier is lack of PCs in the households. Students, newly established persons and people with flexible home locations may prefer to use mobile broadband access, not a fixed mobile access. Figure 1 shows the PC penetration among Western European countries based on OECD statistics [1]. The main part of the Western European countries has a PC penetration larger than 70 %. The yearly increase is estimated to be about 3 %.

Fixed Broadband Evolution

Residential Market

Different sources are used to establish broadband access statistics for the period 1999 – 2007. The sources are: Idate [2], OECD [3], OVUM [4], Point topic [5], IDC [6], Forrester [7], Jupiter [8], IST/ Tonic [9], CELTIC/ Ecosys [10], Idate [11]. The evolution of the broadband

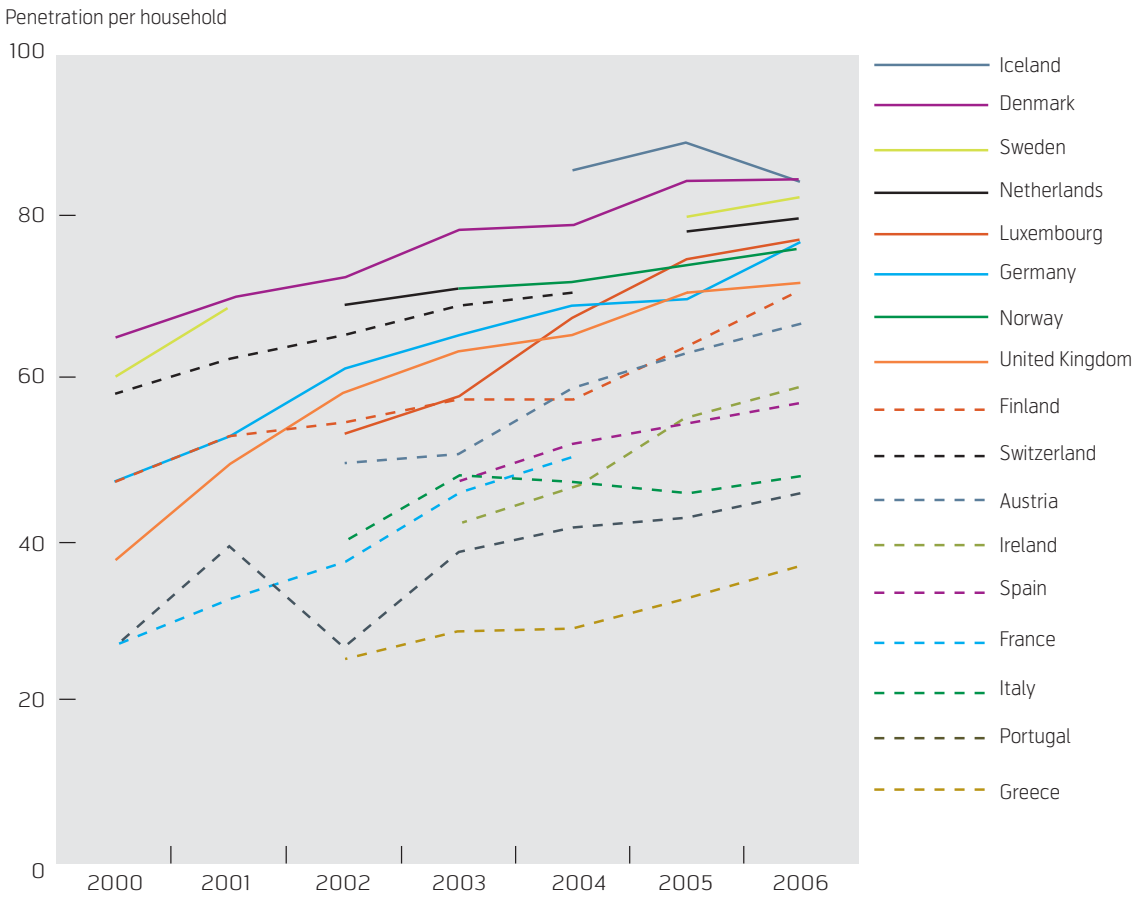

Figure 1 Evolution of PC penetration 2000 – 2006 among Western European countries (OECD) [1]

market from 2000 – 2007 will be shown. Statistics for both the residential and the business market will be presented. The demand data presented in the figures are mainly based on *mean values* from the different sources since there are some variations in the data.

Figure 2 shows the broadband penetration in the residential Western European market. The penetration is described as number of accesses per household. The evolution started smoothly, increased exponentially and is now evolving approximately linearly. The evolution fits very well with Logistic models.

Figure 3 shows the evolution of the market share of DSL, cable modem/HFC and 'Other' broadband technologies from 1999. Other broadband technologies have mainly been fixed wireless accesses and fibre (FTTH/FTTB). WLAN and WiFi are not included as fixed broadband technologies. The figure shows a relatively continuous behavior. Cable modem / HFC has continuously lost market shares, mainly to DSL, but the decrease is smaller each year. It will be shown that the Cable modem / HFC penetration develops differently in various countries in Western Europe. The yearly growth in DSL market share is also reduced significantly during these years. The figure shows that 'Other' broadband technologies have not yet been able to capture significant market shares. However, during the last years some increase is seen.

Figure 4 shows the evolution in number of accesses for the other technologies distributed as fibre/FTTx,

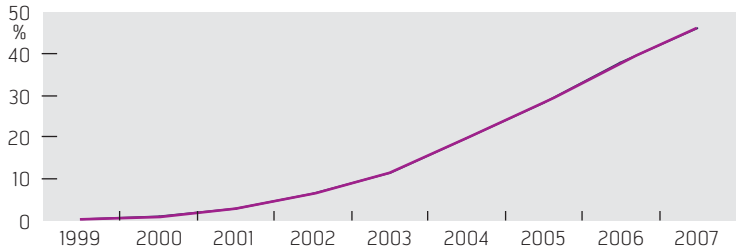

Figure 2 Broadband penetration per household, Western European residential market, 1999 – 2007

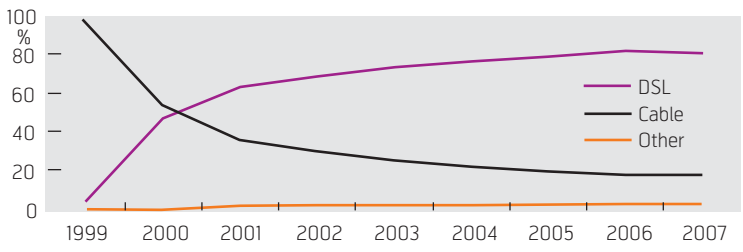

Figure 3 Market Share DSL, Cable modem / HFC and Other broadband technologies, Western Europe residential market, 1999 – 2007

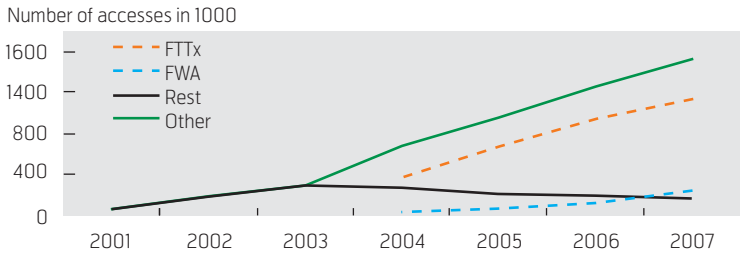

Figure 4 Number accesses of FTTx, FWA and 'Rest' broadband technologies, residential Western European market, 2001 – 2007

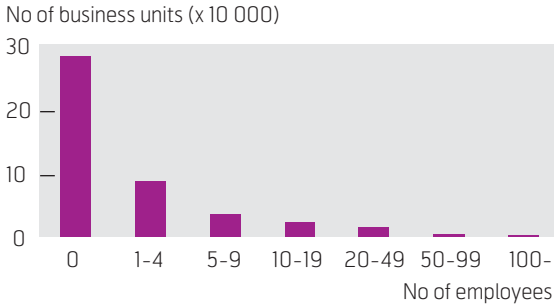

Figure 5 Number of business units in Norway as a function of size (number of employees) (SSB)

FWA and a 'Rest' category. The figure shows that there is a significant increase in FTTx accesses, even if the numbers are small. Especially Denmark, Sweden and Norway roll out fibre to meet competition from the electricity companies. Fixed wireless access starts the rollout very smoothly. Covering the residual broadband market will in the future generate rollout of WiMAX and mobile broadband. The figure also shows accesses denoted as 'Rest' broadband technologies. Because of the data sampling, there is no information about which broadband technology these accesses represent. Probably are power line connections (PLC) and satellite accesses the main technologies.

Business Market

Broadband access statistics for the business market, especially penetration are not readily available. Usually, statistics are made as the sum of residential and business accesses. For pure broadband business statistics the penetration is often found as business accesses per inhabitant.

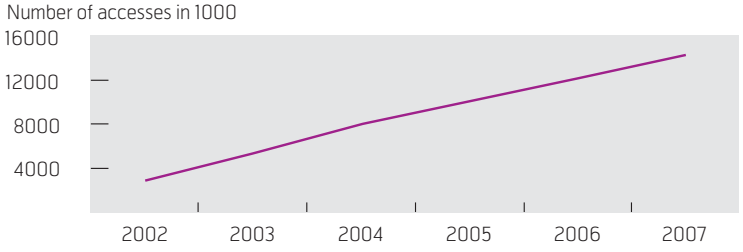

Figure 6 Number of broadband accesses in the business market, Western Europe, 2002 – 2007

The number of business units according to Idate [2] was 28.5 million in 2004. A business unit is placed at a separate geographic site. One example is a branch office, which is a part of a larger enterprise. It is important to note that not all business units will be potentials for broadband access, because some of them are not active. Some of the units are for example constructed for tax reasons. In Norway 80 – 90 % of the farmers and the fishermen have their own companies (business units). They will not order both a private and a business broadband access. Large companies situated at one site may use more than one broadband access. Norway is used as an example to illustrate the size distribution of business units.

Figure 6 shows the broadband business access evolution in Western Europe 2002 – 2007, where the number of accesses, 14.2 million for 2007, is estimated. The figure shows that the yearly growth since 2004 has decreased. The numbers in the figure can be observed relative to the 28.5 million business units in the Western European market. This makes a broadband penetration close to 50 % in 2007.

Fixed Broadband Evolution – the Residential and the Business Market

The broadband evolution, which is the sum of the residential and the business accesses of the Western European market is summarized in Figure 7. The figure shows that there is a significant growth in the Western European broadband market. The total broadband market consisted of about 76 million broadband accesses at the end of year 2006 and increased to 93 million accesses at the end of 2007. The growth is mainly driven by DSL and cable modem (HFC). As mentioned the cable modem is losing market shares, while DSL is acquiring additional market shares, even if the growth in market share is decreasing. Figure 7 shows that increased volumes of FTTx and FWA are moderate compared with DSL and cable modem. However, Figure 4 (residential market) shows that FTTx and FWA technologies now are up-and-coming technologies.

Even if Western Europe is an advanced telecommunication area, there are significant differences between the countries. Figure 8 shows the broadband penetration evolution for the residential and business markets for the different countries in Western Europe. When the broadband statistics do not distinguish between the residential and the business market, the penetration is often defined as the total number of broadband accesses divided by the number of inhabitants. It is

important to note that the penetration shown will be lower compared to penetrations based on number of accesses divided by number of households.

Figure 8 shows that there are large differences in the broadband evolution between some countries in Western Europe. Denmark and Netherlands have the highest penetration. The group with the highest penetration is the five Nordic countries together with Netherlands and Switzerland. The group with the lowest penetration consists of Greece, Portugal, Italy, Spain and Ireland. Especially Greece has a much delayed broadband evolution. The large countries UK, France and Germany are in the middle.

Long-term access forecasts for different broadband technologies depend on detailed knowledge of the technologies – their strengths, limitations and possibilities. A short review of the different broadband technologies will be given.

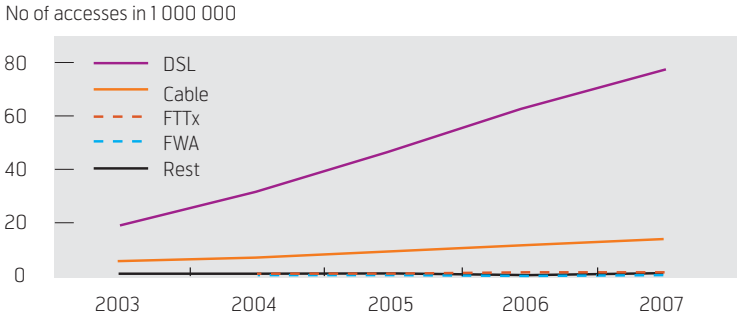

Figure 7 Evolution of number of DSL, Cable modem/HFC, FTTx, FWA and rest broadband accesses, sum residential and business accesses, Western Europe, 2003 – 2007

Broadband Technologies

DSL – Digital Subscriber Line Technology

The DSL dominating position in Western Europe is explained by a cost effective rollout of DSLAM/ eDSLAM together with an expansion of capacity in

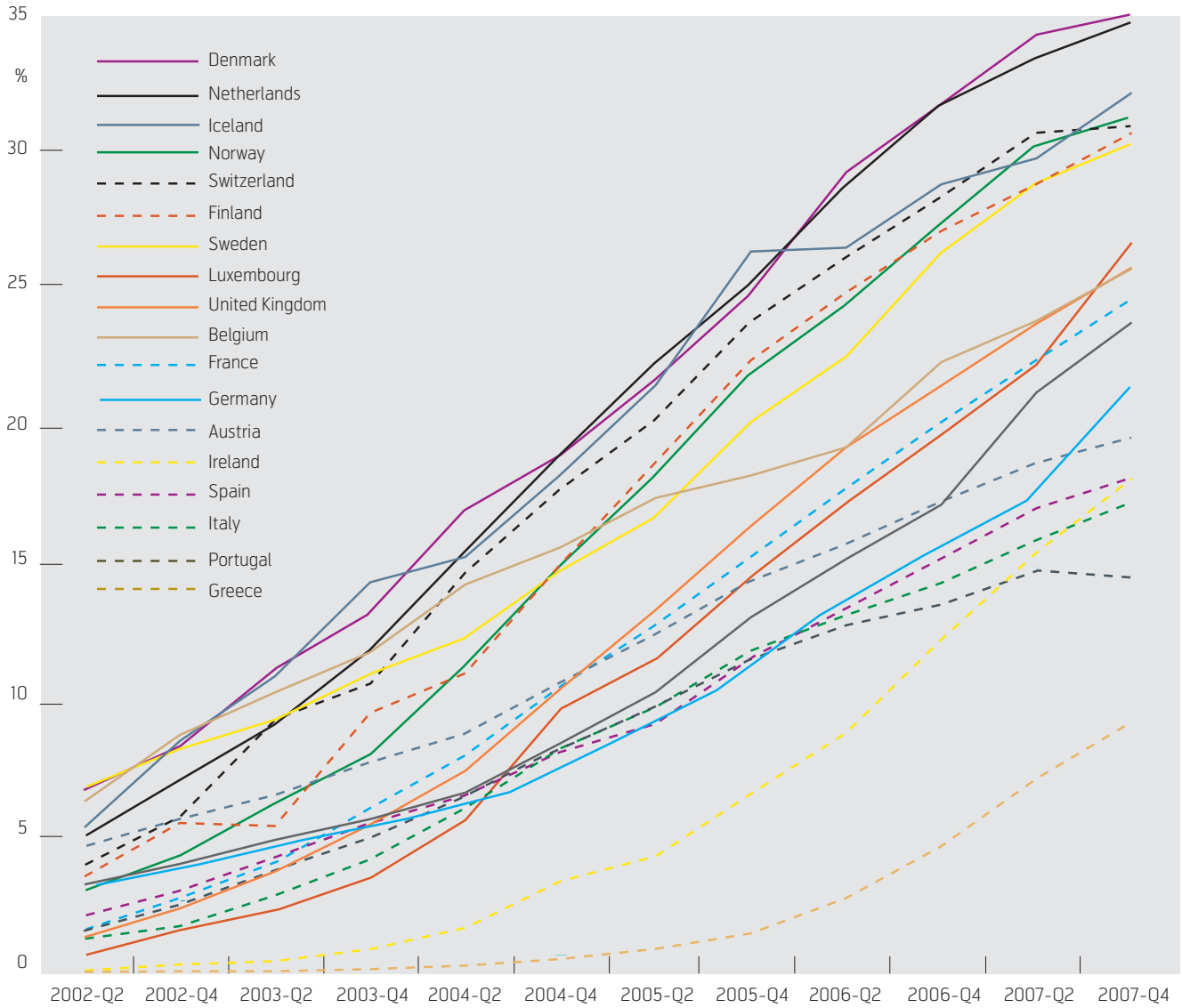

Figure 8 Broadband penetration per inhabitant, sum residential and business market, for Western European countries, 2002 – 2007 (OECD) [3]

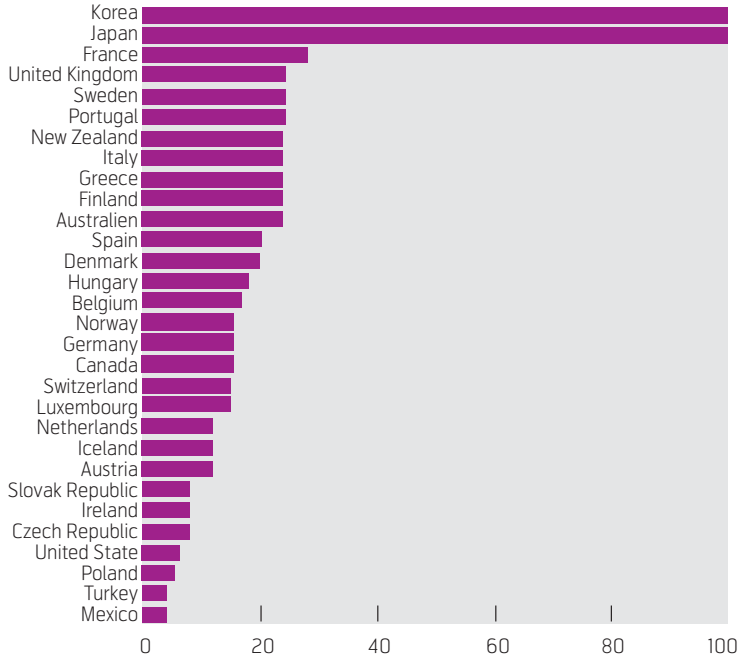

Figure 9 Maximum speed offered using DSL in OECD countries (OECD October 2007) [3]

parts of the access network. Many European countries opened their copper access networks early by introducing Local Loop Unbundling (LLU), which in turn increased the demand for DSL.

ADSL has been dominating so far. The offered speed has gradually increased. Now, ADSL2+ is offered and in some countries also VDSL2. The coverage of ADSL for most countries in Europe is about 94 – 98 % of the population because of the copper loop length. The area which cannot be covered by DSL is called the (DSL) residual broadband market. Long range ADSL can improve the coverage to a certain extent. VDSL2 997/998 and ADSL2+ have much less coverage, 1 – 1.5 km, with an acceptable speed. To increase the coverage the access network has to be expanded with fibre and fibre nodes.

IP-TV is a driver for ADSL2+ and VDSL2. The incumbent operators and LLU operators in some countries also have to meet competition from fibre operators and cable operators with upgraded HFC networks. Hence, the incumbents and the LLU operators have to expand their access capacities by ADSL2+ and VDSL2. OECD reported in October 2007 [3] the figures shown in Figure 9 for maximum DSL speeds offered. The figure shows that Japan and Korea are already offering very high DSL speed. The high speed is caused by fibre deployment to buildings and utilization of short copper lines inside the buildings. Then 28,000 Mbit/s has been introduced in France, while Finland, Greece, Italy, Portugal, Sweden, and UK have 24,576 Mbit/s, and Spain and Denmark 20,480 Mbit/s (VDSL). Countries following the ADSL2+ standard are Belgium: 17,408 Mbit/s, Germany and Norway: 16,384 Mbit/s, Luxembourg and Switzerland: 15,360 Mbit/s, while Austria, Iceland and Netherlands have 12,288 Mbit/s. However, the volume of high speed accesses in Western Europe is so far very limited compared to the ADSL access volume.

Figure 10 gives a picture of the distribution of speed classes offered in different countries. The figure shows the situation at the end of 2006; later changes are not incorporated. At that time Belgium and Netherlands had a high volume of 2 – 8 Mbit/s accesses. The high DSL speed in these countries can be explained by heavy competition with the cable operators. The highest volume of 1 – 8 Mbit/s

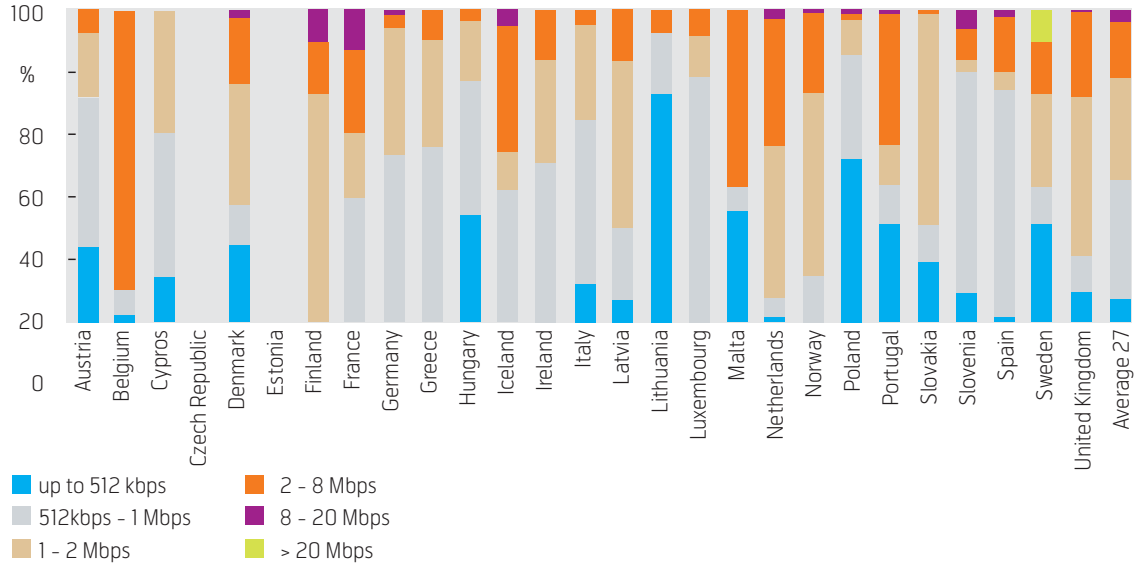

Figure 10 Distribution of DSL download speed, EoY 2006, (Idate October 2007) [13]

accesses including also some higher speed accesses in Western Europe is found in Finland, Belgium, Netherlands, Norway, UK, Denmark and Sweden.

The possibility for the DSL technology to maintain its very high broadband market share is continuous introduction of higher up and down speed and further rollout in rural areas. The economic value (net present value) for DSL rollout starts to decrease because the rollout areas are smaller. However, in [14] it is shown that the operator who first enters these small areas will, in practice, get a broadband monopoly, which improves the business case.

Cable Modem / HFC – Hybrid Fibre Coax

Deployment of CATV networks started more than 40 years ago. The first upgraded CATV networks with two-way broadband connection appeared nearly ten years ago. Figure 7 shows that the cable modem accesses are increasing year by year, while Figure 4 shows how the technology continuously loses market shares. However, the situation varies between the different Western European countries as illustrated by Figures 11 and 12.

All countries except Italy and Greece have reported cable modem / HFC networks. Iceland has a very modest market share. The countries with the highest market share are: Netherlands, Portugal and Belgium (39 – 36 %) followed by Austria and Switzerland with about 31 %. In the large countries Germany and France the cable modem market share is about 5 %. The largest increase in number of accesses from 2006 to 2007 took place in Germany, UK, Netherlands and Spain. In spite of that, cable modem is still losing market shares in UK and Spain.

The figures show that cable modem market shares in Austria, Luxembourg, Spain, Sweden, Switzerland and UK are continually reduced, while cable modem market shares in the group of countries Belgium, Denmark, Finland, France, Germany, Netherlands, Norway and Portugal has started to increase slowly. Summing up the access volume in the two groups of countries, the proportion of cable modem accesses is about 50/50.

In upgraded areas, the growth of new customers is limited. The cable operators' possibilities to consolidate the situation are to upgrade the parts of the CATV networks which so far have not been upgraded. The main upgrade is to install cable modem / HFC. The other upgrade is to expand from DOCSIS 1.0/1.1 to 2.0 and 3.0 together with a possible restructuring of the network to maintain increased traffic. DOCSIS 3.0 is now being installed in the European market. The maximum usable speeds (down/up) are respectively 38/9 Mbit/s, 30/27 Mbit/s and 152/108 for 4 Channel 3.0 DOCSIS and 304/108 Mbit/s for 8 Channel 3.0 DOCSIS. The EURO DOCSIS standard gives slightly higher capacity. However, it is important to note that the capacity is shared between accesses in the last part of the network. Figure 13, made by OECD, shows the maximum cable modem capacity offered in OECD countries. The figure shows that operators in several European countries offer maximum capacity comparable with VDSL2 from 24 Mbit/s and upwards. Only Finland, Switzerland and Ireland have maximum capacity lower than 10 Mbit/s.

Many European cable operators compete with the incumbent and offer broadband telephony in addition to TV broadcast and broadband accesses (Triple play). These possibilities make reasonable business cases for upgrading the traditional cable TV network.

FTTx – Fibre Access

Fibre access is denoted either Fibre to the home (FTTH), Fibre to the building (FTTB), Fibre to the Premises (FTTP), or simply FTTx. In broadband statistics Fibre to the building with a local area network (FTTB/LAN) is also included in this category. The FTTx technology is based on a fibre structure

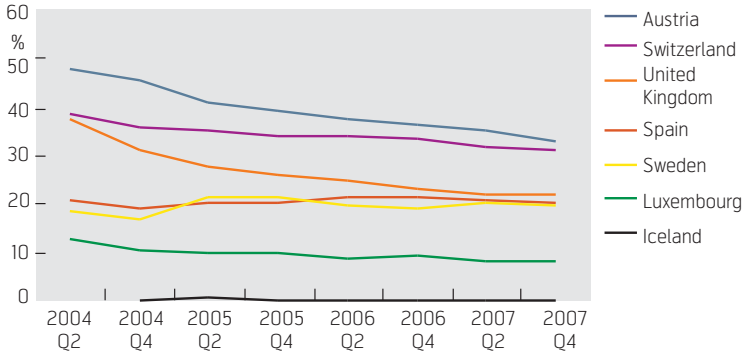

Figure 11 Countries in Western Europe with continuous decreasing cable modem market share

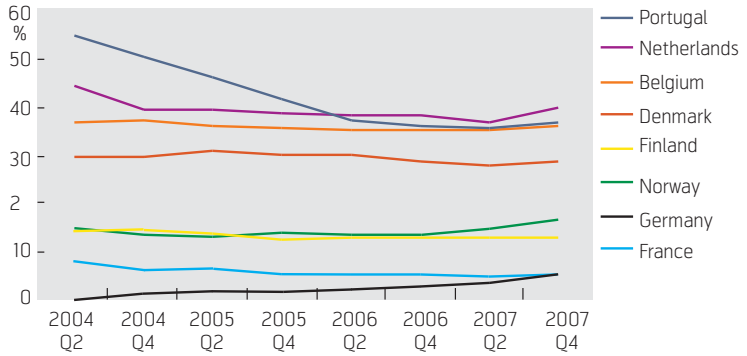

Figure 12 Countries in Western Europe where the cable modem market share has started to increase slowly

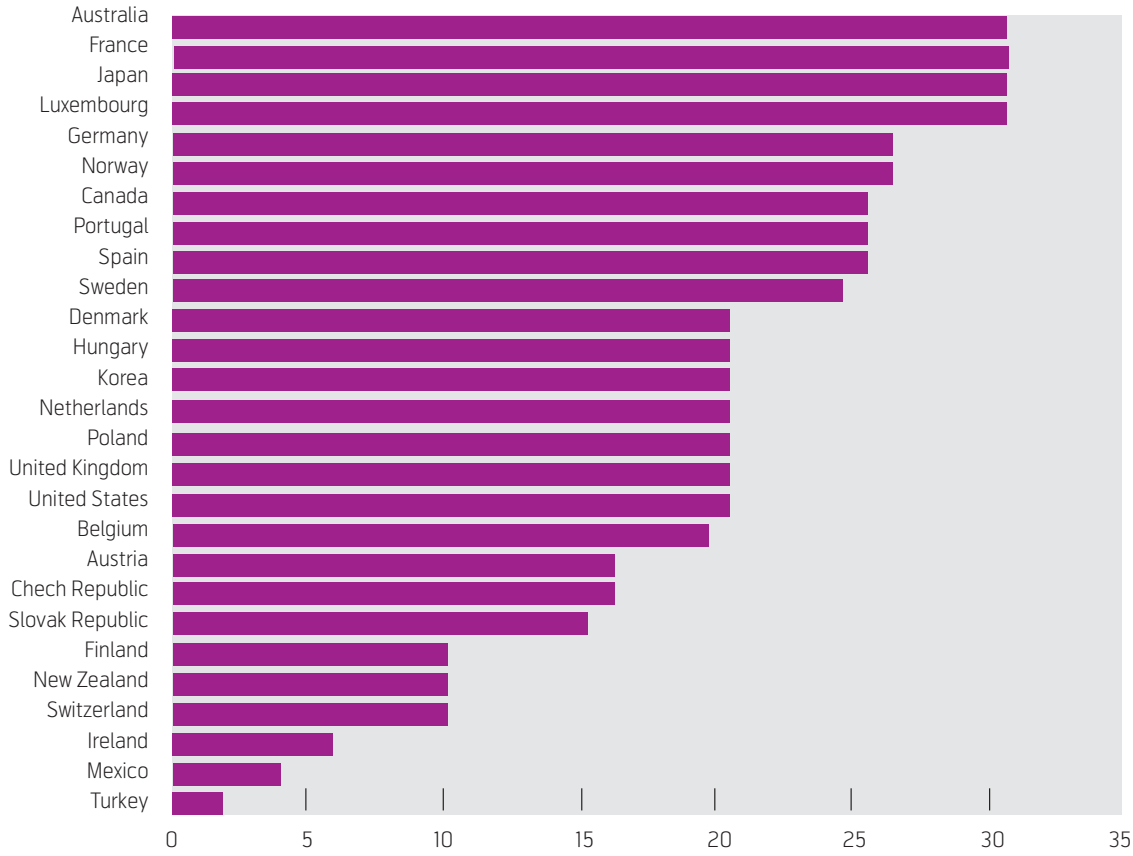

Figure 13 Maximum capacity (Mbit/s) offered using cable modem in OECD countries (OECD October 2007) [3]

down to a fibre node and then dedicated fibres to the customers or shared fibres by using passive optical PON/GPON solutions.

Fibre access makes it possible to use very high capacities. In a way, FTTx is the ultimate telecommunication solution. The demand for FTTx will be driven by IPTV, interactive broadband applications and HDTV.

In Europe the investments made to establish FTTx infrastructure in the access network have been considered to be too high and too risky. The strategy so far has been to utilize other broadband technologies, especially ADSL2+ and then VDSL2. HFC with DOCSIS 3.0 is a very relevant competitive alternative for cable operators.

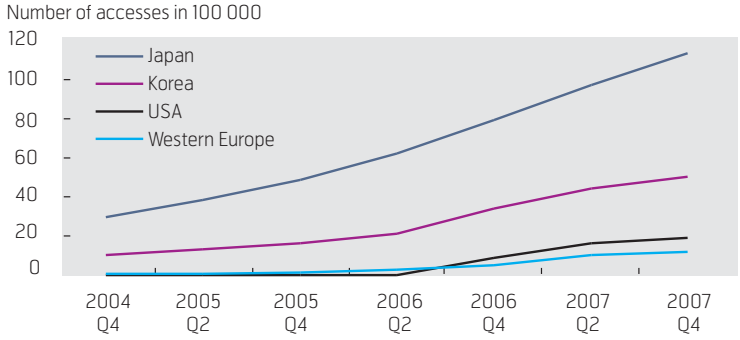

Figure 14 Evolution of number of fibre accesses in Japan, Korea, USA and Western Europe (OECD) [3]

One way to establish fibre accesses is to deploy fibre in new buildings – Greenfield. Another way is to restructure and deploy fibre in areas with a lot of failures. A third possibility is to pull fibre in ducts where there is enough space. Fibre deployment starts to become expensive when parts of the deployment have to be based on digging and ducting. In Japan the poles are also used to stretch the fibres. Figure 14 shows the limited deployment of fibre accesses in Western Europe compared with Japan, Korea and USA.

The populations in Western Europe, USA, Japan and Korea are 400 mill, 291 mill, 127 mill and 47 mill, respectively. Figure 14 shows that Japan has the lead among OECD countries with about 11.3 million fibre accesses, followed by Korea with about 5 million fibre accesses. The yearly increase is very significant for both countries. Now, the fibre market share is 40 % in Japan and 34 % in Korea. Since 2004 the DSL market share has been reduced from 69 % to 46 % in Japan and from 57 % to 31 % in Korea. However, the market share of the cable modem in the two countries has remained fairly constant during these years. Hence, the cable modem technology has so far been able to compete with fibre accesses.

Figure 14 shows that USA has started and already overtaken fibre deployment in Western Europe. Especially Verizon has aggressive rollout plans for the

next five years. A more detailed analysis is described in [15]. The fibre market share is now 2.7 %, nearly a doubling during the last year. In Western Europe the fibre market share has increased from 0.7 % to 1.3 % in the same period. Especially Sweden, Denmark, Norway and Italy have the most significant fibre deployment in Western Europe.

Outside the OECD countries also China and Hong Kong have a significant amount of fibre accesses. During the last year China has got nearly 10 million fibre accesses [5].

The FTTx regulation in Europe is a huge topic. The EU commission denotes it regulation of Next Generation Access Network (NGA). Their draft recommendation is submitted for comments by November 2008 and will be adopted and finalized soon after [16]. The intention of the recommendation is to induce heavier fibre competition in the access networks. The EU recommendation will probably mandate the national regulators to open dominating operators' ducts for competitors. For less dense areas the recommendation will probably mandate national regulators to give competitors access to the dominating operators' fibre access network. Like LLU on copper, a monthly compensation for the leasing will be given. An important document for EU has been a report from WIK [17].

The Organization of European Telecommunication Network Operators (ETNO) issued a press release 18 September 2008 [18] stating the following: Europe is lagging behind other regions in fibre deployment. The investment efforts are slowing down. The New Generation Access Network requires investments up to 300 billion Euro. Key focus should be to make a recommendation on how to boost risky investments by all operators and accelerate network deployment. In its current form it may generate further delay of deployment of NGA. EU should focus on how the operators should be encouraged to invest in new networks.

There are several unanswered questions and uncertainties. Passive optical networks are relevant for fibre accesses. The technology makes it difficult for wholesale. Will it be possible to in practice open the ducts for LLU operators? Where will the natural connection points be? Is there reason to believe that fibre deployment will evolve faster when most of the regulation problems are solved?

BT announced in a press release on 15 July plans to roll out fibre-based, super-fast broadband to as many as 10 million homes by 2012. The £1.5 billion programme will deliver a range of services with top speeds of up to 100 Mb/s with the potential for speeds of more than 1,000 Mb/s in the future.The investment forms part of BT's wider strategy of delivering next generation broadband services nationwide. The UK already has world leading broadband availability and this investment programme offers the prospect of joining the world super league for broadband speeds as well [19].

In the same article BT were asked the following question: Is this investment dependent on Ofcom creating a new regulatory framework? And they anwered, Yes. The right regulatory environment is vital for anyone seeking to invest. The funds required are extremely large and companies need confidence that risk-taking can be appropriately rewarded.

BT's answer shows significant uncertainties regarding the investment decisions based on what so far is not an established NGA regulatory framework.

Wireless Accesses

The wireless technologies are divided into WAN (CDMA, WCDMA, HSPA, LTE), MAN (WiMAX 802.16e, WiMAX 802.16 2004), and wireless LAN. These technologies can also be denoted mobile broadband, fixed wireless access and nomadic access, respectively.

Wireless LAN like WiFi covers the nomadic broadband market. So far international broadband statistics do not render a complete picture of the nomadic broadband market. Therefore, the broadband nomadic market is not a part of this paper.

Fixed wireless access (FWA) statistics are available from most countries and are a natural part of the fixed broadband statistics. WiMAX is the main technology. Even if the mobile broadband technologies CDMA, WCDMA, HSDPA, HSUPA are not fixed broadband connections and not a part of the fixed broadband statistics, the evolution, deployment and coverage will affect the fixed broadband demand. Hence, it is important to take the fast increasing coverage of mobile broadband into account when fixed broadband forecasts are developed.

The wireless technologies are shared resources with limited capacities. The available capacity for the customer is dependent on the number of customers in the area who are using the service at the same time. For WiMAX the shared capacity is 14.4 Mbit/s, which probably gives a few Mbit/s per customer. New generations of WiMax may give higher capacity. For mobile broadband, the maximum capacity is lower. However, new system generations will increase the capacity stepwise. Anyhow, regarding capacity of

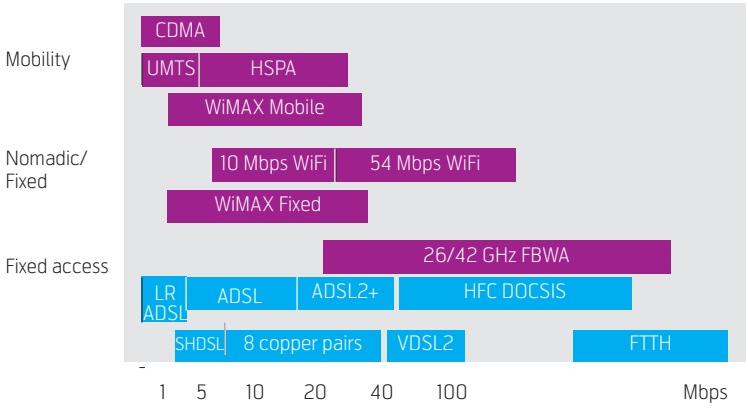

Figure 15 Different technologies, downstream capacity and mobility

the wireless access technologies, they are not able to compete with the wireline broadband technologies. This indicated in Figure 15.

The red blocks in the figure show wireless technologies and capacity. It is important to note that the upper limit for the capacity is shared between active customers in a given area. LTE is not included in the illustration. The technology will offer much higher capacity than HSPA and WiMAX, but the specifications and rollout time so far are uncertain. The blue blocks show the wireline technologies. In general, the capacities of these technologies are higher because they are not based on sharing the capacity. However, the access capacity offered by these technologies may be reduced in the core network because of dimensioning principles. The dimensioning principles are based on queuing models and take into account a reasonable economic dimensioning at busy hour.

Figure 16 shows connections between the core network and areas with different fixed access technologies. When an operator offers broadband on Hybrid Fibre Coax, the core network will also be used to transport traffic between the Head End and the different coax islands. Analogously, when an operator offers mobile services the core network is used to transport traffic from the base stations.

The Norwegian Broadband Case

In Norway the two main cable operators Canal Digital and Get have turned the broadband situation from continuously losing market shares to DSL, to capturing new market shares. Both operators are upgrading their CATV networks to cable modem / HFC. In addition they offer triple play; Broadband, TV and telephony at a reasonable price. In spite of heavy competition from fibre operators with triple play

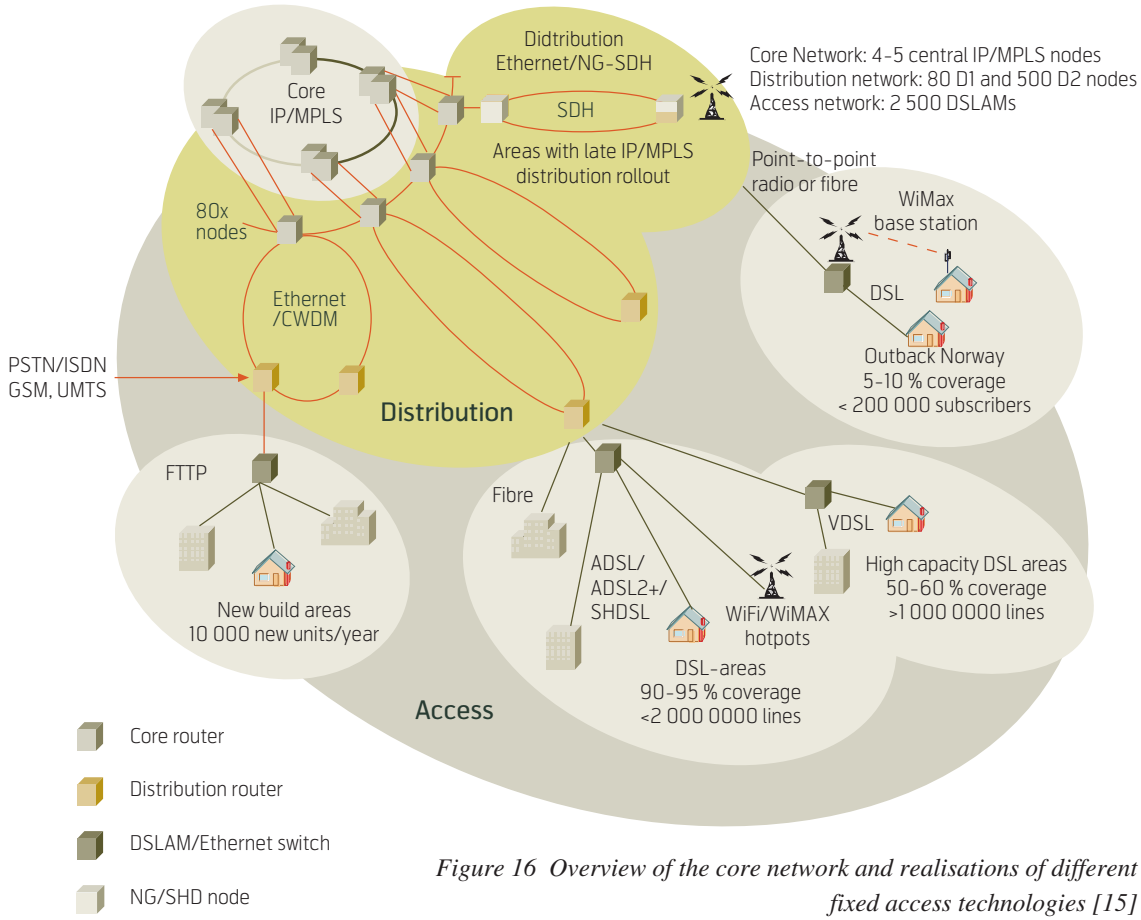

Figure 16 Overview of the core network and realisations of different fixed access technologies [15]

offers and DSL operators, the cable operators have captured new market shares.

There are quite a few fibre operators in the Norwegian market; most of them are electricity companies with very good economic positions because of the high electricity prices in the last years. They are also offering triple play to their customers.

Figure 17 shows the market share evolution in Norway since 2000 based on statistics from the Norwegian regulator, PT [22]. The figure shows that in the last three years DSL has started to lose market shares. FTTx and FWA have captured market shares from DSL and even cable modem / HFC is doing the same.

The broadband penetration (relative to number of households) in the Norwegian residential market was about 68 % at the end of 2007. Norway holds fourth position among OECD countries with the highest broadband penetration, in 2007 there were 31.2 broadband accesses per 100 inhabitants. In addition Norway has the third highest DSL penetration among OECD countries [3].

Norway and the Nordic countries can be considered as advanced telecom countries in Europe. Hence, information about the broadband evolution in these countries can be used as input to the broadband forecasts for Western Europe.

Long-Term Broadband Evolution and Impact of New Technologies

This paper shows long-term forecasts for fixed accesses in Western Europe five years ahead – until the end of 2012. The evolution until 2007 shows a reasonably stable behaviour with DSL and cable modem as the dominating broadband technologies.

As underlined, FTTx will be the ultimate broadband solution for the residential and the business market. Japan, Korea and Hong Kong have deployed fibre and FTTx accesses quite extensively in recent years, making the FTTx market share more than 30 %, while the FTTx penetration per household is more than 20 %! The population in these countries is very dense. Probably have available duct capacities in large parts of the cities made it possible to pull fibre without too much digging. The fibre is also stretched on poles in Japan. In addition the governments have established favourable incentives for the fibre rollout.

In Western Europe the population is more sparsely distributed and huge investments are needed for extensive fibre deployments. Installation of VDSL2

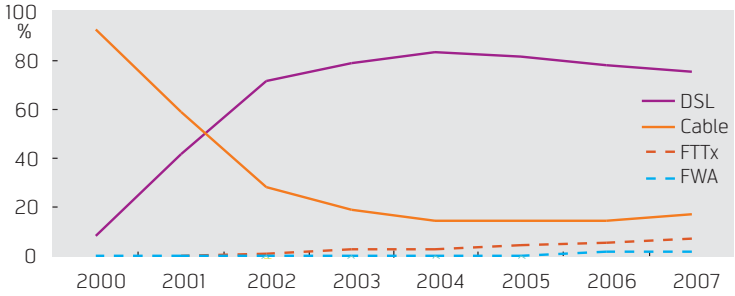

Figure 17 Broadband technology market share DSL, Cable modem / HFC, FTTx, FWA in Norway, 2000 – 2007 (PT statistics) [16]

is for the moment a relevant alternative to fibre since the capacity makes it possible to offer several independent TV streams and IP-TV. To get reasonable coverage even here, fibre has to be deployed deeper into the access network.

Further, the regulation on fibre is still not settled and creates of course uncertainties. However, when some of the unanswered questions are solved, the fibre arena should be opened for less risky investments.

There is certainly a dynamic broadband market in the Scandinavian countries, which have the highest FTTx penetration in Western Europe. The fight for the high capacity broadband market has been going on for several years, mainly initiated by many different electricity companies which have rolled out their own fibre structure. In Norway, the incumbent operator, Telenor, declared in February 2008 that they will start to deploy fibre and will offer FTTx together with IP-TV. The long-term FTTx forecasts for Western Europe takes into account this type of information.

The broadband residual market is important for the forecasts. It is defined as the market which is not covered by DSL, cable modem / HFC or FTTx. The main part of the market consists of potential subscribers in rural areas, but there are also subscribers with too long copper loop length in dense areas. The broadband residual market consists mainly of small areas. In addition, there are customers in each DSL area which have too long copper loop length to utilize DSL.

Figure 18 shows the DSL coverage by the end of 2006. In rural areas there are not many alternatives to DSL. The figure indicates the broadband residual market as the difference between 100 % and the percentage shown. For the countries in the figure there are still potentials for DSL rollout. Norway has increased the DSL coverage by about 3 % since the end of 2006. In the urban and suburban areas different wireline technologies are and will be deployed, while in the non-dense areas DSL will be the domi-

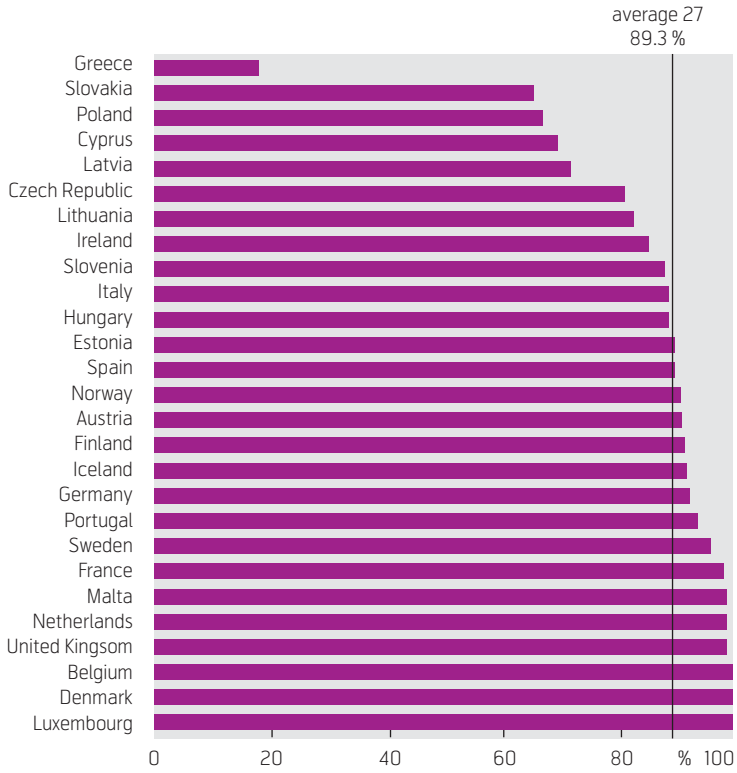

Figure 18 DSL coverage EoY 2006 (Idate October 2007) [13]

nating broadband technology followed by wireless technologies.

In 2005 the newly elected Norwegian government announced that they wanted to roll out broadband to the entire country by the end of 2007. The Norwegian government had so far utilised the free market dynamics and handed over the broadband deployment to the operators. To speed up the rollout of the very last part of the infrastructure, which so far is not commercially profitable, the government decided to support by financing it. These types of actions are of course important for the forecasts.

WiMAX is a relevant technology for covering parts of the broadband residual market. The broadband wireless technologies are rolled out to cover this market. It is assumed that fixed wireless technologies, especially WiMAX, will capture parts of the residual market, while the broadband mobile technologies like HSPA and CDMA will capture the rest.

As mentioned, mobile broadband is not a part of the fixed broadband statistics. However, the evolution affects the demand for fixed broadband accesses in the broadband residual market and also the long term saturation. Since the mean lifetime for a mobile handset is about 1.5 years, there will be significant transitions from GSM, GPRS, and EDGE handsets to the mobile broadband handsets CDMA, WCDMA and HSPA which do not cost very much more. In addition there is hard competition between the mobile operators to capture market shares. The mobile operators upgrade and expand their networks and offer broadband mobile subscriptions at very low prices. Hence, the mobile broadband penetration will increase significantly in the next years.

Long-Term Fixed Broadband Access Penetration for Western Europe

The long-term broadband forecasting model is based on a four parameter Logistic model given by

$$Y_t = M/(1 + e^{\alpha+\beta t})^{\gamma}$$

where Y_t is the accumulated demand at time t, M the saturation level, α a level parameter, β and γ growth parameters. The parameters except M are estimated by a recursive regression procedure.

The 'long-term' saturation level, M, for fixed network accesses depends on parts of the residual broadband market being captured by mobile broadband and parts of the households not demanding fixed broadband accesses. In this category there are households which in the long run will not own a broadband terminal such as a PC, and there will be newly established persons and persons with 'flexible homes'. For these market segments mobile broadband will be applied instead of fixed broadband access. Mobile broadband can be utilized by using the mobile handset or by using a PC connected to the mobile handset.

Demand data from different sources are available from 1999 to 2007. The penetration is defined relative to the number of households in Western Europe, which is about 170 million. Figure 2 shows the broadband penetration up until 2007.

The penetration fits very well to Logistic models, which can also be seen from the shape of the figure. However, estimating the saturation level M is rather difficult. Earlier, estimation has been based on identification of market segments which in the long run have limited interest for broadband. Now, broadband mobile technologies will also affect the demand and generate substitution. So far the saturation level for fixed broadband is estimated at 80 %.

The fixed broadband penetration forecasts for the business market are shown in Figure 20. Here, we define access penetration relative to the number of business units. Statistics of number of business units are available at the National Bureau of Census. The number of business units in Western Europe is estimated to be 28.5 million. However, a significant part of the business units has one owner and no employ-

ees. A part of these units are not considered as potential for broadband accesses. The total number of broadband accesses estimated as potentials is 65 % of the number of business units. Demand data have been available for 2002 – 2006 and estimated for 2007. Data for 1999 – 2001 have been estimated. The penetration forecasts shown in Figure 20 are made for 2008 – 2012.

The fixed broadband penetration forecasts for the residential and the business market are shown in Figure 21. The proportion between number of household accesses and business accesses is 85 % : 15 %. Looking at the number of households relative to number of business units, the proportion is estimated to be 89 % : 11 %.

Figure 21 shows that the broadband penetration in the business market had a faster growth in the first years. Now, the growth is stagnating because of a low saturation level and a more mature market, while the residential broadband penetration is growing faster.

Market Share Forecasts for Different Technologies

Figure 22 shows market share forecasts for the main technologies in the residential broadband market. The main technologies are DSL, cable modem / HFC, FTTx, FWA and a 'Rest' market consisting of other technologies like satellite, PLC (power line connection) etc. The figure shows that the dominating technology DSL is losing market shares already in 2008, but the reduction is small the first years. The reduced DSL market share is caused especially by the new technologies FTTx, WiMax and Mobile broadband.

Figures 11 and 12 show cable modem / HFC market share evolution in two groups of Western European countries where countries in the first group are still losing cable modem market share, while countries in the second group have stabilized and also started to capture some market shares. The number of cable modem accesses is about equally distributed in the two groups.

Competition with FTTx and offensive marketing of triple play packages is part of the picture. The cable operators in Western Europe may capture additional market share, which of course depends on factors like triple play offer, price, TV programme packages, interactive broadband offer, capacity offered etc. Also the possibility for offering quadruple play will affect the demand. The demand for cable modem also depends on upgrading of the traditional CATV network to cable modem / HFC, introduction of higher capacity DOCSIS 2.0 and 3.0 and capturing significantly more customers in already upgraded cable modem/HFC areas. The forecasting model assumes that cable modem for countries in Western Europe (mean) will fairly soon stop losing market shares and converge to 16.5 %.

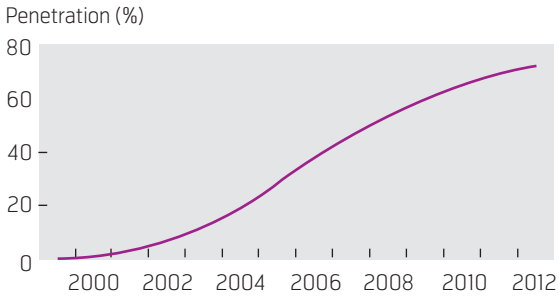

Figure 19 Broadband penetration forecasts per household, residential market Western Europe, 2008 – 2012

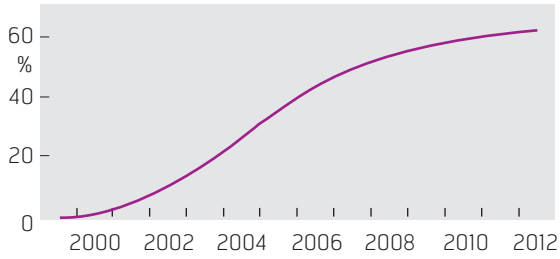

Figure 20 Broadband penetration forecasts, business market Western Europe, 2008 – 2012

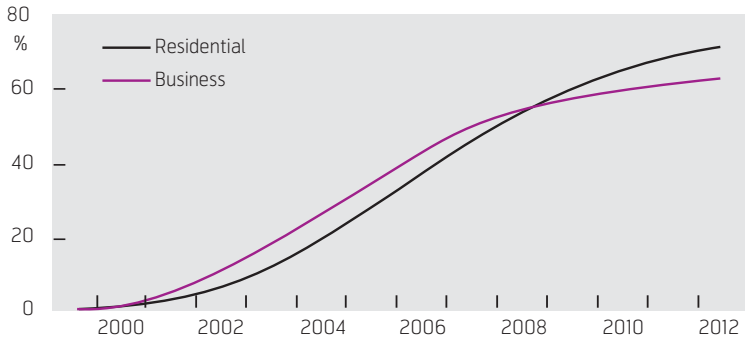

Figure 21 Broadband penetration forecasts for the business and residential market, Western Europe, 2008 – 2012

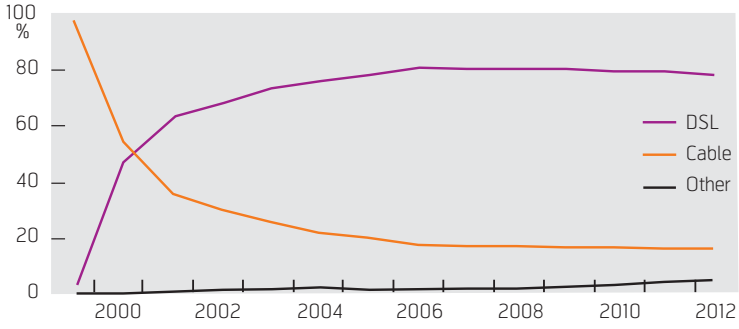

Figure 22 Market share forecasts for DSL, cable modem/HFC and Other technologies, residential market, Western Europe, 2008 – 2012

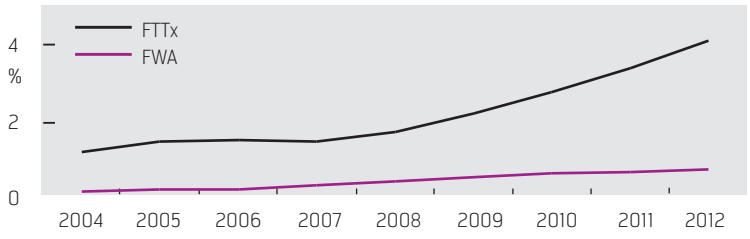

Figure 23 FTTx and FWA market share forecasts, residential market, Western Europe, 2008 – 2012

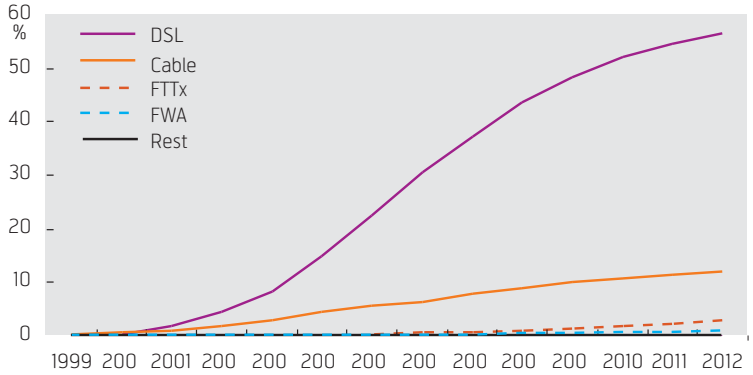

Figure 24 Technology penetration forecasts for DSL, cable modem / HFC, FTTx, FWA and Rest technologies, residential market, Western European, 2008 – 2012

Other technologies in Figure 22 are FTTx, FWA and a rest group (Rest). Figure 23 shows the market share evolution of FTTx and FWA. The figure shows an increased market share for FTTx. Probably the forecasts for the Western European market is conservative, going from a market share of 1.4 % in 2007 to 4.1 % in 2012. Some crucial questions influence the evolution. How quickly will the primary regulatory questions for fibre be resolved? How active will the operators be in installing fibre accesses in Greenfield? How offensive will the European operators be in deploying VDSL2? Will the competition after some years be as we now see it in the Scandinavian countries?

It is assumed that FWA will take about 20 % of the residual broadband market, while mobile broadband will take the rest. The long-term potential FWA market share is estimated to be 0.8 % of the total fixed broadband market. The forecasts indicate about 0.7 % FWA market share in 2012.

Since not much broadband statistics is available for other technologies and there is so far no indication of a significant growth of other broadband technologies, the assumptions in the forecasting model set the market share for 'Rest' technologies at 0.2 % in the years 2008 – 2012.

Figure 24 shows the penetration for each technology. The penetration is found by multiplying the total broadband penetration forecasts given in Figure 18 by the market share forecasts for each technology given in Figure 21. Figure 24 shows that even if DSL is losing market shares, penetration is still increasing significantly. The situation is the same in the Scandinavian countries, but there are many urban areas where DSL growth has stopped because of FTTx and cable modem / HFC competition. In Japan and Korea, however, the DSL penetration is decreasing significantly.

Conclusions

DSL has been the dominating broadband technology in Western Europe and in most other countries. One exception is the US where the demand for cable modem / HFC has been, and still is larger. In Western Europe cable modem / HFC has continually been losing market shares until recently. During the last few years fibre accesses have started to catch a significant part of the broadband market in the densely populated countries Japan, Korea and Hong Kong. In some other countries there has been some evolution of fibre accesses and in some other countries a modest evolution. The fibre access evolution in Western Europe is dependent on the regulatory regime which is still unsettled. Unsolved questions create uncertainty and prevent investment in fibre infrastructures in the access part of the network. An LLU regime on fibre including natural connection points has not been defined. The degree of possibility for duct sharing and/or fibre sharing for new operators entering the area is not clarified. The residual market, which cannot be covered by DSL, opens for wireless technologies, especially WiMax and CDMA, WCDNA, HSPA and later LTE.

The forecasts show that DSL in Western Europe soon starts to lose market share to fibre accesses, fixed wireless accesses and mobile broadband. It can also be seen that cable modem/HFC will have a stabilized market share. Fibre access is the ultimate telecommunication solution, but there are huge investments related to comprehensive fibre access rollout. The forecasts are uncertain, especially because of still unresolved regulatory questions. The forecasting model includes the residual broadband market as one segment, and the long-term forecasts reflect the demand for how fixed wireless access and mobile broadband create new opportunities in this segment even if the market segment is limited.

Positioning of operators and their possibilities to offer N-play (Triple play / Quad play) are important for capturing new broadband market shares. The positioning also creates substitution effects between technolo-

gies. This is illustrated in [22] where conjoint analysis is used to identify market potentials for different N-play packages. In addition mobile broadband will in some market segments be a substitute to fixed broadband. The forecasting models used take this effect into account by reducing the fixed broadband saturation level. Because of the short history of mobile broadband the identified effects are uncertain and further work has to be carried out to improve the models.

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