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**Conference Paper**

## Long-term penetration and traffic forecasts for the Western European fixed broadband market

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**22<sup>nd</sup> European Regional ITS Conference  
Budapest, 18-21 September, 2011**

**Kjell Stordahl**

**Long-term penetration and traffic forecasts for the Western European  
fixed broadband market**

**Abstract**

The objective with the paper is to describe, analyze and forecast the future fixed broadband penetration and traffic growth in NGN and NGA networks in Western Europe – one of the most advanced telecommunications areas in the world. Analyses show that the broadband penetrations are very well fitted by Logistic models. Here, extended Logistic four parameter models are used to develop broadband penetration forecasts 2011 - 2015. Separate forecasts are developed for DSL, HFC(Hybrid Fiber Coax), FTTx and FWA (Fixed Wireless Access)

The traffic forecasts are developed per user in the busy hour. Hence, it is possible to assess the future fixed broadband busy hour traffic in NGA networks and also the accumulated busy hour traffic in NGN networks taking into account the fixed broadband penetration forecasts.

**JEL codes: O33**

**Keywords: Fixed broadband, NGA, NGN, long-term forecasts, penetration, traffic**

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## 1 DSL

The DSL (Digital Subscriber Line) dominating position in Western Europe is explained by cost effective rollout of DSLAM/eDSLAM together with expansion of capacity in parts of the access network. Many European countries opened their 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 from about 94 % to nearly 100 % of the population because of the copper loop length. 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 fiber and fiber nodes (FTTN).

IPTV is a driver for ADSL2+ and VDSL2. The incumbent operators and LLU operators in some countries also have to meet competition from fiber 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.

Japan and Korea have since 2006/2007 offered extremely high DSL speed (102 Mbps). Now, Portugal has started to offer the same speed same places. The high speed is caused by fiber deployment to buildings and utilization of short copper lines inside the buildings. In Hungary, Sweden and Denmark also very high speed is offered on copper.

The signal on the copper lines is affected of the noise and cross talk on the lines in the bundle. Hence, available speed is high for short copper lines, but the speed is reduced nearly exponentially as a function of loop length.

The ADSL speed for long loop length is comparable with the one for ADSL2+, but the reach is longer especially when RADSL - rate adaptive DSL is used.

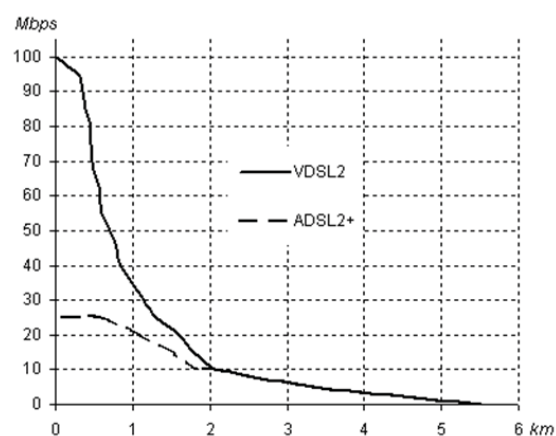


Figure 1 ADSL2+ and VDSL2 speed as a function of loop length.

An important long term target for EU and specific countries has been “broadband to all”. The key technology for the broadband roll out has been DSL. The technology is rather cheap because the copper lines are already in place. However, when more sparsely populated areas are left, there economic value of the DSL roll out is more questionable. In [1-2] it is shown that the operator who first enters these small areas will, in practice, get a broadband monopoly, which improves the business case.

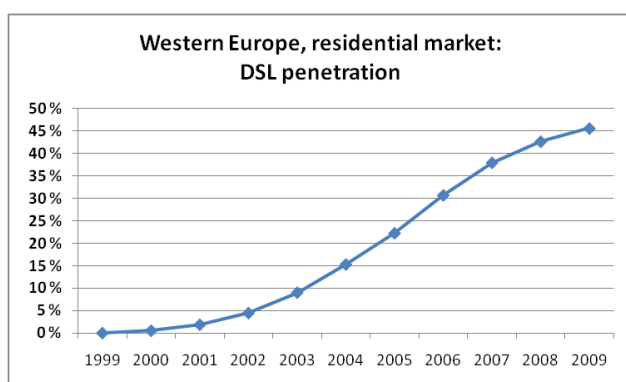
The part of the area which will not be covered by DSL is called the DSL residual area. According to OECD statistics [3] the DSL mean national coverage increased from 92,7 % to 94 % from December 2008 to December 2009, while the rural coverage reached 80 % at the end of 2009.

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, Payback period) for DSL rollout starts to decrease because the rollout areas are smaller.

The last years have shown that DSL meets competition from Fiber and HFC operators in high density areas and fixed wireless access (FWA) like WiMAX and also mobile broadband in the low capacity markets/areas.

Based on statistics from EU, Eurodata, OECD, Strategy Analytics, Ovum, Forrester and Point topics the demand data for broadband has been structured and collected carefully from 1999 to 2009 for the Western European market. The countries are EU15 and Iceland, Norway and Switzerland. During these 11 years the population has increased from 390 million to 405 million, while the number of households has grown from 157 million to 175 million.

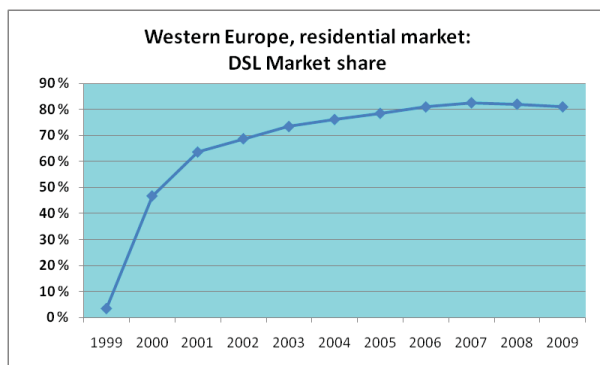
DSL has been a very attractive broadband technology during these years. Figure 2 shows the DSL penetration in the residential market.



**Figure 2** *DSL penetration Western Europe in the residential market, 1999 - 2009*

The figure shows a clear S-curve form which is very good fitted by diffusion models.

The forecasting models also utilize the market share evolution. Figure 3 shows the evolution of DSL market share. The total market consists of DSL, HFC, Fiber and FWA. In the fixed wireless access (FWA) category there are broadband wireless accesses like WiMAX.



**Figure 3** *DSL market share, Western Europe 1999 - 2009*

DSL has continuously caught market share until 2008, but it is interesting to see that in 2009 the technology is losing market share.

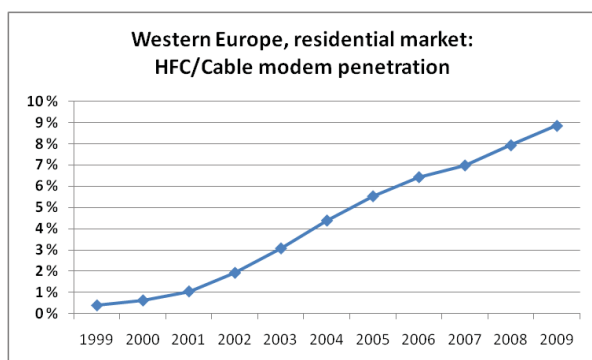
## 2 HFC/Cable modem

CATV networks started to be deployed for more than 40 years ago. The first upgraded CATV networks with two ways broadband connection appeared for nearly 13 years ago.

All countries except for Italy and Greece have reported HFC/cable modem networks. In Iceland there is a modest market share: 0,2 %. The broadband market share of the cable modem technology at the end of 2009 was 38,8 % in Netherlands, 38,7 % in Portugal and 36,1 % in Belgium followed by 31,1 % in Switzerland 31,0 % in Austria and 28,5 % in Denmark. UK had a market share of 21,5 %, Sweden 19,8 %, Spain 19,4 % and Norway 16,6 %. In the large countries Germany and France the cable modem market share is 5,7 % and 5,1 %.

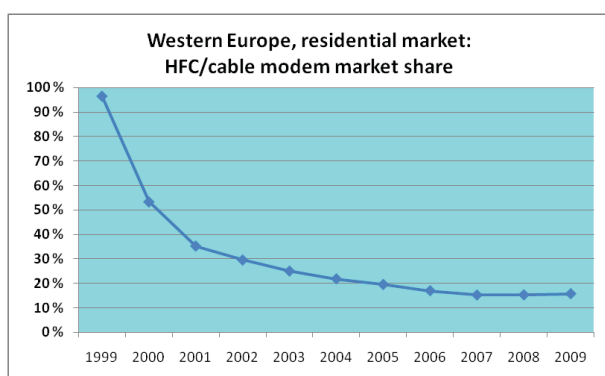
In upgraded areas, the growth of new customers is limited. The cable operators' possibilities to consolidate the situation are to upgrade parts of CATV networks which so far have not been upgraded. The main upgrade is installing of cable modem/HFC. The other upgrade is expansion from DOCSIS 1.0/1.1 to 2.0 and 3.0 together with a possible restructuring of the network to maintain increased traffic. DOCSIS 3.0 is now installed in the European market. For 4 Channel DOCSIS 3.0 the maximum speed is 171/123 Mbps, while the speed for 8 channels is 343/123 Mbps. The EURO DOCSIS standard gives slightly higher capacity. However, it is important to note that the capacity is shared among accesses in the last part of the network.

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



**Figure 4 HFC/Cable modem penetration in Western Europe, residential market 1999 -2009**

It is interesting to see that the HFC penetration growth was reduced 2005 -2007. However, during the last years the cable operators have intensified the CATV upgrading. This is also shown in figure 5 which shows that HFC for the first time increases the market share. There is a modest market share increase from 15,3 % to 15,7 %.



**Figure 5 HFC/Cable modem market share evolution, Western Europe, residential market, 1999 -2009.**

### 3 FTTx access

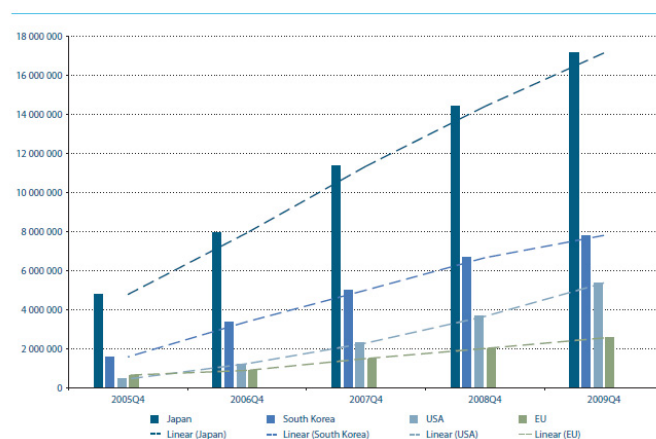
FTTx access is denoted as fiber to the home FTTH or fiber to the building FTTB. In broadband statistics fiber to the building with a local area network FTTB/LAN is also included in this category. The FTTx technology is based on a fiber structure down to a fiber node and then dedicated fibers to the customers or shared fibers by using passive optical PON/GPON solutions.

Fiber 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, HDTV and entertainment demand.

In Europe the investments for establishment of FTTx infrastructure in the access network have been considered to be too high. 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 competing alternative for cable operators.

One way to establish fiber accesses is to deploy fiber in new buildings – Greenfield. Another way is to restructure and deploy fiber in areas with a lot of failures. A third possibility is to pull fiber in ducts where there is enough space. Fiber deployment starts to be expensive when parts of the deployment have to be based on digging and ducting. In Japan the poles are also used to stretch the fibers. Figure 6 shows the limited demand of fiber accesses in Western Europe compared with Japan, South Korea and USA.

The populations in Western Europe, USA, Japan and South Korea are 405 mill, 291 mill, 127 mill and 47 mill respectively. The figure shows that Japan is the leading country having about 17 millions fiber accesses followed by South Korea with about 8 million fiber accesses. The yearly increase is very significant for both countries. Since 2004 the DSL market share has been reduced from 69 % to 32 % in Japan and from 57 % to 20 % in South Korea.

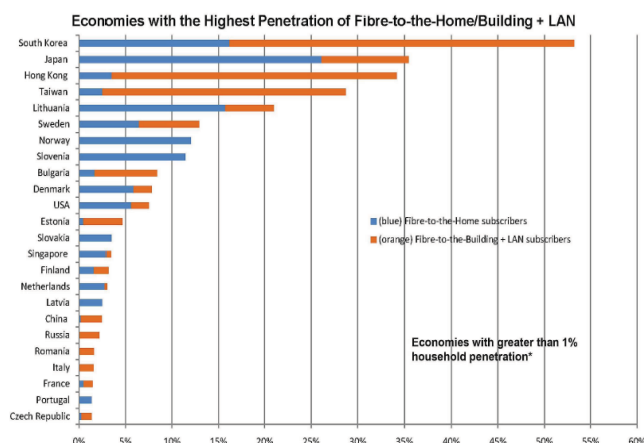


**Figure 6 Evolution of number of FTTx accesses in Japan, South Korea, USA and EU (EU [4])**

However, the market share of the cable modem in the two countries has remained fairly constant during these years. Hence, the cable modem technology so far has been able to compete with fiber accesses. Outside the OECD countries only China has FTTx market volume comparable with

Japan and Korea, while Hong Kong has a market share volume which is comparable.

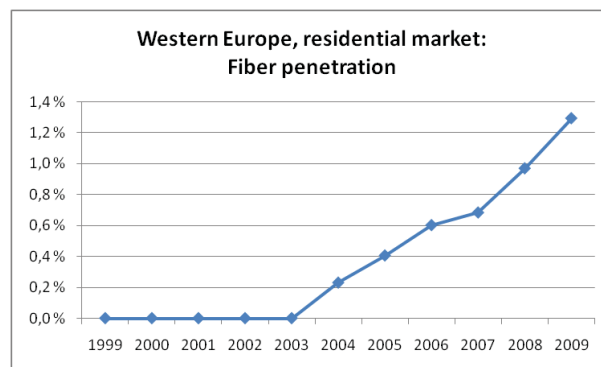
The figure shows that USA has started and passed the fiber deployment in Western Europe. Especially Verizon has aggressive rollout plans for the next five years. According to the OECD statistics the fiber market share in US was 4,9 % in Q4 2009. In Western Europe the fiber market share was 2,0 % at the same time. Especially Sweden, Norway, Denmark and Italy have the most significant fiber deployment in Western Europe regarding fiber access volume and also penetration. New updated fiber statistics was released by the FTTH council in September 2010. It is important to note that the FTTH council statistics showed in the following figure is relative to number of households (not number of inhabitants).



**Figure 7 FTTH and FTTB/LAN penetration relative to number of households. September 2010 (FTTH council press release) [5]**

Figure 7 shows that only few Western European countries are on the top of the ranking. However, Eastern European countries as Lithuania, Slovenia, Bulgaria, Estonia, Slovakia, Latvia, Russia and Romania are on the list. This indicates that the countries are building network with new technology because the available network gives poor performance.

Figure 8 illustrate the difficult situation for Western European countries.



**Figure 8 FTTx penetration, Western Europe, residential market 1999 – 2009.**

The figure shows that an extremely passive demand in Western Europe so far. The reason is limited offer because of the fiber deployment. The limited deployment is caused by significant uncertainties of expected revenue for the Western European fiber operators since the EU commission has been significantly delayed in their NGA fiber recommendation regulation.

Based on several years work including hearings and comments, the EU commission published guidelines for NGA fiber regulation in September 2010. The intention is to regulate fiber accesses like copper accesses. So far it has been difficult for the large Western European fiber operators to start huge fiber investment and fiber rollout simply because of uncertainty regarding price for leasing fiber capacity to other operators.

ETNO calls on NRAs to further use more targeted instruments made available in the NGA recommendation, such as geographical segmentation and symmetric remedies, and create real incentives for access seekers and investing operators to engage in longer term agreements, as the best way to reduce investment risk.

#### **4 Fixed wireless accesses**

The fixed access wireless technologies are mainly WiMAX 802.16e, WiMAX 802.16 and wireless LAN. These technologies can also be denoted as fixed wireless access and nomadic access respectively.

Wireless LAN like WiFi covers the nomadic broadband market. So far international broadband



statistics give not a complete picture of the nomadic broadband market.

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, HSPA and LTE 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 of the number of customers in the area, which 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 will give higher capacity. For mobile broadband, the maximum capacity is lower. However, new system generations will increase the capacity stepwise.

The demand for fixed access wireless technologies has been modest during the last 10 years. The FWA penetration in Western Europe is increasing very slowly from 0,1 % in 2002 till 0,6 % in 2009. In Norway substantial means are transferred from the government and the municipalities for rolling out broadband – especially in DSL-residual market. Here FWA solutions have been attractive solutions for covering the residual market. This process is not finished in Western Europe and in other counties and will still be a driver for FWA.

The fixed wireless access will meet competition in rural areas from HSPA and when LTE is rolled out in some part of these areas. The opening of the digital dividend, 800 MHz band, will make possibilities for longer reach for the mobile technologies.

### 5 The fixed broadband market situation

It is difficult to concentrate analyses on specific countries. In this paper part of the analyses and

forecasts are concentrated on mean values from Western Europe.

This OECD statistics covers both the residential and the business market. Usually the business market is 10 – 15 % of the total fixed broadband market.

Figure 9 and 10 are summing up the *residential* broadband technology demand in Western Europe from 1999 to 2009.

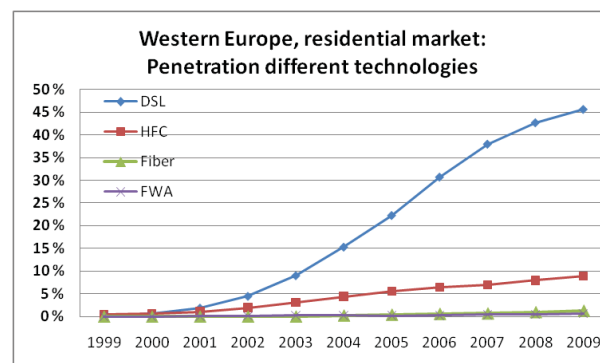


Figure 9 Penetration different technologies, Western Europe, residential market 1999 -2009

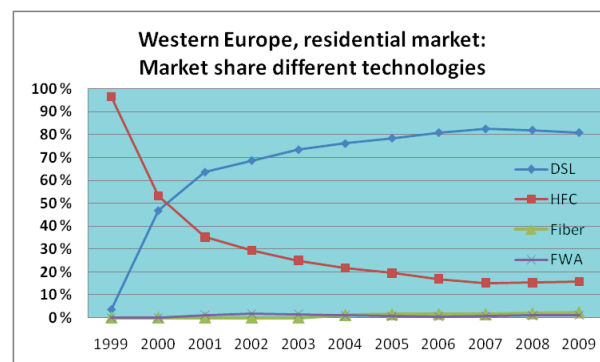
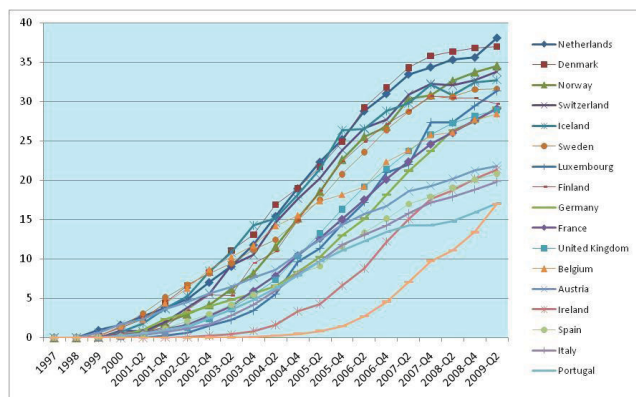


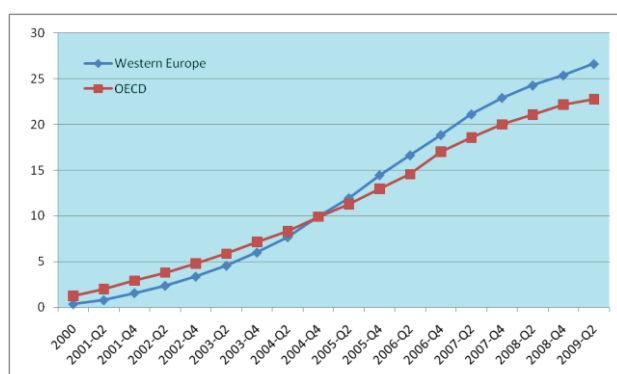
Figure 10 Market share different technologies, Western Europe, residential market 1999 -2009

Figure 11, 12 and 13 show number fixed broadband accesses as a sum of residential and business accesses per 100 inhabitants.

Figure 11 shows that number of broadband accesses in Finland has decreased since the end of 2007. The figure also shows that the five Nordic countries are among the 8 OECD countries with the highest broadband penetration.

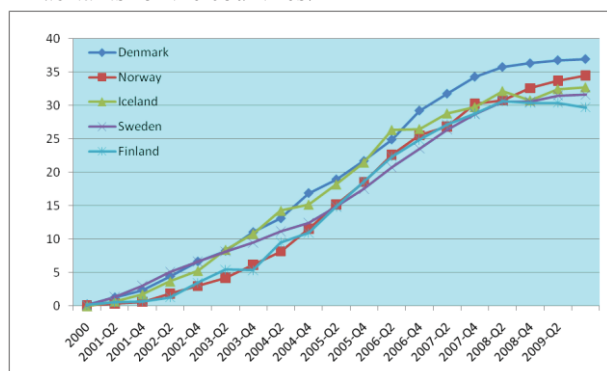


**Figure 11** Number of broadband accesses per 100 inhabitants (sum residential and business market) by country, 1997 – 2009Q2



**Figure 12** Number of broadband accesses per 100 inhabitants (sum residential and business market) for OECD countries and Western European countries.

The OECD had a faster broadband penetration the first years after introduction, while during the last years the penetration in Western Europe has grown faster and is significantly higher. Looking on the Nordic countries, figure 13 shows fixed broadband penetration between 30 and 37 accesses per 100 inhabitants for the countries.



**Figure 13** Number of broadband accesses per 100 inhabitants (sum residential and business market) for the Nordic countries

The penetration is close to saturation and as mentioned in Finland the saturation is now

decreasing. The penetrations in the Nordic countries are much higher than the group means for OECD countries and the Western European countries

## 6 Drivers for additional broadband subscriptions

The fixed broadband evolution started mainly in 1999 – 2001. The subscription growth has followed an S-shaped curve, with an initial exponential growth followed by an approximate linear growth and with more limited growth the last years as the aggregated demand starts to come closer to saturation.

Still there are areas which are not covered by fixed broadband networks. Hence, one important driver is rollout in rural, sparsely dens areas. Also the government and the municipalities in various countries have declared support to broadband rollout in such areas. The objective for the support is to have the same educational standard, to have possibility to maintain working places and living standard also in these rural areas. A driving force is “Broadband to all”.

Still there are specific user segments where the willingness to pay for broadband is low. Especially older people, who are not familiar with PC usage, generate low demand. Also young people for instance students and persons without own family generate low demand. This user group prefer mainly mobile broadband subscriptions.

In addition the population is growing, the number of divorces is increasing, the living age is increasing and also number of immigrants. Hence the number of households is growing which generate new potentials for broadband subscriptions. Also new broadband applications and more extensive usage of existing applications, broadband user groups, social networks and gaming and entertainment applications generates new broadband subscriptions.

At the same time there is a transition from the traditional fixed broadband market to the high speed broadband market with access capacities from 20 Mbps and upwards. The interest for the high speed, individual video and entertainment also create demand for broadband accesses.



## 7 Long-term penetration forecasts for the residential market

A relevant long-term forecasting model is the extension of the Logistic model with three parameters model to four parameters also by including the  $\gamma$  parameter for modelling the asymmetry in the demand. The models have been applied successfully for long-term telecommunication forecasting [6-12]. The model is defined by the following expression:

$$Y_t = M / (1 + \exp(\alpha + \beta t))^\gamma$$

where the variables are defined as follows:

$Y_t$  : Accumulated demand at time  $t$

$M$  : Saturation level

$t$  : Time

$\alpha, \beta, \gamma$  : Parameters

$\alpha, \beta, \gamma$  are growth parameters. The variable  $t$  is time in years.  $t = 0$  is the introduction year. Without the parameter  $\gamma$  ( $\gamma = 1$ ), the demand curve will be symmetric.

The parameters  $\alpha, \beta, \gamma$  cannot be estimated simultaneously by ordinary least squares regression since the model is nonlinear in the parameters. The main objective in the fitting is to get the best overall fit. Therefore, the parameters in the model are estimated by ordinary least squares regression (OLS) for different values of  $\gamma$ . The OLS estimation is based on the following transformation:

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

The saturation level  $M$  and  $\gamma$  are fixed values in the estimation process.  $M$  is usually found by market research, while  $\gamma$  is estimated by systematic calculations of RMSE (root mean square error) for a set of different values or by using a nonlinear estimation procedure.

The fixed broadband demand from 1999 to 2009 is described. Here, these data is used as input to the Logistic four parameter forecasting model.

Usually long-term forecasts are made for a period of 5 years. There will of course be large forecast uncertainties in forecasts for such a long period.

Especially in areas which are significantly influenced of technology evolution and even technology shift.

The first step in the forecasting procedure is to make long-term forecast of the broadband penetration and then split the forecast in separate forecasts for DSL, HFC, Fiber and FWA. *Here, we concentrate on the residential fixed broadband market, which is 8-9 times larger than the business market.*

Figure 14 shows the fixed broadband penetration.

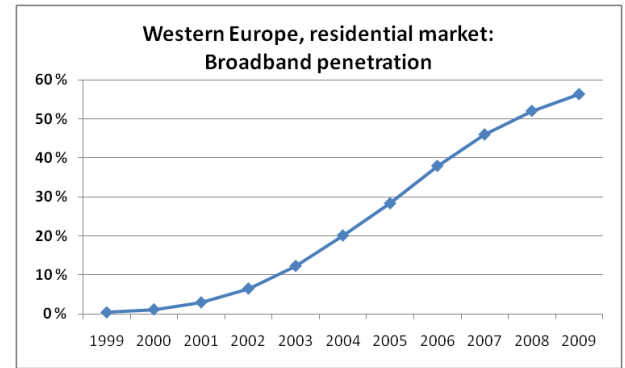


Figure 14 Fixed broadband penetration, Western Europe, residential market, 1999 -2009

In 2009 the number of households in Western Europe was about 175 mill. The penetration was about 56,5% and the number of broadband household subscribers was nearly 99 mill. The figure shows that the yearly growth during the last years is reduced.

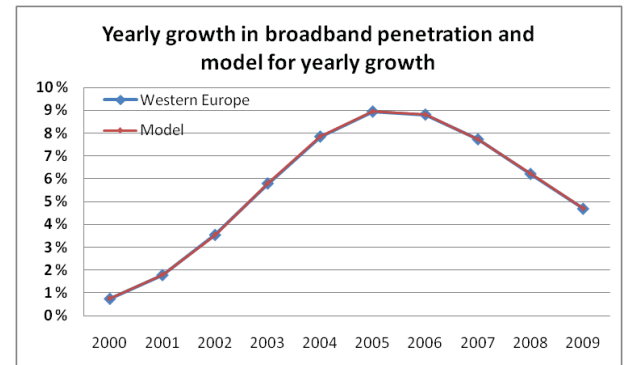
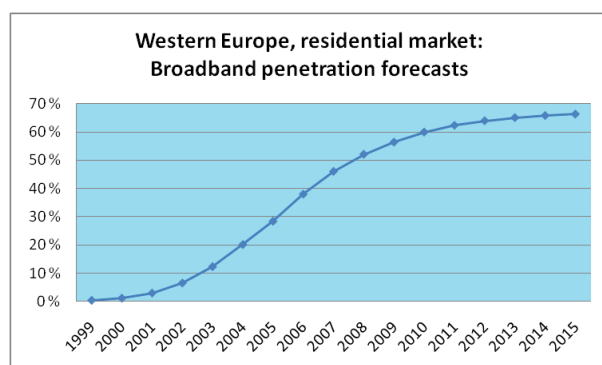


Figure 15 Yearly growth of fixed broadband penetration and the fitting by Logistic four parameter model, Western European residential market, 2000 – 2009.

Figure 15 shows the yearly growth in the broadband penetration. In addition the figure shows the fitting by using the Logistic four parameter model. The two curves are remarkable similar, which indicates an extraordinary good fitting.

The accumulated penetration and the forecasts are shown in the next figure.

The saturation is estimated to 67,2 % and the forecasts is close to the saturation in 2015.



**Figure 15 Broadband penetration forecasts, Western Europe, residential market 2011 – 2015**

However, there are significant uncertainties which may affect the long-term forecasts. In Finland the penetration has started to decrease especially because of churn to mobile broadband. In the coming period it must be expected that there could be substitution effects which is not included in the development of the demand curve so far. Hence, it is important to follow the demand and examine the evolution.

On long-term it is expected that entertainment applications and other very heavy traffic consuming consumer habits will attract the broadband customer and churn many mobile broadband customer without fixed broadband subscription back again.

In the following, separate long-term forecasts for the market share between DSL, HFC, Fiber and FWA are shown. The sum of the market shares of the four technologies are 100 %. The market share forecasts of HFC, Fiber and FWA are made individually, while DSL is the residual.

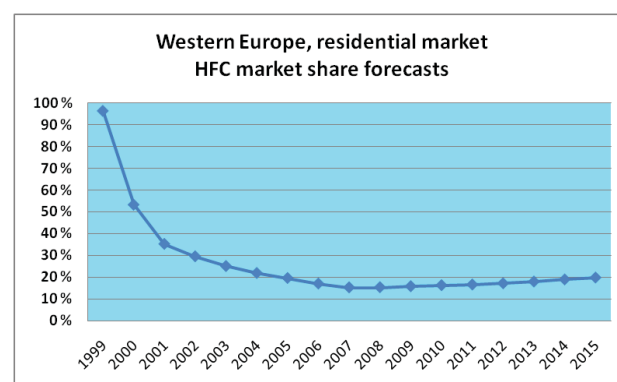
### 8 Long-term HFC market share forecasts

The HFC market share evolution is interesting. As mentioned, HFC has continuously lost market share until 2007. Then the market share has started to increase very slowly. It is important to note that HFC is partly a fiber network with ability to offer very high capacities when it is fully upgraded.

Investments and upgrading to DOCSIS 3.0 is necessary. But the first step of course is the two ways broadband upgrading itself. The demand is based on selling HFC broadband subscriptions to homes passed and to sell to households in newly broadband upgraded areas.

This procedure has been carried out for a long time. Some HFC/cable operators have nearly reached their upgrading possibilities. Some others have larger potential network areas left for upgrading. The operators in main part of European countries are in first mover advantage position because they offer very high broadband speed before the fiber is introduced. VDSL2 has also been delayed in many countries.

It is interesting to note that HFC has retained its market share position in Japan and South Korea in spite of an extreme rollout of fiber accesses in the two countries. Hence, it is assumed that the HFC/cable operators are able to increase their market share from about 15 % to nearly 20% during the next years because of delay in fiber rollout in Western Europe, because of to slow introduction of VDSL2 in the market and because the possibility to utilize First Mover Advantage which means that many customer already have chosen HFC before fiber and VDSL2 is offered in the areas.



**Figure 17 HFC long-term market share forecast, Western Europe, 2011 – 2015**

### 9 Long-term FTTx market share forecasts

The fiber access forecasts are very difficult to develop. There are many significant uncertainties. The largest uncertainties are related to EU's delayed regulation of the fiber market.

Hence as a consequence, only few operators in Western Europe so far have decided to roll out FTTx extensively. The risk seems to be too high to make major fiber roll out investments and get competitors who could claim to use the same fibers without digging and ducting. However, the situation may change if the price for leasing fiber capacity is reasonable high. Then the risk for making fiber investments and fiber rollout will be reduced compared with the situation where this prices are not known.

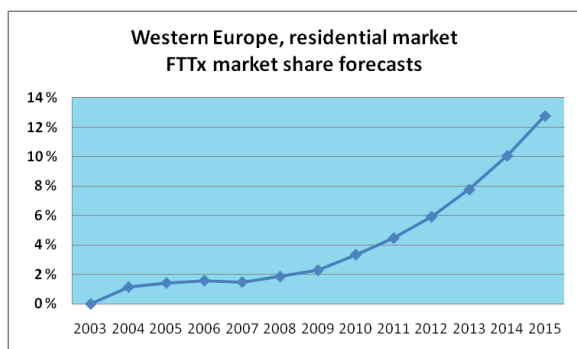


Figure 18 FTTx access market share forecasts, Western Europe, residential market, 2011 -2015

In countries like Norway rich power utility companies are able to roll out fiber. It is also important to note that fiber because nearly unlimited capacity is the ultimate solution, but it is also huge investments for the fiber roll out.

So far there are significant uncertainties in the future fiber access forecasts for Western Europe.

### 10 Long-term FWA market share forecasts

FWA – fixed wireless access is a minor technology. Probably the market share will increase to some degree because of coverage of the DSL-residual market. On the other hand FWA will also be attacked by Mobile broadband. Therefore, a modest market share forecast have been developed which indicate a smoothly increase from about 1 % in 2009 to 1,5 % in 2015.

### 11 Long-term DSL market share forecasts

The resulting market share forecasts is DSL which is shown in figure 19.

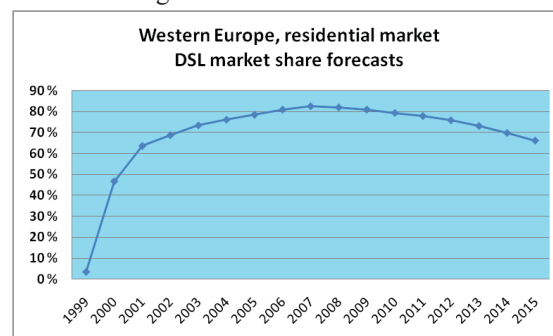


Figure 19 DSL market share forecasts, Western Europe, residential market: 2011 - 2015

DSL started to lose market share from 2007. There are uncertainties in these forecasts. A key point is how fast the various operators in the Western European countries are able to roll out VDSL2 to compete with HFC and fiber. In Norway the market share evolution is more dramatic than the forecasts shown in the figure. In 2005 DSL started to lose market share. In Q4 2010 the DSL market share is about 51%. This is caused by extensive fiber and HFC rollout.

To be able to maintain significant DSL market share, it is important to roll out VDSL2.

Figure 20 gives an overview of the market share evolution of all four technologies. The figure shows that fiber, HFC and FWA is increasing, while DSL is the big loser.

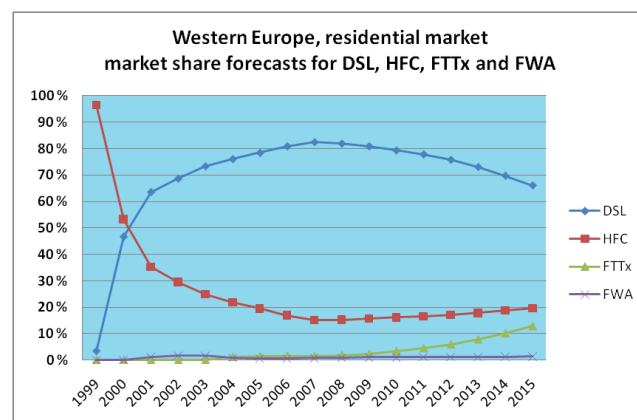


Figure 20 Market share forecasts for DSL, HFC, Fiber and FWA, Western European, residential market, 2011 - 2015

### 12 Long-term penetration forecasts for DSL, HFC, FTTx and FWA

Then each of the market share forecast is multiplied with the overall penetration forecasts which results in penetration forecasts for each technology. Figure 21 shows the forecasts.

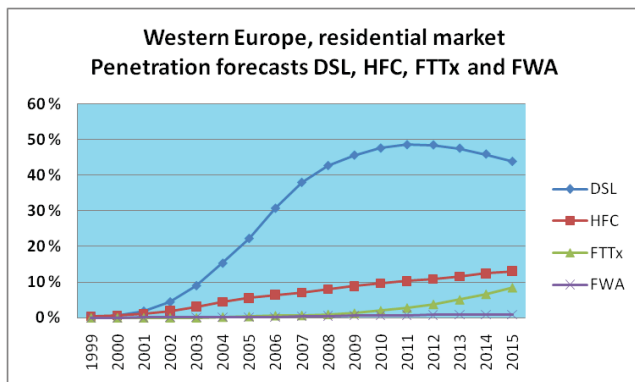


Figure 21 Penetration forecasts DSL, HFC, FTTx and FWA, Western Europe, residential market, 2011 -2015

The subscription forecasts are found by multiplying the penetration forecast by forecast for number of households. For network dimensioning purposes, the traffic generated of the different fixed network technologies are important

### 13 Broadband access evolution

Figure 16 shows that the fixed broadband penetration is reaching a saturation level. During the period 2011 – 2015 there will be churn effect caused by mobile broadband substitution. The reasons are especially cheaper prices for mobile broadband compared with broadband, but limitations of traffic volume usage.

It is expected that churn effect during some years in most countries will stabilise and there will be some user segments which will only have mobile broadband. But most households will have both fixed and a mobile broadband subscriptions.

Especially the entertainment applications will play an import role in the future. The traffic generated by these applications demand will soon be much higher than peer to peer traffic. And the traffic volume per month will be so high that mobile broadband will not be able to transport the traffic. Hence, there will substitutions both ways between fixed and mobile broadband.

There are significant uncertainties which may affect the long-term penetration forecasts. In Finland the penetration has started to decrease especially because of churn to mobile broadband. In the coming period it must be expected that there could be substitution effects which is not included in the development of the demand curve so far. But as mentioned there will also be substitutions from mobile broadband to fixed broadband because need for downloading and uploading of high traffic volumes. Hence, it is important to follow the demand and examine the evolution.

### 14 Drivers for the traffic forecasts

The number of fixed broadband subscribers and the forecasts is an important driver. In addition the population growth is a driver for the traffic growth.

The fixed broadband market changes from a low speed market to a high speed market. There is a continuous upgrading of access speed. The operators offer higher speed. DSL is upgraded to ADSL, ADSL2+ and VDSL2 and also internally in the different categories. HFC is upgrading its protocol DOCSIS 1.0 to 1.1, 2.0 and 3.0. Higher speeds will also be offered for fiber access. Fixed wireless access will do the same.

Another very crucial point is change of broadband technology. To get higher speed many users leave DSL and order fiber or HFC technology.

The inheritance from internet has influenced the tariff structure for fixed broadband. The traffic usage is supposed to be free – no charge for traffic volume usage. The principle is called flat rate. The consequence is no higher price to pay for high traffic users than for users with low or extremely low usage. This is not a fair tariff system. The low traffic users, and there are many of them, are financing the high traffic users.

The traffic per subscriber started very modest when fixed broadband was introduced. It is interesting to note that the traffic has increased nearly exponentially for many years. The first years after introduction, the growth was especially caused by the significant increase in number of subscriptions, but growth was also caused by traffic growth per subscriber.

Surfing was the main driver the first years. Then file sharing and peer to peer (P2P) has been very important. File sharing is distributing or providing access to digitally stored information, such as computer programs, multi-media (audio, video), documents, or electronic books. It may be implemented through a variety of storage, transmission, and distribution models. Common methods of file sharing incorporate manual sharing using removable media, centralized computer file server installations on computer networks, World Wide Web-based hyperlinked documents. Peer-to-peer computing or networking is a distributed application architecture that partitions the tasks or workloads between the users. The most important P2P applications are BitTorrent, Limewar, Shareza, Kazaa, iMesh and eDonkey.

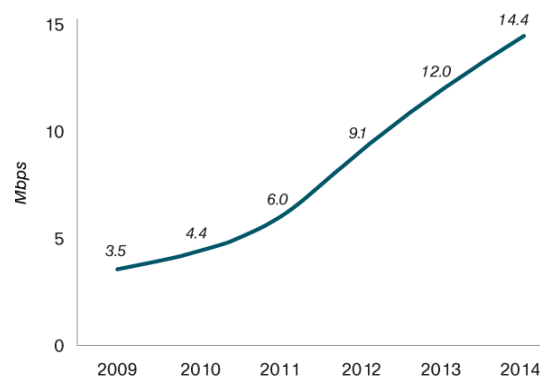
File sharing and peer to peer is widely used on film/movie file exchange. During the last years it is identified that less than 10 % of the customers generate more than 90 % of the traffic. Still peer to peer is the most dominant driver. However, the picture is changing. Cisco [13] forecasts that global video communication, especially internet video to PC and internet video to TV, will dominate the market in the future and already in 2011 generate more traffic than P2P.

Important broadband applications are P2P, two ways video communication, video on demand, Internet video to PC, Internet video to TV, advanced Internet video (3D and HD), video conferencing, online gaming, Web and data transfer.

Multitasking and passive networking is characteristic for many broadband users. Their work processes are continuously going on without an active participation all the time. Still much traffic is generated.

Hyperconnectivity has emerged as an important dynamic concept. Important drivers for hyperconnectivity are: Growing of high speed penetration, expansion of digital screen surface area and resolution, evolution of network enabled devices, increased power and speed of computing devices.

Figure 22 shows the average global broadband access speed forecasts.

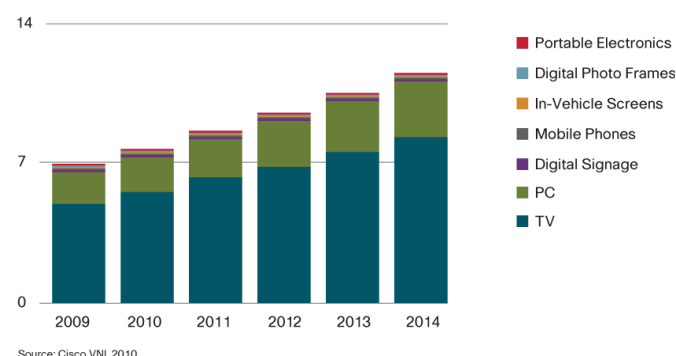


Source: Cisco VNI, 2010

**Figure 22 Average global broadband access speed forecasts 2009 – 2014 (Source CISCO [13])**

The increased screen surface area is a factor which generates additional traffic. The installed screen surface is dominated by TV and PC screen which have got a significant growth the last years.

The screen surface areas forecasts are shown in figure 23.



Source: Cisco VNI, 2010

**Figure 23 Installed screen surface areas in billion squares feet. Forecast 2009 -2014. Source (CISCO [13])**

Morse law for increased computing power is a fundament for increased traffic. The PC's ability to produce more structured information cause additional traffic.

In general a digital video ecosystem compound of consumer electronic, consumer behaviour, the media and entertainment sector and the service providers and operators is evolving.

Significant number of video devices like game consoles, dedicated DMA, SetTop box/DVR, DVD/Blue ray and Flat panel TV are now connected to fixed broadband.



Because of analog switch-off, global digital TV homes are growing strongly. DTT (Digital Terrestrial Television network) and DTH (Direct to The Home satellite) will increasingly deploy hybrid solutions using the fixed broadband access for video on demand. *All platforms will increasingly offer Web video options for access TV at any time and also accessing TV anywhere.*

IPTV is offered by several European DSL and fiber operators. The TV channels are transported by the core network, and then by multicast in the access network. The multicast technology saves significant traffic by not transferring TV channels which are not demanded and not more than one dedicated TV channel to customers who demand the channel. Multicast is based on broadcasting of the TV channels in real time.

However, the real explosion in the traffic will occur when the customers individually generate demand for downloading TV films, TV news, TV programs, etc not in real time, but at time it suites the customer either on PC or TV. Instead of broadcast by the multicast technology, there will be individually TV demand transferred on demand basis by the broadband customers. This will create an explosive evolution of the broadband traffic.

The next step is increasing of the traffic by going from TV to HDTV and 3DTV. The question is the ability to transfer such information on individually demand basis. In parallel optimal coding methodologies are developed to reduce the amount of data transfer, but the will only reduce the data steams marginally.

There will be limits of how much traffic which can be transported on the fixed broadband network without additional payments. Will the flat rate tariff principle survive the steadily increasing broadband traffic or will it be necessary some time to implement other business model than today. Probably there will be limits, as we now see it in the mobile broadband network, for the operators to extend the network capacity without getting paid for it.

### ***15 Busy hour traffic and dimensioning***

There will always be traffic bottleneck in the fixed broadband and mobile network. If not the networks will be extended based on fixed overcapacity which gives no optimal investments.

The applied network dimensioning is based on busy hour traffic data. It is interesting to know that the busy hour traffic is much lower than the available capacity to the mean user. See figure 22. The network dimensioning is simply based on the mean traffic the users generate in the busy hour.

There are not much available official traffic statistics for the busy hour. One reason is that busy hour traffic for the fixed network is not charged and is therefore not interesting for revenue controlling purposes. However, the traffic measured in the busy hour is important for evaluation of rollout strategies, upgrading and continuous expansion of the fixed broadband network.

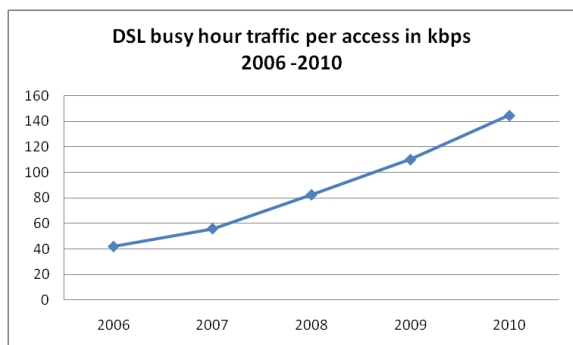
The busy hour traffic per customer is defined as the sum of all traffic generated by a given number of customers in the area (NGA) divided by the number of customers. It is important to note that many customers are not using the broadband access in the busy hour. Hence, the customers who are using the broadband at that time will have higher speed than the mean busy hour speed.

### ***16 Busy hour traffic evolution per subscriber***

In this paper the evolution of DSL traffic per subscriber in the busy hour from 2006 until 2010 is stipulated for the Western European countries. The basis for the stipulation is Telenor's DSL busy hour and traffic statistics from CISCO ([13]). Telenor's broadband traffic is not published, but the stipulated broadband traffic for Western Europe will be a reasonable good basis for the analyses and the forecasts. The traffic statistics is measured on routers at the edge of the core network.

The traffic is based on number of subscriptions multiplied with the traffic per access for the various technologies. The total traffic is found by summarizing the traffic for each technology.

Figure 24 shows the traffic per subscription for the DSL traffic.

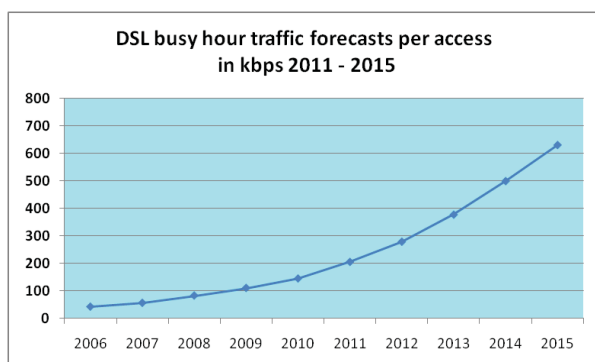


**Figure 24** Busy hour traffic in kbps per DSL subscription 2006 -2010

The traffic evolution per DSL subscription these four years show increasing growth year for year. The yearly growth has been close to 40 % and continues to increase with the same rate.

### 17 Busy hour traffic forecasts per subscriber

Based on the traffic evolution 2006 – 2010, forecasts have been developed for the period 2011 – 2015. The period is very long and there are definite uncertainties connected to the very long forecasting period.



**Figure 25** Busy hour traffic forecasts in kbps per DSL subscription 2011 - 2015

Observation of the busy hour traffic in Telenor's network show that the HFC traffic per customer is on the same level as the DSL traffic. However, the HFC broadband traffic will due to capacity upgrading offer higher speed than DSL even when DSL subscriptions get higher speed because of higher speed offerings and transitions from ADSL to ADSL2+ and VDSL2. It is assumed that a mean HFC customer in the long run will generate 30% higher traffic per access than a DSL customer.

Measurements show that fiber accesses have generated about doubles as much broadband traffic as DSL customers. There are significant

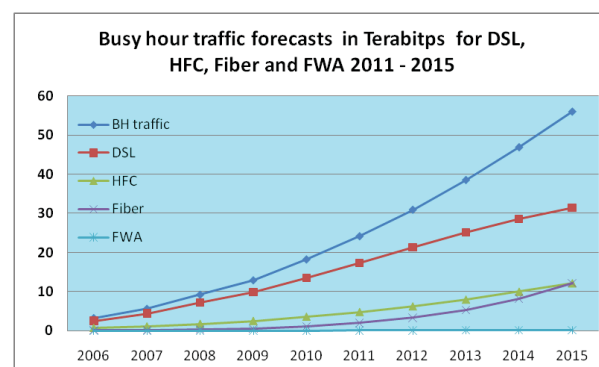
uncertainties about the future evolution. However, the same proportion is used in the traffic forecasts per customer.

Fixed wireless access systems like WiMAX have capacity on 14,4 Mbps. It is a shared medium and many subscribers have to use the system at the same time in the busy hour. Such a system may have 500 - 750 subscribers per site. It depends of course how the operators are rolling out the sites for the system. Here, it is assumed that the busy hour traffic per subscriber is 30 kbps. As mentioned speed for a customer using WiMAX in the busy hour will be much higher than 30 kbps simply because not all customers are using the WiMAX at that time. The busy hour traffic is a mean traffic for all subscribers connected to the specific WiMAX site.

It is difficult to forecast the busy hour traffic per subscriber for fixed wireless systems because the future portfolio is not very well described. Therefore, it is assumed that the traffic increase per subscriber follows the DSL increase proportionally based on the relative level between the two access technologies. There may be some danger for overestimation of the FWA busy hour traffic.

### 18 Total traffic forecasts in the busy hour

Now, the busy hour traffic forecasts per access are estimated as described. Then the total forecasts between the NGN networks and the NGA networks in the Western European countries are found by multiplying the number of inhabitants, 175 million by the respective penetration rate for each technology and the busy hour traffic for the technologies.



**Figure 26** Busy hour forecasts Western Europe in Terabits from the broadband technologies DSL, HFC, FTTx and FWA 2011 – 2015

The traffic forecasts are summarized in the figure 26.

The busy hour traffic in the figure is the traffic basis on the real penetration in the given years. The busy hour traffic for a mean subscriber is larger. The busy hour traffic in figure 26 is calculated based the proportion of the subscribers who have fixed broadband access.

The figure shows that DSL gives the largest contribution to the busy hour traffic. The reason is much higher penetration for DSL compared with the penetration of the other technologies. However, DSL will be less dominating closer to 2015 because higher FTTx and HFC penetration and the fact that the traffic per subscriber for these technologies is larger.

IPTV is not included in the described traffic forecasts. The IPTV traffic will be traffic generated by transferring a set of TV channels down to Customers in the NGA networks. The IPTV traffic will give a significant additional contribution the fixed broadband internet traffic.

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