A FUTURE FOR BROADBAND FIXED WIRELESS ACCESS

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Abstract: The remarkable growth in broadband access networks results from the technology push for faster two-way networks and a society increasingly aware of the benefits offered by such a network. The dominant technology is digital subscriber line (DSL) followed by cable and then others. It is questioned whether there is a future for broadband fixed wireless access (BFWA) technologies. However, in the long run the future is wireless access considering the first meters of any broadband connection. The wireless zone may be fairly small but will eventually grow to support nomadic and mobile users in a larger area freely within the building, to the outside and serve to user on the move.

Keywords: broadband, access, wireless

1. INTRODUCTION

There is a remarkable growth in providing broadband services. Among several possible explanations: most importantly the technology push for faster two-way networks and the society increasingly becoming aware of the benefits offered by a true broadband network. In judging the current situation in Europe, or globally, only a fraction of the systems in use are based on wireless technology, if the access to the household is considered. The dominant technology is digital subscriber line (DSL) followed by cable and then others.

Is there a future for broadband fixed wireless access (BFWA) technology?

The authors are of the opinion that the answer is yes, and this paper describes the main supporting arguments and reasons for this. These are based on research activity over a ten year period done in internal and collaborative international projects, for example lessons learned from the EU framework projects BROADWAN (2003-2006) (BROADWAN, 2006a), EMBRACE (2000-2002) (EMBRACE, 2002), and CRABS (1996-1999) (CRABS, 1999).

The paper is organised in three main sections: Broadband services, full coverage is needed, and wireless technological developments.

2. BROADBAND SERVICES

Broadband services means today high speed Internet, and at an increasing rate, broadband telephony or voice over Internet Protocol (VoIP), and broadband television or IPTV, to offer triple play to fixed users as well as to users on the move.

2.1 Fixed service

However, considering published statistical data, broadband services have never been clearly defined and include now a wide range from a capacity larger than offered by integrated service digital network (ISDN) to high quality two-way video connections. One characteristic is that the user is normally always connected without having to pay more. The trend is clearly towards higher capacity for a wide range of services covering communication, information share, education, health care, governmental issues, and entertainment. Soon the normal capacity to the home will be in the order of 20-30 Mbit/s and significantly more symmetric than today's dominating asymmetric DSL (ADSL) technology (Elek, *et al.*, 2004). Technology push dictates that the typical residential access capacity doubles every 1.9 yeas (Eldering, *et al.*, 1999), as sketched in Fig. 1. In fact, a doubling rate of 1.6 years, as illustrated by the broken line, seems even closer to typical rates offered today.

2.2 Nomadic service

The services will more and more become triple play providing broadband communication, broadband voice, and broadband television. The users will not be satisfied just having access to these services from a fixed point, say in the living area, but wish to some degree bring personalised services along on the move. As a minimum the service has to be accessible all over in the living area, inside or outside the residence, but also when travelling larger distances. For example, mobile TV has received a lot of attention lately.

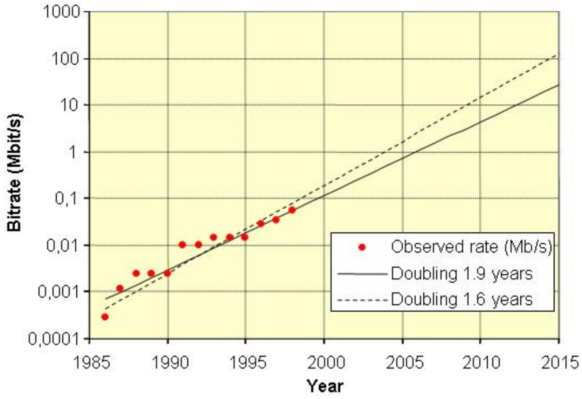

Fig. 1. Capacity of access network at homes (red dots) and predicted future trend (Data reproduced (red dots) from Fig. 2 in (Eldering, *et al.*, 1999).

Nomadic services will become more important for providing true personal broadband to users when they are away from the home or the office. Such services will be cheaper to use and have better performance than corresponding mobile services and will be the preferred solution in many situations where full mobility is not required.

Broadband access offered by a fixed network has significantly higher capacity than similar services by a mobile network, as sketched in Fig. 2. With time both types of networks will become better, but a fairly clear trend offering higher capacity with mobility, and not at least mobile networks providing very high capacity, but in the low mobility mode.

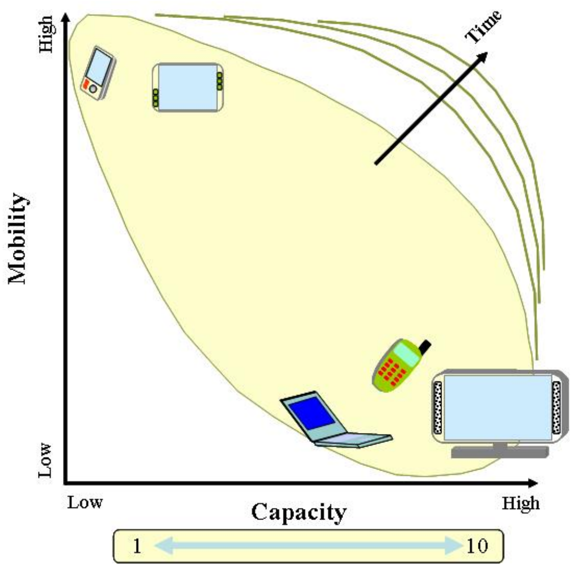

Fig. 2. Mobility versus capacity evolvement with time where the peak capacity of fixed networks typically is ten times the peak capacity of networks able to offer high mobility.

Another important application of nomadic services will be for providing ubiquitous backbones. Combined with local access technologies like Wi-Fi, such solutions will provide Internet access to end-users in situations like one time events and meetings at locations without wireline Internet access.

2.3 Hybrid WLAN and mobile service

WLAN technologies such as Wi-Fi are a suitable candidate for providing low mobility or nomadic services. Wi-Fi is a fast growing access technology, particularly within the home zones, but the use is also increasing within enterprises, government and education. Wi-Fi originally meant for data connectivity includes now voice services also. The Wi-Fi technology and VoIP have started to embrace each other to drive the adoption of Voice over WLAN as broadband voice service.

The next step will be the introduction of mobile IP telephony over Wi-Fi. The capability of deploying voice services over a Wi-Fi network integrated with a cellular system will enhance the freedom of movement during each session and is therefore a potentially very interesting service. But it is not just about voice services, also multimedia and other mobile broadband services are driving the mobile and nomadic requirement. The trend is that computer centric data networks are moving towards more mobility and at the same time the mobile technology is developing towards higher bandwidth and data support.

A hybrid concept where Wi-Fi and GSM/UMTS are complementing each other could meet the requirements for both mobility and bandwidth. One of the challenges in such system is to obtain seamless service provision (seamless handover) between the cellular system (GSM, UMTS) and Wi-Fi in order to provide service continuity. There are a number of solutions available or under development for support of seamless Wi-Fi – GSM/UMTS handover. These solutions can mainly be divided into two groups: Service-based handover and Net-based handover.

Within standardisation the IP Multimedia Subystem (IMS) and Unlicensed Mobile Access (UMA) are two main architectures under the 3GPP umbrella which both support seamless service provision between Wi-Fi and cellular systems. The UMA specifications where adopted by 3GPP in 2005 (3GPP, 2005). This solution influences mainly the mobile core network, meaning that the bearer network and the service platform can support UMA without any changes. The cons are that UMA only support handover between GSM and Wi-Fi and it is thought as a short or medium term solution. For IMS 3GPP has defined a standard for WLAN and 3GPP system interworking (3GPP, 2006), a full interworking solution towards all types of services that can be offered on the IMS platform of 3GPP.

Types of services include Voice over IP as well as video streaming and interactive games. IMS support handovers between a wide range of networks (GSM, UMTS, CDMA, WiMAX,Wi-Fi) and it might become the long-term solution for seamless service handovers.

3. FULL COVERAGE IS REQUIRED

From a business point of view it is clearly challenging to provide every remote spot with broadband access networks. And there are a number of studies published showing that it is not economically feasible to reach out everywhere. Actually no service has normally full coverage in the sense of everyone or everywhere. Full coverage means a percentage approaching 100 %.

By using hybrid architecture with the right technology at the right place, it becomes possible for a large portion of the population to access a broadband service. Wireline technologies like DSL and cable, now dominating the market, have either to be upgraded, in particular DSL, or their market share will be reduced significantly.

3.1 ADSL with WiMAX fill-in

One way to provide broadband to the users who cannot be served by ADSL is to overlay the ADSL network with a WiMAX network operating in a licensed frequency band, see Fig. 3 (Bichot, *et al*., 2004; Tardy, *et al*., 2004a, b). As WiMAX systems do not require line-of-sight, they will usually have good coverage in an area. The WiMAX network will not only provide broadband access to those users out of ADSL reach but also offer complementary services, for example nomadic access.

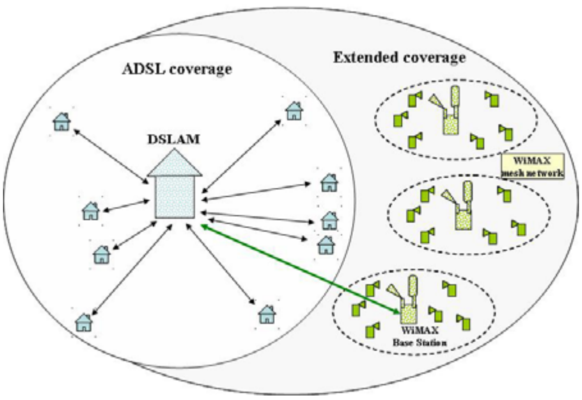

Fig. 3 Hybrid DSL and wireless, e.g., WiMAX.

3.2 VDSL/ADSL2+ with BFWA fill-in

In areas with good copper infrastructure, ADSL2+ and very high capacity DSL (VDSL) will be the most efficient way of offering triple-play services, matching the increasing need for capacity. Yet, both these technologies have a shorter range and in order to cover the same area as before it is necessary to move the backbone to feed digital subscriber line access multiplexers (DSLAMs) closer to the customers, within a kilometre wire length. It is expected that some DSLAMs will never be updated because of lack of profitability.

BFWA technology at frequencies above 20 GHz has sufficient capacity and significantly longer reach than VDSL. Wireless solutions below 20 GHz, or perhaps below 11 GHz where the vendor industry focus is, have less bandwidth but compensate with advanced signal processing methods to still offer impressive capacities within narrower bandwidths. This means for intermediate reach and scenarios with few users, these technologies are competitive with VDSL solutions. Therefore, a scenario with VDSL/ADSL2+ with BFWA fill-in, corresponding to the lower capacity ADSL/WiMAX variant, should be envisaged (Tardy, *et al*., 2004a, b).

In the rural areas with a very low population density, there can be a void in the backhaul infrastructure. If the backhaul is fibre or copper, there is a risk that it does not reach sufficiently close to the end-user. Point-to-point radio links have often been used to overcome obstacles such as mountains. Operators can relatively rapidly deploy several-tiered radio networks with radio links for trunks and WiMAX or Wi-Fi technologies to reach the end-users, such as the one depicted in Fig. 4. In an interference-limited environment such as in rural areas, ad-hoc Wi-Fi networks could be envisaged as a cost-effective method (Bichot, *et al.*, 2004; Soro, *et al.*, 2006).

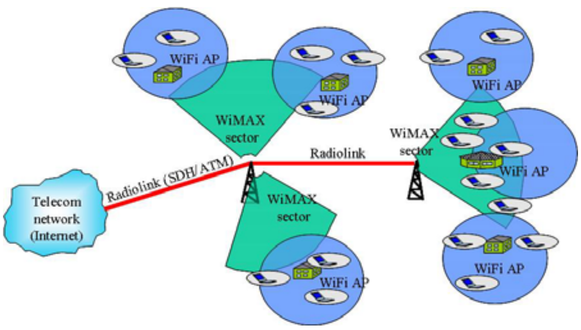

Fig. 4. Hybrid radio link or fibre networks with WiMAX/Wi-Fi local distribution networks.

Lastly, one can resort to satellite technologies. The satellite link can be used as a direct link to the end-user or a community of end-users sharing the rather costly satellite segment and terminals and using a local distribution network.

The satellite technologies can therefore be used to mitigate the digital divide and provide broadband in areas where it would otherwise not be economically feasible.

The complementarities of satellite and terrestrial systems can also allow for service extension, with broadcast, broadband and even real-time services combined. The strength of the cooperation of satellite and terrestrial networks lies also in the possibility to offer the aforementioned services for nomadic or mobile users. This permits using mass-market mobile terrestrial equipment with a satellite backhaul at much lower operating costs than with two separate systems.

It has to be born in mind that alternatives within digital terrestrial television (DTT) technology are coming also. For the satellite and DTT solutions the return link technology is a limiting factor, by cost and technology, respectively.

4. WIRELESS TECHNOLOGY DEVELOPMENTS

Wireless BFWA systems can be divided into two main categories; systems operating at low frequencies (typically below 6 GHz) and systems operating at high frequencies (typically above 20 GHz). Today most of the interest is on the low frequency systems.

An important advantage of the low frequency systems is that they can operate in non Line-Of-Sight (LOS) conditions, giving them better coverage than high frequency systems which requires LOS. In addition, equipment is usually cheaper at lower frequencies.

In the next generation of low frequency BFWA systems we will see a wide range of improvements for increasing the systems' capacity. This includes:

- Use of Time Division Duplexing (TDD)
- Advanced Radio Resource Management (RRM)
- Advanced antenna solutions

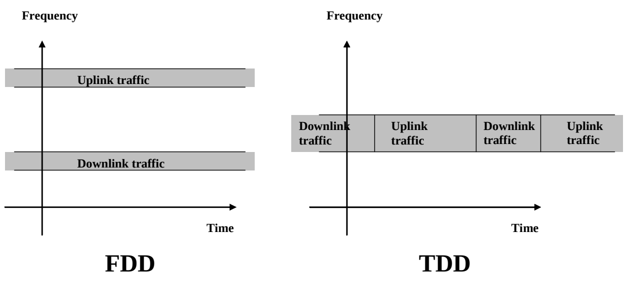

Fig. 5. Principle of Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD).

4.1 Time division duplexing (TDD)

The duplexing technique specify to how the transmissions from the base stations (downlink) and from the user terminals (uplink) are organized in order to not disturb each other. The two most used schemes are called Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD). In FDD schemes, the required isolation is obtained by letting the uplink and downlink transmissions use different frequencies. In the TDD case, the uplink and downlink transmissions use the same frequencies, but transmissions are only allowed in one of the directions at any given time. Fig. 5 illustrates the FDD and TDD principles.

Use of TDD is not new; in fact several low frequency BFWA manufacturers produce TDD equipment today. But in next generation low frequency BFWA systems, TDD is expected to play a more dominant role.

The two main advantages of TDD are:

- TDD enables adjustment of the downlink/uplink ratio to match the actual traffic pattern
- TDD assures channel reciprocity for better support of link adaptation, MIMO and other closed loop advanced antenna technologies.

The main drawback of TDD systems is that interference both within an operator's network and between different operators' is more challenging to handle than in FDD systems. There are methods for handling this, but they are complex and it will take some time before they will be implemented in equipment.

4.2 Radio resource management (RRM)

The Radio Resource Management (RRM) consists of the network functions that decide how the available spectrum resources (often in the form of time/frequency slots) are shared between the user terminals and base stations in the network.

Up to today the usual approach for controlling interference between cells and sectors has been to do frequency planning where each sector are allocated a fixed set of channels and no adjacent cells or sectors are allocated the same frequency channels. Such schemes guarantee that there will be no harmful interference, but is not the most efficient way to use the frequency resources.

Future approaches will use very dynamic spectrum allocation schemes. The spectrum will typically be allocated as time/frequency slots instead of frequency channels. The RRM will re-allocate the slots at frequent intervals to keep the allocation of slots to the different sectors optimal at all times. The RRM algorithm can be very advanced taking into account such factors as the traffic load and traffic type of each sector. This approach is much more flexible than the traditional fixed frequency planning approach and improves the spectrum efficiency significantly.

4.3 Advanced antenna solutions

Advanced antenna solutions can be grouped into three classes of methods; transmit diversity, beamforming and spatial multiplexing.

Transmit diversity is used to increase the robustness of signals by using several transmitting antennas. This is achieved by exploiting the fact that signals transmitted by spatially separated antennas will experience physical channels with different fading. Since it is unlikely that all the physical channels experience deep fades simultaneously (the more antennas, the less likely), the receiver will see a good quality signal most of the time. A simple yet efficient example of this is the Alamouti scheme where two antennas are used at the base station and one antenna at the user terminals [Alamouti, 1998]. In transmit diversity schemes the data stream to be transmitted is encoded and distributed among spaced antennas and across time. The increased robustness of the transmissions can be used for reducing the fading margin and/or increasing the capacity. To increase the capacity, higher order modulation schemes and/or higher rate forward error correction schemes can be used.

With beamforming the system uses multiple antennas to shape the antenna radiation pattern to improve coverage and capacity of the system and reduce outage probability. The beamforming can be performed in different ways depending on what the system tries to optimize. It can for example be used to optimize the size and shapes of sectors, to track moving devices or to maximize the signal-to-noise plus interference ($C/(N+I)$) ratio for individual users.

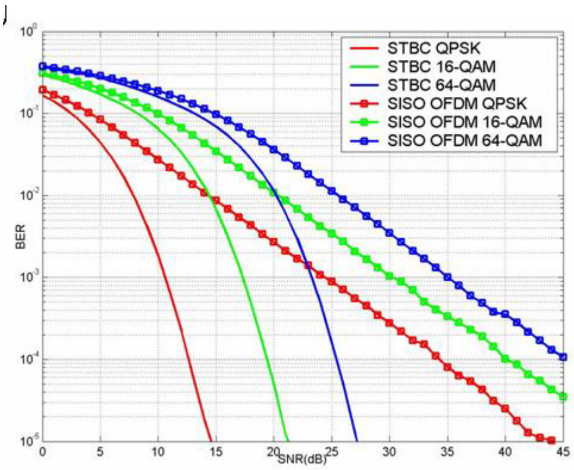

Fig. 6. Performance improvement for a simple spatial multiplexing scheme using two antennas at the receiver and one antenna at the receiver.

Spatial multiplexing is used to get higher peak bitrates and increased throughput. With spatial multiplexing, multiple streams are transmitted over multiple antennas. If the receiver also has multiple antennas, it can separate the different streams to achieve higher throughput than single antenna systems. If both the transmitter and receiver have N antennas, the throughput can theoretically be increased by a factor N if the channel has sufficiently rich multipath characteristics. Fig. 6 shows an example of the performance improvements that can be achieved by a simple spatial multiplexing scheme using two antennas at the transmitter and one antenna at the receiver (BROADWAN, 2006b).

4.4 High frequency systems

One concern using low frequency BFWA systems for providing fixed broadband access is the limited amount of spectrum available. An operator must expect the capacity requirements to increase as more users use the service. In addition there is an underlying trend in the market that the capacity offered to each customer is doubled every 1.9 years on average (Eldering, *et al*, 1999), resulting in an even stronger need for more capacity. But it is expensive for an operator to buy more spectrum to increase the capacity. Alternatively, the operator can increase the base station density (decrease the cell sizes), but this is also expensive. Hence, at some point the cost of increasing the capacity will become very high.

But there are very large portions of yet unused bandwidth available at frequencies above 20 GHz. For instance, there are 3 GHz of continuous bandwidth (40.5-43.5 GHz) reserved for BWA (Multimedia Wireless Services - MWS) in Europe. Since these frequencies will be used for LOS communication, the available bandwidth can be doubled by employing polarization discrimination. These portions of spectrum represent an enormous potential transport capacity, see Table 1. Hence, high frequency BFWA systems will be able to match wired access bitrates for many years to come.

Table 1. Examples of total bitrates (uplink + downlink) per channel that can be achieved with high frequency BFWA systems. The roll-off is 0.25 and the effects of forward error correction is not included

	28 MHz	56 MHz	112 MHz	168 MHz	224 MHz
QPSK	44.8 Mbps	89.6 Mbps	179.2 Mbps	268.8 Mbps	358.4 Mbps
16-QAM	89.6 Mbps	179.2 Mbps	358.4 Mbps	537.6 Mbps	716.8 Mbps
64-QAM	134.4 Mbps	268.8 Mbps	537.6 Mbps	806.4 Mbps	1075.2 Mbps

The main drawback of high frequency BFWA systems is the LOS requirement which reduces coverage for these systems. But HF-BFWA can be used for providing broadband access to a neighbourhood if there is a place within the neighbourhood having LOS with the base station. The individual users can then be provided with broadband by a local distribution network, e.g., a local Wi-Fi or Ethernet network.

5. CONCLUSIONS

In several countries half of the homes or even more, subscribe to broadband services. The technologies offered by broadband fixed wireless access however, cover only a fraction of this market. This paper has drawn the attention to the possible future for a more significant market share for wireless technologies.

The most obvious trend is that people more and more connect to broadband services using a wireless technology also when the actual residence is connected to a wireline solution. To serve nomadic users the most convenient technology is wireless, and for full mobility there is no other alternative to the wireless options.

As capacity demands grows the current main technology in the broadband market, the DSL solution, has to use versions allowing only for a few hundred meters of wireline lengths. The typical range for future broadband mobile technology will also be within a few hundred meters. Conversely, a fixed wireless technology can offer the higher capacity at a significantly longer reach. It can easily become part of a convergent network with either high capacity feed using, e.g., optical fibre and meet future broadband mobile demands.

For the developing markets where the existing telecommunication infrastructure is poor or non-existent, broadband fixed wireless access offer economical solutions for both feed networks and access.

The opportunity window for broadband wireless access seems to be there now for vendor industry to refine and develop new technology, and for operators to use in advanced high-capacity broadband access networks.

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BIOGRAPHY

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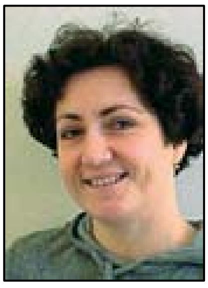

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1990, and the Doctorat degree from the Bordeaux University, France in 1995. From 1991 to 1998, she worked with EADS Toulouse, France, where she worked on high-frequency electromagnetic scattering modelling of and around aircraft. In 1998, she joined Telenor R&I (then R&D), Norway. She has been involved in a number of broadband radio (LMDS and WiMAX type of systems) and satellite studies. She has focused on access and backhaul radio networks, interoperability and hybrid network architecture. She has also actively contributed to LMDS frequency planning recommendation in the 40.5 – 43.5 GHz band within CEPT SE19 and ETSI-BRAN (mostly HiperMAN) standardization. Isabelle Tardy has participated in the EU-funded projects CRABS (FP4), EMBRACE (FP5), and BROADWAN (FP6), where she also was deputy leader.

Ole Grøndalen received a Master of Science degree in physics from the University in Oslo in 1987. Since then he has been working with development of interactive broadband satellite and radio systems at Telenor Research & Innovation. He has participated in several international cooperative research projects within the European Commission framework programs focusing on Broadband Fixed Wireless Access systems.

Lisa Henden is Research Scientist at Telenor R&I. Henden received the Master of Science degree in physics from the University of Oslo, Norway, in 1994, and her PhD degree in physics from the University of Oslo in 2000. In 2001 she joined Telenor Research and Innovation, where she has been involved in work with broadband wireless access systems mainly within architecture, multicast, coverage and capacity. She has also been working with mobile systems on positioning and hybrid Wi-Fi and GSM/UMTS systems. Henden participated in the EU-funded projects, EMBRACE (FP5), and BROADWAN (FP6), where she took part in both scientific and management work.