Overview of the optical broadband access evolution – A joint paper of operators of the IST network of excellence e-Photon/ONe

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Abstract

In this paper, the authors present the operators' view on the evolution towards broadband optical access networks. Firstly we describe a possible evolution of the optical access solution for point-to-point and point-to-multipoint architectures. Finally, we consider regulatory issues inside and outside Europe and conclude with a recommendation with respect to regulation.

1 Introduction

The present fast development of new broadband telecommunication services makes upgrading of the access infrastructure a necessity. To run video voice as well as advanced Internet applications, i.e. triple-play services, residential customers require the availability of a high bit rate "wired" solution. Different solutions for the access network have been developed for several years. The most important among these solutions are the digital subscriber loop (xDSL), hybrid fibre coax (HFC) and fibre to the x (i.e. to the premise, curb, home…) (FTTx). The optical fibre solution is receiving at present more attention than in the past by telecommunication operators because of some important factors, such as:

<u>Revenues increase</u>: Optical Access networks enable carriers to offer any kind of service over a single network:

- Multiple voice channels using Voice over IP
- Multiple quality of service data offerings (bandwidth of up to or greater than 100 Mb/s to the home)
- Video may either be offered in an overlay configuration or within the data stream (e.g., video over IP)

<u>Competition</u>: Increased service and pricing competition force operators to differentiate their products. Furthermore, bundled services have been proven to be attractive and lead to a reduced churn probability – keeping the existing customer base.

<u>Cost Reductions</u>: As the deployment of FTTH/B has taken off in recent years especially in Asia, volume production has picked up and the cost of equipment has started to fall. This makes fibre-rich access solutions increasingly viable over time [1].

<u>Bandwidth demand</u>: Access bandwidth demand is constantly increasing due to the arrival of new applications such as HDTV, P2P applications, Video On Demand, interactive games, e-learning, the use of multiple PCs at home, etc. As a result, residential users may require connections of more than 30 Mbps in the not so far future [2].

<u>Technology Maturity</u>: The appearance of standardized solutions (e.g FSAN, ITU G.983 and G.984, IEEE 802.3ah) drastically reduced the complexity and cost of optical access networks. Furthermore, there currently exist IP multicasting techniques and technologies that are mature enough to handle hundreds of HDTV channels. These give providers more choices from a deployment point of view. In addition, as these solutions are tried the world over, experience leads to improved systems: improved security and resilience, smaller and neater cabinets, easier techniques to build fibre infrastructure e.g. with micro-cables in existing pipes, etc. Also the fast evolution of Ethernet is reflected upon the maturity and price of solutions that leverage this technology.

<u>Coverage:</u> The penetration of ADSL is quite high in many European countries. However upgrading to higher bit rates in order to meet triple-play service requirements requires considerable investments. The reason for this is that while ADSL can be delivered to customers at a distance of around 3km from the central office, VDSL and ADSL+2 with a bandwidth over 20Mbit/s have a maximum reach of less than 1km, and this distance is drastically reduced for more symmetric solutions. Hence fiber nodes need to be built within some 100s of meters from the subscriber for xDSL to deliver triple-play services and beyond. For owners of copper infrastructure, this solution may be more economical today than building FTTH. However, it is clear that xDSL technology is not far from the end of its life cycle and that further upgrades will be increasingly costly, as schematically illustrated in Figure 1. Hence owners of fiber infrastructure will have a considerable competitive advantage in the near future. The time may therefore be ripe also for operators that own copper infrastructure to consider a gradual technology shift to fiber.

An appropriate regulatory environment is a key factor that can stimulate access deployments. Regulatory issues are addressed in Section 3 of this article.

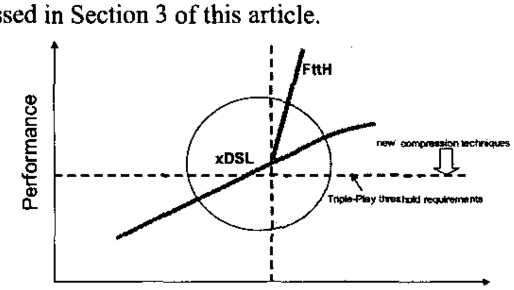

Figure 1: The performance/cost ratio of fiber is significantly superior to that of xDSL.

2 Evolution of optical access network

2.1 Historical development

Two alternative solutions exist to introduce optical fibre in the access loop: *Point-to-Point* (PtP) and *Point to MultiPoint* (PtMT) systems. Figure 2 illustrates the evolution of PtP (Media Converter systems) and PtMT (PON systems) and shows the architecture of both alternatives:

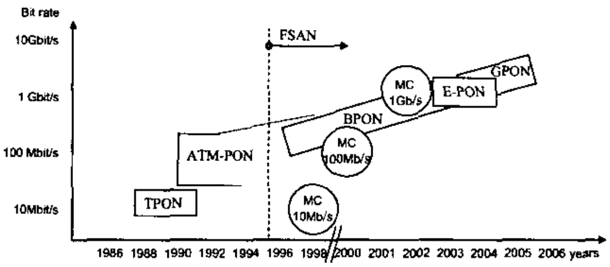

Figure 2: Evolution of broadband access solutions

The first alternative, PtP system, can use Media Converter (MC) [3] to achieve an optical fibre connection with dedicated fibre runs from the central office to each end-user subscriber. Subscribers can be up to 80 km from the Central Office (CO). While this is a simple architecture, it is cost prohibitive in most cases due to the fact that it requires significant outside plant fibre deployment, connector termination space in the local exchange and powered equipment in the field. Considering N subscribers at an average distance L km from the central office, a FTTH PtP design requires 2N+2 transceivers and N * L total fibre length (assuming single fibre is used for bidirectional transmission). However, FTTB PtP networks could present significantly lower costs in certain scenarios such as cable UTP (Unshielded Twisted Pair) cable-installed apartment complex . MC access system supports Ethernet access with best effort from 10Base-T to GbE. PtP is a very flexible solution for an operator and it can be managed remotely because the equipment in the network (Ethernet switch) is intelligent. However, the main disadvantage of FTTB/N architectures is the required management and maintenance of a high number of active nodes. In this respect FTTH networks that are based on passive network elements (Passive Optical Network, PON), lead to larger operating expenditure (OpEx) savings than legacy broadband networks.

The second alternative, PtMP system, uses a Passive Optical Network (PON) with a tree topology and passive optical splitters. PONs have several advantages over other access network architectures. The tree topology offers a single network-port over a single fibre to a plurality of users. The costs of infrastructure and network element at central office are distributed over all users: for instance, in FTTH deployments the number of transceiver is N+1, while PtP design requires 2N+2. Also each user can access the full bandwidth of the network that all users share. This allows for better service quality for a given amount of available resources. Subscribers can be up to 20 km from the CO. So, in most cases, PON is the most suitable solution for FTTH deployments.

The challenges of the PON physical layer are associated with Time Division Multiple Access (TDMA). Because the network uses passive multiplexing, the Optical Network Units (ONU) need to be synchronized with high precision so that their respective frames will interleave correctly in the fibre system. Also, because frames from multiple ONUs are received in close succession, the Optical Line Terminal (OLT) needs a large and fast dynamic range. Note that only the upstream side of the PON is concerned by these difficulties.

The search for a TDMA system over PON was originally proposed in 1987 by researchers at BT Laboratories via the TPON [4], and the first TDMA-based system was developed and demonstrated in the field in 1989 [8]. Researchers quickly recognized the technological value of upgrading these in order to support ATM-based services. The upstream capacity of these ATM-PON demonstrators ranges typically between 50Mbps and 622 Mbps. Since June 1995, there has been an international initiative from telecommunication operators and manufacturers to work towards a consensus on the optical access network in order to deliver a full set of telecommunications services, both narrowband and broadband. This initiative was called Full Service Access Networks (FSAN) and has produced the initial recommendations for Broadband-PON (B-PON) since 1996, which has been normalized by the ITU-T with the G.983.x since 1998.

In 2001, the IEEE 802.3ah began the definition of the Ethernet PON (EPON) that carries all data encapsulated in Ethernet frames (1000Base-x). Ethernet looks like a logical choice for an IP data-optimized access network and cost reduction of Ethernet versus ATM switches and network cards. Ethernet quality of service (QoS) techniques like prioritization and virtual LAN tagging have made Ethernet networks capable of supporting voice, data and video.

In 2003, the FSAN proposed the first recommendation for general characteristics of Gigabit-capable PON (GPON), with typical maximum nominal line rates of 2.4 Gbps in downstream direction and 1.2 Gbps in upstream direction. ATM and Ethernet cells are supported in these G.984.x specifications.

2.2 Next generation

The first step of evolution from today's systems is the use of "modular" devices to achieve the opto-electrical function of the OLT and ONU. This modular approach allows to integrate a high number of OLTs in a network card and to simplify wavelength allocation for the OLT and ONUs. Next generation optical access network studies consider many approaches. One approach is to further increase the speed of TDMA. Burst mode transceivers at 10Gbps are under development [5] with monolithic integration in order to attain low access device cost and small packaging.

Another approach is to increase the number of wavelengths. Wavelength division multiplexing (WDM) can be used to superimpose several TDMA PONs over the access fibre line. This solution offers desirable characteristics for an access infrastructure, such as the use of one single fibre for both upstream and downstream transmission in order to reduce network size and connection complexity.

Another WDM scenario is to allocate one wavelength to one user, by using Wavelength Division Multiple Access (WDMA) [6]. The number of wavelengths corresponds to the number of users. Other key desirable characteristics of a WDM(A) access optical network are the elimination of the laser source at the ONU and wavelength independence of all ONUs, so as to fit transparent user interfaces. Different solutions exist to obtain this colourless property.

2.3 Architecture perspective

Where different standard optical access solutions are deployed such as PtP and PtMP systems, a range of next generation solutions may still be deployed as upgrades. A possible evolution of MC-based PtP optical access architectures could be a WDMA system where wavelength-based PtP dedicated connections are maintained (cf. figure 5). This evolution allows to upgrade the bit rate, and to achieve protocol transparency. A possible evolution of PtMP architectures could be to increase the optical budget, in order to attain higher splitting ratio and/or longer transmission distance. Also the bit rate may be increased, e.g. to around 10 Gbit/s. A second step of evolution could be to build hybrid access architectures. This evolution integrates WDMA and TDMA to ensure flexibility and migration compatibility for users on existing access solutions.

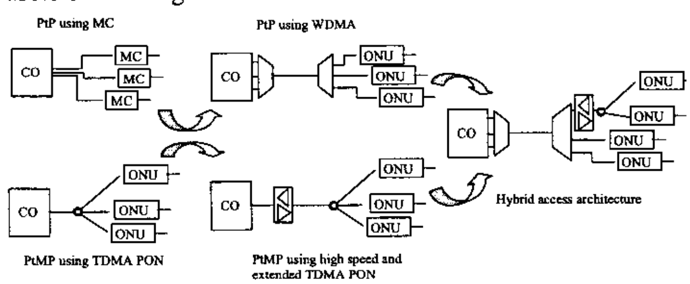

Figure 5: Architecture evolutions towards next generation optical access networks.

3 Regulatory issues

3.1 Current access network regulation in the EU

EU politicians defined in 2000 the Lisbon strategy, the objective of which was to turn EU into the most competitive and dynamic knowledge-based economy in 2010. Since then, action plans (eEurope 2002, eEurope 2005 and the last plan called i2010) in the ICT sector has been designed to achieve this goal. In all of these, competition has been considered as the best way to improve quality of service, reduce prices and promote service innovation.

Incumbent networks were opened to facilitate competition. According to this policy, new entrants could rent the elements of the incumbents' networks with stipulated prices (by the National Regulatory Authority in each European country).

This has had in particular a lot of importance in access networks, which are the most expensive to deploy. Clearly, the recommendation regarding the opening of access networks had a large impact. It has been called Unbundled Local Loop (ULL), by which incumbent operators are obliged to open their copper-based line access networks. Figure 6 shows the strategy of new entrants in access networks. The most common solution adopted by new entrants is the bit-stream and resale access, instead of fully ULL or shared access line. This clearly demonstrates that investment in new infrastructure by new entrants grows slowly:

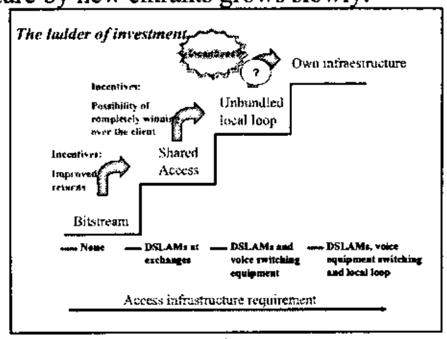

Figure 6: The ladder of investment: New entrant "accommodation"

Another key objective of the EU is the promotion of investment in new infrastructures. Tthis goal has not been fulfilled in Europe. A healthy level of investment is a strong pre-requisite in order to build networks that allow the provision of emerging broadband services.

The European regulatory environment is especially favourable to all new entrants, since they have the opportunity to obtain revenues without making the risky investment. In this situation, the incumbent operators are not likely to want to carry out new and very costly deployments since they are forced to share the new infrastructure and grant their competitors free benefits. The serious consequence of this vicious circle is the very low deployment of new infrastructure (like FTTx) in the European broadband market. The way chosen to reach a full competitive broadband market based on ULL policy has caused a stop to the introduction of new access technologies and to infrastructure deployment. The damaged agents, that have suffered market share loss, are the incumbent operators; however, the real damage regards the region itself where high bandwidth broadband penetration has been slow.

There are at present only a few fibre deployment projects in Europe, more or less entirely initiated by newcomers and not incumbents. By December 2004, according to FTTH Council, there were 0,5M FTTH subscribers and 2,6M passed homes, with a 90% concentrated in 5 countries. There were 167 FTTH projects deployed, and most of them were small or medium pilots, in which regional or local authorities are involved.

The table 2 shows that, instead of operators, the players who are carrying out FTTH deployments are municipalities and power utilities, a fact that demonstrates that something is failing in the European broadband development model.

Moreover, the European Commission will not develop a new regulatory framework before the end of 2006. Therefore, Europe and its broadband market will live in an uncertain regulatory environment for at least another year. Furthermore, as it is presented in the next section, other developed countries, like USA, Japan and Korea, are more advanced in the 'broadband race'.

Incumbent operators	7,77%
Municipalities/Power utilities	69,90%
Alternative operators/ISPs	8,74%
Housing companies & other	13,59%

Table 2: Players involved in the FTTH projects in Europe. December 2004. Source: FTTH Council Europe (study of IDATE)

3.2 Regulation in other countries

USA : In 2003 USA was, in terms of broadband development, in a technological standstill, and there was no investment in infrastructure. Since then American authorities have adopted several policy measures that have lead to an impulse on investment effort by main telecommunication companies. The main measures are:

- Priority on increasing the speed of access networks.
- Progressive elimination of unbundling local loop policy:
- Suppression of shared access.
- Setting of definitive ULL finish data (2010).
- No regulation in new infrastructure deployment.

Evidently this is a positive regulatory environment and it has had an immediate response of telecommunication operators that have started a progressive growth of investment in new broadband infrastructures in access networks, specially deploying FTTx infrastructures.

JAPAN : The Japanese broadband market is currently very competitive. This, and the public initiative to promote and facilitate the investment in broadband infrastructures, is increasing the bet for FTTx technologies by telecommunications operators. The results are:

- FTTH is growing more than ADSL.
- Japan is the first country in broadband penetration with alternative technologies.
- 3 M FTTH users in March 2005.
- NTT will invest 38 Bn euros so as to reach 30 million FFTH clients in 2010.

SOUTH KOREA : Korea market is the first in broadband penetration (currently about 25%). For a long time, the Korean government had an active behaviour in broadband development, taking the initiative in investing in infrastructures to stimulate competence. Actually, Korean ADSL market is saturated, and operators have started the "fibre deployment race". The current state of the market is:

- First country in broadband penetration.
- In April 2005, first FTTH commercial offers.
- First trials with the incoming WDM-PON technology.

3.3 Summary

A new regulatory framework is necessary to facilitate the evolution of the access networks, stimulating network development and investment in new infrastructures.

In this respect, some key aspects in the development of the new regulatory framework could be considered, as for example:

Temporal limit to ULL policy, the idea is to stimulate the new infrastructure deployment, especially in the initial introduction phase.

Promotion of investment in new infrastructures: It is important to eliminate the regulatory uncertainties. Although in some cases municipalities could deploy their own fibre infrastructure, it is evident that there will not be a large infrastructure without the participation of telecommunications operators. So, new politicies, in a new regulatory framework, are required in order to achieve a timely broadband development.

4 Conclusion

In this paper we have presented the view of operators in the Network of Excellence e-Photon/ONE on broadband access deployment and on the development towards "broadband for all" in Europe. We have first given an overview of the evolution of optical access networks and presented the development and future perspectives of point-to-point and point-to-multi-point optical access systems. In addition we have discussed access network regulation in the EU as well as in other regions and have evaluated the impact regulation has had on the local evolution of broadband.

In the market for high-speed access, competition has been focusing on price and speed. We are certainly entering the FTTH era, however, the cost of first investment is very high and creates a certain entry barrier. In order to make a profitable FTTH deployment, we have to step up efforts to introduce evolution-friendly infrastructure and technologies. The key prerequisite to achieve Broadband for All in Europe lies with the regulation that applies to access infrastructure. Regulation that gives incentives also to incumbent operators to invest in FTTx infrastructure is needed in order to achieve a fast broadband development that will provide the foundation for a competitive European economy in the years to come.

Acknowledgements

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