Fibre Access in MUSE: an End-to-End Approach to Achieve Broadband for All

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Abstract*: The paper highlights the issues related to the integration of optical access in an end-to-end multi service architecture using packet based network technologies. The MUSE research project aims at standardised solutions and their evaluation in trials.*

Introduction

MUSE (MUlti Service Access Everywhere) is a large integrated research project of the European 6th Framework Programme. It started in January 2004. It targets a future low cost, multi service access and edge network [1],[2].

While previous European research projects provided significant advances on specific optical access solutions (e.g. [3],[4]), it was recognised that an integrated end-to-end approach is needed to achieve "Broadband for All". In addition to research on innovations for the first mile (optical fibre and DSL (Digital Subscriber Line)), MUSE hence puts a lot of emphasis on network architectural aspects. The project addresses functionality in the different network elements ranging from the home gateway up to the edge, as well as their integration in an end-to-end solution.

Another important requirement for a successful breakthrough in broadband access is a significant investment from the research community in consensus work to achieve standardised solutions. The MUSE consortium consists of major European players in the field, among them vendors (Alcatel, Ericsson, Lucent Technologies, Siemens, Thomson, Infineon, ST Microelectronics), operators (BT, FT R&D, T-Systems, Telecom Italia, Telefonica, TNO Telecom (for KPN), TeliaSonera, Portugal Telecom) and research institutes (IMEC, INRIA, NTUA, ACREO, BUTE, Lund TH, UC3 Madrid, TU Eindhoven, University of Essex, HHI). The project is hence well placed to perform pre-standardisation work in the area of broadband access.

The present paper gives an overview of the different research challenges in the domain of broadband access that will be addressed by MUSE. A first section gives the major trends expected in the access network. The next section describes the issues for the access network architecture. It highlights different generic options for the network architecture and their pros and cons when applied to a high bandwidth optical access solution. The last sections summarise the specific activities in MUSE on optical first mile technologies and the challenges for integrated lab trials.

Trends in Access

MUSE anticipates various trends in the access network with respect to service capabilities, network technology, and bandwidth. Today, a large part of the broadband subscribers in Europe is connected via an ATM (Asynchronous Transfer Mode) based ADSL (Asymmetric DSL) or DOCSIS based Cable modem. The offered bandwidth is a few Mbit/s for high speed Internet access services via a PC (Personal Computer).

With the erosion of the flat subscription fees for high speed Internet access, providers aim to offer new revenue generating services over the same broadband infrastructure. Access providers, network service providers, and application providers will join their expertise in alliances to offer the most attractive service package to the end-users. A future broadband access platform should hence have multi service and multi hosting capabilities.

Another trend is the introduction of packet based network technologies in the access and edge network. While ATM remains a well-suited technology for multi service networks, Ethernet is emerging as a fashionable alternative in several segments of the access market [5]. This is due to the general acceptance of Ethernet in private networks, the efficient multiplexing capabilities of Metro Ethernet, an attractive price setting of optical Ethernet interfaces and the efficient reuse of know-how and components from the large LAN (Local Area Network) market. At the network layer, IPv6 (Internet Protocol version 6) may offer new opportunities for the access network.

The evolution of the commercially available bandwidth per subscriber in the first mile seems to follow a trend similar to Moore's law for processing power of silicon chips. Figure 1 shows the evolution of the access bandwidth available for around 50 Euro/month or less to at least 10% of the European population. Although various high bandwidth access solutions have been technically feasible since a long time, their commercial deployment is subject to a complex socio-economic process of application pull, technology push, low cost production capabilities, competition, marketing, and roll-out of infrastructure. It however results in a simple exponential increase of the access bandwidth. Extrapolation from the early voiceband modems via today's ADSL, shows that a bandwidth between 10 and 100 Mbit/s is expected to become generally available by 2010. Hence further penetration of fibre to a street cabinet (with VDSL (Very high bitrate DSL) drops) or the home (FTTH (Fibre To The Home)) is inevitable. While people previously wondered about the killer application to justify deep penetration of fibre in the access network, the general understanding today is that a mix of existing and future applications will consume any available bandwidth.

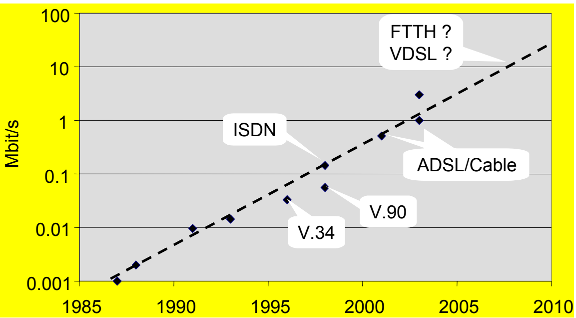

Figure 1: Evolution of commercially available access bandwidth for residential users.

Many future applications delivered over a broadband access network will not only be triggered by a PC, but by several other appliances in the home. It is hence very important to address the configuration of such services, as well as the interworking between the home network and the access network via a home gateway.

Access Network Architecture Issues

Figure 2 shows a typical access architecture, which consists of a home gateway, a first mile solution terminated in an access multiplexer, and an aggregation network connecting the access multiplexers with a BRAS (Broadband Remote Access Server) at the edge. The BRAS manages the access sessions and interfaces with the IP core network. Two solutions have been standardised to evolve from a best effort access network to a DSL multi service network. One approach adds only IP QoS capabilities at the borders of the access and edge network in the home gateway and the BRAS [6]. Another uses ATM QoS capabilities in the access multiplexers and aggregation network [7]. The latter allows for a more efficient use of bandwidth in the aggregation network. It will therefore also be of specific interest for high bandwidth fibre access.

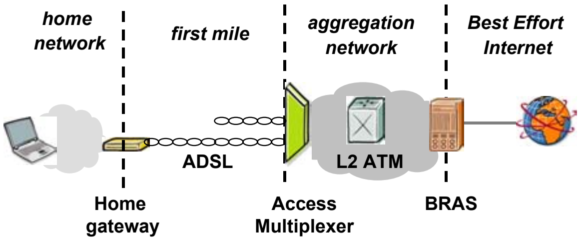

Figure 2: Basic architecture for broadband access (present ADSL deployment).

It is expected that Ethernet will migrate into the access network, first in the aggregation network and later in the first mile. MUSE studies several architectural possibilities to evolve from today's best effort access network to a multi service network with QoS (Quality of Service) support.

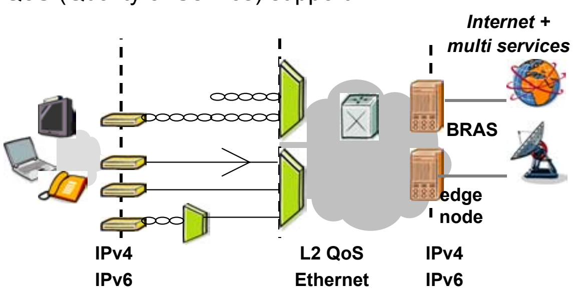

Figure 3: Evolution to high bandwidth and multiple services in Ethernet based architecture.

The first option is based on the use of Ethernet technology for connectivity and relies on L2 and/or L3 QoS capabilities. This evolution is illustrated in Figure 3. New services can be gradually introduced by adding edge nodes optimised for a specific set of services. The access multiplexer has QoS intelligence to optimise the required bandwidth in the aggregation. This is especially of importance for optical first mile solutions for which the aggregate bandwidth otherwise becomes high and expensive. Further optimisation of the bandwidth for multicast traffic is possible by introducing multicast intelligence in the access multiplexer.

The second architectural option is one in which the forwarding for connectivity and QoS management in the access multiplexer and aggregation network are entirely based on IP information at L3 (Figure 4). Some IP edge functionality will be moved to the access multiplexer, which possibly allows for an optimisation of the distribution of functions and cost.

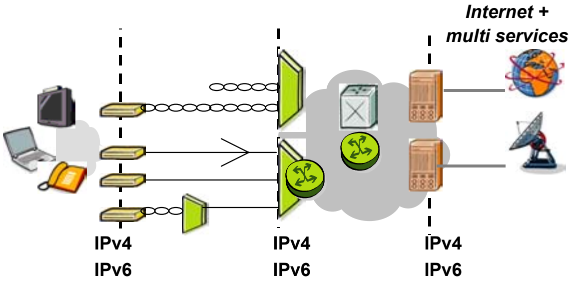

Figure 4: L3 based access architecture.

New solutions need to be elaborated to use Ethernet and IP in a multi service access network. Intelligence in the access multiplexers should enable to forward data to and from subscribers in a secure and scalable fashion. Network management systems should be adopted for a multi provider environment. Functionality is required to allow for the auto-configuration of services (including Authentication, Authorisation, and Accounting) and the provisioning of the appropriate QoS (Quality of Service). Service enabling functions embedded in the access platform should help the access provider to create added value for the offered services and as such create more revenues.

Solutions to some shortcomings of Ethernet when used in the access network are being worked out and their standardisation recently started (e.g. DSL Forum, EFM (Ethernet in the First Mile)). Ethernet is designed for a LAN with trusted users that belong to the same organisation. The shared nature of Ethernet and the possibility to spoof Ethernet MAC addresses (Medium Access Control) however represent unacceptable security threats when used in a public access network. Filters are needed in the access nodes to ensure address uniqueness. Intelligence is needed to prevent broadcasting of confidential data to other subscribers or competing service providers. Such broadcast messages are e.g. transmitted during the autoconfiguration with certain control protocols (e.g. PPPoE (Point-to-Point protocol over Ethernet, ARP (Address Resolution Protocol), or DHCP (Dynamic Host Configuration Protocol)).

The emergence of IPv6 may offer new opportunities for the access network. The large address space of IPv6 does not only provide a possible solution for the dooming exhaustion of IPv4 addresses, but also allows for new hierarchical addressing schemes (in a fashion similar to the international numbering scheme for telephones) and as such simplify the design of access nodes. In addition, IPv6 provides new ways for auto-configuration, more efficient support of nomadic subscriber connectivity, inherent security features, and efficient QoS support per flow [8].

The architectural studies will take into account the needs for applications and services offered on the network. In addition to the conventional Internet, video streaming, and conversational services, more recent trends such as gaming, peer-to-peer delivery models, and nomadism will be included. The new co-operative business models will impose new requirements on the access network as well. MUSE will further investigate how the new multi service architectural solutions described above will be integrated with existing broadband networks.

The architectural choices will be supported by techno-economical evaluations. Previous studies often focused on the investment cost and operational expenses for different first mile solution [9]. MUSE will focus more on the comparison of network architectural options. MUSE will evaluate the total business case, which includes the revenues for the different players in the value chain. Case studies will assess whether additional revenues can justify the extra cost of a specific service enabling function in the network architecture.

In order to achieve a successful broadband deployment, the network architectural solutions need to be standardised. Examples of target bodies in this domain are DSL Forum, ITU-T, ETSI, FSAN, IEEE 802.1 and 802.3, IETF, and MEF.

Fibre Access in MUSE

MUSE will evaluate optical access technologies in an end-to-end network, taking into account the network architectural issues described in the previous section. Both an Ethernet point-to-point [10] and Ethernet GPON (Gigabit Passive Optical Network) [3] solution will be integrated in an access platform and evaluated in an end-to-end lab trial. Fibre to the cabinet with VDSL drops and FTTH will be considered.

A specific challenge for Ethernet point-to-point is the cost-effective handling of the large amount of fibre strands terminated in the central office. Fibre ribbon cables, transmitter arrays and receiver arrays, which are known for optical intra-system interconnections, will be evaluated against the specific requirements for an optical access network [10]. An important issue will be the cross talk at the receiver array considering the differences in optical power level that are possible between neighbouring channels.

MUSE maintains some research at the physical layer to explore longer-term innovations that may further reduce the investment or deployment cost of fibre access. This also includes a critical review of known concepts with respect to new architectural insights or the availability of new state-of-the-art components. The related activities are briefly summarised here. More details can be found in [11], [12], [13], [14].

A first activity deals with HFR (Hybrid Fibre Radio) that uses MMF (Multi Mode Fibre) [12]. It provides a possible low cost implementation for a short range access network with a transparent connection to a wireless home network. For distributing the microwave signals, the so-called Optical Frequency Multiplying technique may allow for longer reaches (say beyond 2 km) when deploying the higher-order transmission lobes of MMF. Alternatively, SMF (Single Mode Fibre) is used in the feeder link followed by short MMF festoon/star links to the antenna sites (e.g. for fixed wireless access).

A second activity focuses on hybrid fibre VDSL in a fibre to the cabinet configuration. Analogue signals of different VDSL subscriber lines are up-converted to a specific subcarrier frequency at the cabinet. The different subcarriers are then multiplexed and transparently converted to an analogue signal that is carried over an optical feeder. The approach is potentially lower cost than the conventional solution with a digital baseband feeder due to a smaller cabinet size and lower power consumption. It has been demonstrated before for single carrier VDSL. New in MUSE is the use of the multi carrier modulation(also known as DMT (Discrete Multi Tone), which is now the standard for VDSL. It is also intended to use digital subcarrier-multiplexing techniques to both increase spectral efficiency and provide a means for directly-modulating low cost laser transmitters [13].

A third activity explores the possibilities of lower cost CWDM (Coarse Wavelength Division Multiplexing) components for use in the access network. Schemes to upgrade the bandwidth of a PON or point-to-point optical access with additional analogue or digital channels will be evaluated. The configuration flexibility and ways to provide redundancy in such networks are studied as well [14].

Lab Trials

The different network elements and first mile solutions will be integrated in end-to-end lab trials. While previous research on optical access often focused on the physical layer performance, MUSE will also evaluate functional aspects of the network such as the end-to-end QoS support, scalability, robustness against security attacks, support of services, and manageability. Another important aspect of lab trials is the verification of interoperability.
Some of the prototypes will be taken a step further and evaluated in a field trial in the Swedish National test bed [15].

Conclusions and Outlook

The real challenge to achieve a breakthrough in "Broadband for All" is the integration and standardisation of access solutions in an end-to-end architecture. In addition to the physical layer, there are many issues to be solved at the data link and network layer. Several aspects are generic for any type of access technology (DSL or fibre). The use of high bandwidth fibre access however favours specific QoS enabled network architectures that allow to optimise the bandwidth in the aggregation network.

MUSE will generate a first consolidated view of a packet-based access architecture by end 2004. First results of lab trials are expected by 2006. Interoperability of (pre-)standard solutions and advanced features will be demonstrated by the end of the project in 2007.

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