MUSE ACHIEVEMENTS: EXECUTIVE SUMMARY

The overall objective of MUSE was the research and development of a future, ***low cost***, ***multi-service access*** network that provides secure connectivity between end-user terminals and edge nodes in an open, ***multi-provider*** environment suited for the ubiquitous delivery of ***broadband*** services to ***every European*** citizen.

MUSE (MUlti-Service access Everywhere) was an integrated research project that contributed to the strategic objective “Broadband for All” of the 6th Framework Programme of the European Commission. The project addressed access network architectures, access nodes, first mile solutions, residential gateways, and their evaluation in lab trials (cf. Figure 1).

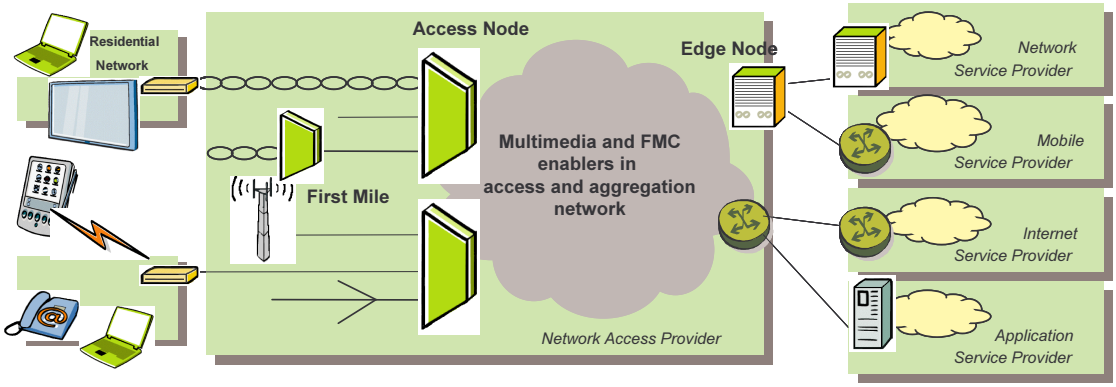

Figure 1: MUSE architecture and scope.

The project was organised in two consecutive phases, which ran between January 2004 and March 2008. During the first phase, MUSE defined and demonstrated a multi-service access architecture based on IP (Internet Protocol) / Ethernet technology. The second phase advanced the architecture into a more mature solution and extended it with additional service capabilities for multimedia and fixed mobile convergence.

The MUSE consortium consisted of major European players in the field of broadband access, among them vendors (Alcatel-Lucent, Ericsson, Nokia Siemens Networks, Thomson), operators (BT, FT R&D, T-Systems, Telecom Italia, Telefonica, TNO (for KPN), TeliaSonera, Portugal Telecom, TP), research institutes (IBBT, INRIA, ICCS/NTUA, ACREO, BUTE, Lund TH, UC3 Madrid, TU Eindhoven, University of Essex, HHI), and a SME in engineering (Robotiker). During Phase I, component vendors (Infineon, STMicroelectronics) and a regional access provider (Broadband Society of Aarhus) also contributed. The project budget of 60 MEuro (total for two phases – 50% funded by the European Commission) covered the equivalent of one hundred full time researchers per year, but, in reality, approximately three hundred people were involved. This turned MUSE into a powerful instrument for orchestrating a consensus on the future access and edge network in Europe.

Thus an important result was a joint position in standards bodies, following extensive pre-standardisation work, as well as many proof-of-concept demonstrators and lab trials. This is expected to lead to a new generation of access equipment from European vendors, which will be widely deployed across Europe, as operators upgrade their current networks.

General access architectures

MUSE defined a novel complete and comprehensive multi-service access architecture, branded as "GSB" (Global System for Broadband). The architecture is open to multiple retail/wholesale providers and supports multiple applications (quadruple play including voice, data, video, and fixed mobile convergence).

In the first phase, this IP and Ethernet based architecture that provides secure connectivity was specified and demonstrated in lab trials. In the second phase, enhancements to the access network architecture were further elaborated in detail and aligned to the new concepts. Aspects like business roles, auto-configuration and authentication, IP sessions, flows, QoS (Quality of Service), and policy control were driven to maturity in order to bring solid standards contributions to the DSL Forum. Although MUSE mainly targeted residential subscribers, specific requirements for business users were also elaborated, such as the support of multi-party VoIP (Voice over IP) and L2VPN (Layer 2 Virtual Private Network).

Complementary to the architecture definition, a well-documented test suite was defined for the evaluation of multi-service solutions. Parts of the test suite were used at an ETSI Plugtest event for triple play solutions.

Multi-Media Rich Access

The project investigated and demonstrated how the access network defined in MUSE can be enriched with new service enablers that enhance the QoE (Quality of Experience) and facilitate the deployment of multimedia services. This entailed the distribution of higher layer intelligence into the access network closer to the subscriber. As a first case study, MUSE evaluated the integration of SBC (Session Border Controller) functionality into the access node or residential gateway, to reap the potential advantages this offers in terms of network security, QoS control, and scalability.

The project extended the QoE requirements available for video and voice to other services, such as high-speed Internet access, gaming, and multimodal services. New concepts were studied for the monitoring and control of QoE, such as truncated packet interception and virtual buffer management. A monitoring plane and knowledge plane allowed for automatically measuring and correlating the performance of services. The MUSE test suite was enhanced to experimentally determine a mean opinion score for the characteristics of video services, such as channel zapping performance. The work on QoE also resulted in relevant contributions to the DSL Forum.

In order to improve the QoE over a network that includes error prone DSL (Digital Subscriber Line) or wireless sections, two approaches were developed and compared to achieve a more reliable transport of video services. One is based on a retransmission proxy in an access node and the other is based on FEC (Forward Error Correction) at the transport layer. The benefits of retransmission resulted in the initiation of a new work item in DVB (Digital Video Broadcast) standardisation.

Other studies on higher layer service enablers included the use of DPI (Deep Packet Inspection), legal interception, and options for the provision of QoS for video delivered by P2P (Peer-to-Peer) technology.

A Service Plane that allows the embedding of higher layer functionality in an access node in a generic manner was developed and evaluated by MUSE operators. Several of the studied architectural concepts were implemented as use cases for the Service Plane: Distributed SBC, QoE Monitoring, and Video Retransmission. A concurrent techno-economic evaluation showed that a distributed approach is economically feasible if several service enablers can share the cost for the distributed processing power and operations. This was the first time that such set of functions was demonstrated on a real access node and integrated in an end-to-end lab trial.

A new video gateway allows for aggregating streams from distributed video sources and processing of high-layer functions at high speed. An advanced multi-service edge router that features an innovative architecture to partition the IMS (IP Multimedia Subsystem) functions was developed and evaluated. As a more long-term evolution of a high-speed distributed access architecture, novel algorithms for self-organised service nodes and distributed P2P caching were studied and prototyped.

Fixed Mobile Convergence

MUSE extended the multi-service access architecture with capabilities for nomadic services and session continuity. Though FMC (Fixed Mobile Convergence) is tackled by many research and standardisation initiatives, the expertise of MUSE provided a unique contribution by addressing FMC from a fixed network provider's perspective.

Functions like AAA (Authentication, Authorisation, Accounting), and Policy Control were investigated for nomadic use cases and mapped onto the overall architecture. Special attention was paid to roaming agreements and to the interworking of the fixed access network with 3GPP (3rd Generation Partnership Project) and WiMAX mobile networks. This allows for fixed network subscribers moving into a mobile network and vice versa. Two solutions for session continuity, based on MIP (Mobile IP) and SIP (Session Initiation Protocol), were elaborated. A techno-economical evaluation of fixed mobile convergence showed that the business case could be made profitable within a reasonable payback time of three years, only by first optimising the operational processes in terms of cost.

One of the lab trials showed authentication and authorisation, policy and QoS Control for nomadic users in an Ethernet based access architecture. A key element of the set-up was a resource manager, which is responsible for keeping track of used and available resources in different parts of the access network. A topology-discovery mechanism suited for the self-management of dynamic network configurations in nomadic service scenarios was prototyped. Roaming between fixed networks and between fixed and cellular networks was addressed as well. The lab trial also featured session continuity based on MIP within fixed and WLANs (Wireless Local Area Network), as also within fixed and WiMAX networks. Another lab trial demonstrated mobility at the application layer with additional privacy protection. It allowed a user to be seamlessly switched between one fixed SIP videophone and another SIP phone or mobile phone without his correspondent being able to detect a transition.

First Mile Solutions

Thanks to the co-operation within the project, MUSE made important standards contributions on improvements and convergence of VDSL2 / ADSL2 (Very high-speed DSL / Asymmetric DSL) to DSL Forum, ETSI TM6, and ITU-T. The discussion threads involved a variety of topics, such as DSL noise environments, band plans, cable models, spectral management, line testing, DSL profiles, and future low power broadband evolution. Also the more long-term-oriented work on XL-PON (eXtra Large Passive Optical Network) and the liaison with the PIEMAN research project has already resulted in guidelines into FSAN and ITU-T.

Research also aimed at drastically reducing operational costs through the use of technology requiring only planned visits to flexibility points and remote electronics, whilst enabling 'zero touch' service provisioning for all the served customers. The different options were compared in terms of capital and operational expenditures.

An advanced Loop Qualification and Monitoring system was developed and improved through extensive lab and field tests. It was integrated with a network and service management platform in order to achieve an efficient provisioning process.

As for Optical Access, MUSE developed an XL PON system and demonstrated a world record 2.5 Gbit/s burst mode transmission upstream and 10 Gbit/s downstream over 100 km and 1:1024 optical split. The transmission convergence layer is an evolution of the FSAN compliant GPON (Gigabit Passive Optical Network). An alternative Burst Mode Receiver design using edge detection even promises 10 Gbit/s upstream performance.

Other optical access technologies studied were a resilient CWDM (Coarse Wavelength Division Multiplexing) ring access system, which features bi-directional transmission on a single wavelength, and a hybrid fibre radio solution, which is suited for feeding WiMAX base stations over long optical feeder sections.

Residential Gateway

MUSE also performed an extensive study into the design and development of a residential gateway that is compatible with the defined network architecture and suited for quadruple play. A functional block diagram was defined and generic functions for connectivity, authentication and authorisation, and QoS control were elaborated. It was specified how the residential gateway can support IMS and can act as a proxy for non-IMS terminals. In co-ordination with the overall network architectural studies, a lot of effort was spent on new solutions to provide secure access to nomadic visitors and users of co-located private hotspots. Another challenge was the configuration and management of the residential gateway and home devices to enable services from multiple providers and for multiple subscribers (including nomadic). This work resulted in numerous standards contributions to the HGI (Home Gateway Initiative).

Following the specifications, advanced multi-play residential gateways were prototyped. Lab models based on a Linux platform were used for quick prototyping and evaluation of new capabilities: interworking between TR-69 and UPnP to manage devices in the home, an OSGi based solution for the management of multiple services by multiple providers on a single residential gateway, authentication of nomadic users, and realisation of an IMS proxy. In anticipation of future low cost products with an embedded processor, a solution based on a Remote OSGi Cache was evaluated. In parallel to the lab models, industrial low cost prototypes of an advanced multiplay residential gateway were realised, which were compliant with the GSB specifications and proved to be interoperable with two access platforms developed in different subprojects.

Figure 2: Multimedia Broadband Access demo in MUSE booth at BB Europe 2007.

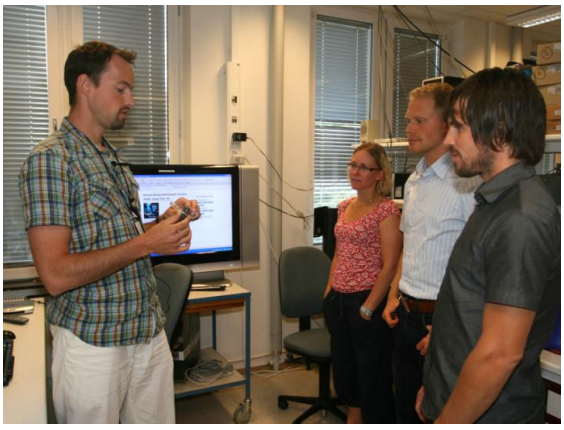

Figure 3: Nomadic services demonstrated in Ethernet access platform at NOC 2007.

Lab trials

The studied concepts were successfully integrated into four lab trial systems by different subprojects. Each trial proved the end-to-end operation for a different deployment scenario in the lab of a provider: (a) multimedia enhancements in a broadband access architecture; (b) fixed mobile convergence; (c) high-speed access with distributed control; and (d) long reach optical access solutions for node consolidation. They were evaluated using a jointly defined test suite. In addition, three cross subproject trials were realised to show the interoperability between the different platforms. Two lab trial platforms were connected via the trans-European test bed of the MUPBED project.

MUSE extensively disseminated its results via more than a hundred co-signed contributions to standardisation, about three hundred publications and presentations at conferences, and eight editions of the MUSE Season School. Public demos were shown at various conferences, such as BB Europe and NOC (cf. Figure 2 and Figure 3).

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