

RESULTS OF MUSE PHASE I

Project objective and organisation



The overall objective of MUSE is 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) contributes to the strategic objective "Broadband for All" of the 6th Framework Programme of the European commission. The expected impact and results of the project are a consensus about the future access and edge network by major operators and vendors in Europe. Anticipated major results include pre-standardisation work aiming at a joint position in standards bodies, as well as proof of concept demonstrators and lab trials. This should lead to a new generation of Access equipment from European vendors, which is expected to be widely deployed across Europe, as operators upgrade their current networks.

The project started in January 2004 and is planned for four years. A first phase of two years is now completed and the consortium was granted a second phase of two years.

The **MUSE consortium** consists of major European players in the field of broadband access, among them vendors (Alcatel, Ericsson, Lucent Technologies, Siemens, Thomson, Infineon, ST Microelectronics), operators (BT, FT R&D, T-Systems, Telecom Italia, Telefonica, TNO (for KPN), TeliaSonera, Portugal Telecom, BSA), research institutes (IMEC/IBBT, INRIA, NTUA, ACREO, BUTE, Lund TH, UC3 Madrid, TU Eindhoven, University of Essex, HHI), and a SME in engineering (Robotiker).

The project is **organised in a matrix** with four SPs (SubProjects) and four TFs (Task Forces):

SPA is an umbrella subproject that provides the network vision to the other subprojects and task forces. It deals with the end-to-end **access and edge network architecture** and techno-economic studies. The other SPs are the vertical dimension of the matrix. They study detailed solutions at network element level and validate the concepts for three end-to-end deployment scenarios: **SPB on migration, SPC on non-legacy scenarios, and SPD on FTTx.**

The TFs are the horizontal dimension of the organisation. They ensure communication and consensus in specific technical areas across the subprojects. The outputs of the task forces are common contributions to standardisation bodies, position papers, comparisons of different approaches, common specifications, and test methods: **TF1 on Access and edge platforms; TF2 on First mile solutions; TF3 on Home gateways; and TF4 on Lab trials.**

Achievements

The **first year** of the project was mainly focused on the definition of a multi-service access architecture, the specification of requirements for the network elements and feasibility studies of some enabling concepts. During the **second year**, MUSE elaborated the network architectures and started to influence standardisation with a significant number of contributions in the DSL Forum, ETSI, HGI, and ITU-T. Solutions for the network architectural requirements were studied in detail and three lab trials were integrated according to three different SP scenarios.

Access Architectures

SPA and TF1 defined two network models for the access and edge architecture: Model 1 is based on L2 Ethernet forwarding and Model 2 on L3 IP forwarding. In the 1st year, mainly Model 1 was studied. Although Ethernet access network solutions already exist and are being standardised, an important innovation of MUSE is the study of the multi-service and multi-provider capability of such a network. In the 2nd year, Model 2 was elaborated. The IP forwarding model is an entirely new access architecture, which offers advantages with respect to the Ethernet model in terms of security, scalability, and QoS support. It was proposed for future work in the DSL Forum. Research was also dedicated to opportunities for IPv6 in an access network, its coexistence with IPv4, and impacts on autoconfiguration.

In order to realise multi-service capabilities in both network models, authentication, QoS provisioning, and multicasting were studied in a generic way. In addition to the conventional PPP approach, alternative autoconfiguration methods and per user authentication were elaborated and promoted in the DSL Forum. The studies on QoS resulted in a novel distributed resource admission control architecture, which solves the scalability of a centralised approach. It was proposed for a future release of ETSI TISPAN. MUSE provided a framework and reference nomenclature on multicast in access to the DSL Forum. Another innovation in multicast was the impact on the access architecture when an end-user becomes the source of a multicast tree. As groundwork for phase II, MUSE explored issues on nomadicity and service enablers in access.

In order to address the multi-hosting capabilities, a thorough analysis was made of the business models and this was presented to the DSL Forum. In addition to the roles of the network access provider, network service provider and application provider (as known from previous DSL Forum documents), an important improvement was to explicitly define the new business roles of a packager and connectivity provider. The former packages the services from different providers as a single entity to the end-user, whilst the latter is responsible for the connection and QoS across networks owned by different providers. MUSE described a reference architecture with the interfaces between the different possible players at data plane, control plane, and management plane. A dedicated deliverable describes the network and service management model for a multi-provider environment.

Techno economic evaluations confirmed the architectural choice to migrate to the new MUSE access architectures. Previous research projects mostly concentrated on the up-front investment cost for different first mile solutions. MUSE made an evaluation of the total business case and compared several options, not only for the physical layer infrastructure, but also for functional choices in the higher layer network architecture.

Access platforms

Each SP studied solutions and developed prototypes in line with the network architectural specifications defined by SPA.

SPB on “migration scenarios” studied a multi-edge access platform that provides triple-play services. The demonstrator was built according to the Model 2 (IP forwarding) architecture defined by SPA-TF1. The migration scenario is supported by legacy ADSL solutions and access to the legacy Internet. The access platform contains edge nodes with innovative capabilities, such as a packet-to-packet gateway for multi-media conversational services and a TVoIP Head-End with a novel Pro-MPEG FEC capability. A TCP accelerator and Time Shifted TV proxy are integrated in the access node to illustrate how higher layer service awareness can provide added value to the end users and the providers. A lab model of IPv6 in the Access was realised that proves the network architectural concepts of SPA-TF1. A methodology was elaborated that allows operators for assessing different variants of the MUSE platform against specific deployment requirements.

The platform developed in SPC offers Public Ethernet Carrier-grade multi-service access in accordance with the Model 1 (Ethernet forwarding) architecture. It is based on service binding, a network access service connection bundled with an application service connection. It is an innovative implementation of the service connection concept developed in SPA-TF1 providing a lightweight architecture to implement traffic separation. This ensures flexibility and scalability where a multitude of services can be delivered to several hundred thousand users attached to multiple edges in the network. A revolutionary and evolutionary approach to IPv6 in the access was compared. A node architecture based on the evolutionary concept that exploits the low cost paradigm of Ethernet was proposed. It concentrates IPv6 functions to the borders and uses standard Ethernet within a node.

First Mile Solutions

Important research was required to get more bandwidth and quality out of the “copper resource” used by DSL. SPB compared the efficiency of dynamic spectral management and dynamic line management. The SPB results on modelling and mitigation of impulse noise in DSL lines were highly relevant for a good quality delivery of video streams. The autonomous loop qualification and monitoring methods studied by SPC allow for the reduction of the operational expenses and maximising the bandwidth capacity of individual lines by measuring their characteristics. SPC also evaluated the promising concept of UWB (Ultra Wide Band) over copper paradigm aimed at transmitting up to 1 Gbit/s over short distances of DSL and evaluated the spectral compatibility of ADSL and VDSL in the same binder. SPD simulated dynamic spectral management for VDSL. At TF2 level, MUSE made a significant number of standards contributions in these areas to ETSI TM6, ITU-T and DSL Forum.

While PON solutions have reached technical maturity in other IST projects, the research by MUSE on optical access focused on reducing the footprint of point-to-point fibre architectures and a review of more advanced FTTx architectures. SPC developed and evaluated compact dual bi-directional transceivers that allow for a PTP optical access node with a density comparable to a DSLAM. SPD reduced the size of the access node by an asymmetric PTP-PON approach. SPD also prototyped a new WIMAX over fibre solution. The same principle of transmission of analogue radio signals over fibre was also investigated for a new DSL over optics solution. Lower cost CWDM technology was evaluated in a ring architecture, which allows for feeding cabinets with different drop technologies, as well as fibre to the premises.

Residential Gateway

SPB performed an extensive study into a residential gateway that would be suitable for use with the MUSE network architecture and triple play. Starting from the best effort, high speed Internet ADSL deployment and from the current standard specifications, the system research led to the specification of the functional requirements for a multi-service capable CPE. A prototype with an ADSL2+ interface was realised in line with the specifications. A service gateway was realised that illustrates the capabilities of an OSGI based platform.

SPD studied and prototyped a residential gateway as well. While SPB researched solutions within the constraints of an industrial low cost HW and SW environment, SPD explored the design of the residential gateway on a generic processor platform with fewer restrictions in processing power and more flexibility to try new functions. SPD also paid special attention to the high throughput typical for a FTTX deployment.

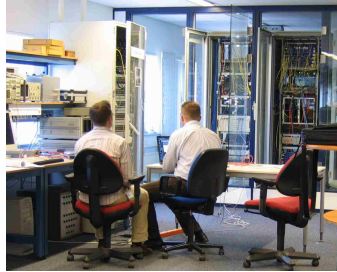
In the joint task force TF3, the MUSE partners agreed and described a rigorous functional reference model of the residential gateway at the data plane, control plane and management plane. MUSE forwarded its result on access architecture and residential gateway to the newly started HGI. Contributions on auto-configuration and remote management capabilities were made to the DSL Forum.

Lab trials and test suites

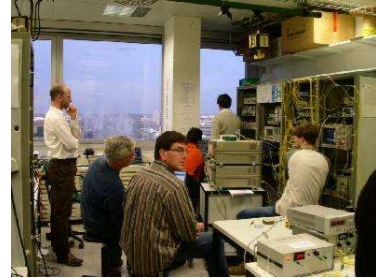
Each of the three subprojects successfully integrated the results from different workpackages into an end-to-end lab trial, which proved the correct operation of the architectures and concepts.



SPB demo at BB Europe



SPC lab trial at TNO



SPD lab trial at HHI

The SPB lab trial demonstrated the operation of the novel Model 2 IP forwarding architecture, as defined in SPA. The set-up was on display at the BB Europe conference in Bordeaux in December 2005 and will be evaluated in operator labs in the first semester of phase II.

SPC realised a lab trial demonstrating the multi-service and multi-provider capable Ethernet Access platform. The set-up was evaluated in the lab of TNO and another set-up at Acreo was connected to the Swedish National Testbed.

SPD successfully realised a lab trial of advanced optical access technologies. Low cost CWDM technology is used to integrate analogue signals of DSL over optics and radio over optics, as well as high-speed digital baseband signals on a single fibre infrastructure.

In TF4, the partners jointly explored the possibilities for an interconnected cross SP lab trial envisaged for phase II. Efforts were also shared to jointly define a test suite of the evaluation of an end-to-end multi-service access network. This multi-disciplinary approach resulted in test objectives and methods on physical layer (DSL and Fibre), connectivity, and QoS.

Outlook of Phase II

MUSE has successfully achieved its objectives for Phase I and is ready to capitalise on the joint expertise to address the challenges of Phase II. During the extension, MUSE will continue to bring the results of the first phase to standardisation and evaluate them in integrated lab trials. The MUSE access network solutions will be further enhanced by

- embedding new service enablers in the access network elements to create more added value from multimedia applications,
- preparing the fixed access architecture to support fixed mobile convergence,
- comparing new concepts like distributed architectures and node consolidation.

The extensions will be validated by upgrades of the integrated lab trial set-ups.

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