MUPBED: ASON/GMPLS Architecture, Interworking Solutions and Test Network Implementations

Jan Späth, Ericsson, Gerberstr. 33, 71522 Backnang; E-Mail: jan.spaeth@ericsson.com
Hans-Martin Foisel, T-Systems, Goslarer Ufer 35, 10589 Berlin; E-Mail: Hans-Martin.Foisel@t-systems.com

Abstract

European research networks are often seen as „early adopters“ of new network functions, which is mostly due to their goal to support future looking, highly demanding applications in terms of e.g. bandwidth, availability, or dynamic behaviour. In the IST project MUPBED („Multi-Partner European Test Beds for Research Networking“; www.ist-mupbed.org) ASON/GMPLS solutions for next generation research networks are evaluated and a European scale test network is setup for experimental assessments.

This paper gives an overview on the MUPBED ASON/GMPLS network architecture and network solutions, and their relation to the European research networks, enabling seamless multi-domain multi-layer interworking among multiple network domains for supporting new, upcoming applications. The paper also describes the implementation of the pan-European MUPBED test bed and how this test bed allows to investigate the developed networking concepts in a field trial environment.

Introduction

Seamless interworking in a heterogeneous fast evolving network environment is one of today's top challenges network operators are facing generally, indifferent if incumbent, newcomer, or research network service provider. Additionally the on-demand service requests from the customer side have to be satisfied. Solutions to cope with these requirements are mostly based on ASON/GMPLS control plane based functions. The MUPBED project is tackling these issues conceptually and prove these theoretical results in a European, multi-domain and multi-layer test network.

The paper presents first an overview of the IST project MUPBED, highlighting especially the networking oriented working areas in this project. Then, a section is dedicated to the network situation of European research network providers, and elaborating on key issues that arise from the very heterogeneous network environment that can be found there. This is followed by a section describing the network architecture work in MUPBED, leading to a reference architecture solution, which is promising for the future research networks in Europe. The last main section is providing detailed information on the MUPBED test bed realisation, and on how this test bed allows to implement and investigate different aspects of the reference network architecture.

Overview of MUPBED project

The IST project MUPBED ("Multi-Partner European Test Beds for Research Networking") is a European Union funded project within the IST (Information Society Technologies) priority, focusing on "Research Networking Test Beds". It focuses on advanced networking technologies for future research networks [1]. Further information, including access to all project publications and deliverables can be found on the MUPBED web site [2].

MUPBED started in July 2004 and will run over 3 years. The MUPBED consortium consists of 16 partners from 8 European countries, representing major network operators, system vendors, research and education networks, and research institutes: Ericsson GmbH (project co-ordinator), Marconi S.p.A. (an Ericsson company), Acreo AB, Telecom Italia, T-Systems / Deutsche Telekom, TU Denmark, Telefonica I+D, Magyar Telekom, DFN-Verein, GARR, CSP – Innovazione nelle ICT, University of Erlangen, RedIRIS-Red.es, Juniper Networks, Institute of Bioorganic Chemistry – Poznan Supercomputing and Networking Centre (PSNC), Politecnico di Milano.

The main objective of MUPBED is to investigate and to demonstrate advanced network technologies and solutions that will help to build future ultra-broadband research networks, which are fundamental building blocks to ensure the competitiveness of research in Europe.

The advanced applications of the research and scientific community increase the requirements for the communication networks interconnecting the various research centres and users. One key aspect will be the introduction of latest ASON/GMPLS (Automatically Switched Optical Networks/Generalized Multi-Protocol Label Switching) control plane technologies into research networks in a multi-domain environment. One of the ambitious project goals is the realisation of a pan-European intelligent networking test bed (**Figure 1**). This test bed forms the basis for practical experiments and tests of the developed networking concepts, and it is the basis for far reaching dissemination activities.

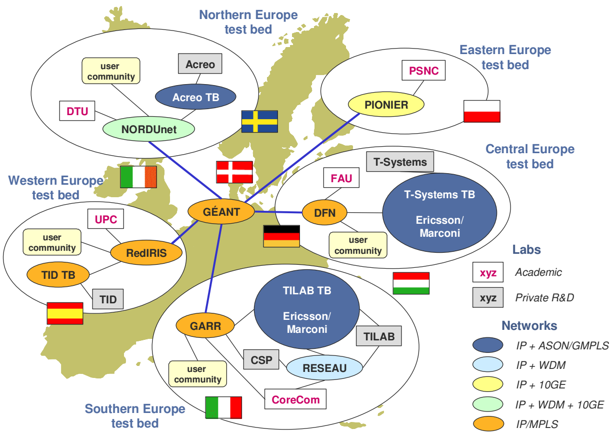

Figure 1: MUPBED pan-European network layout

European Research Networks

MUPBED, being a Research Network Infrastructure Project, is mainly focussing on transferring its results to the National Research and Education Networks (NRENs) and GÉANT2 (the European Research Backbone network) enabling further network function upgrades and enhancements. Therefore, the starting point of architectural evaluations was the current NREN/GÉANT2 network environment. This section gives an overview on research networks, with a focus on the situation in Europe.

The European research networks are organised and structured as shown in **Figure 2**. Campus networks and selected national and European projects are interconnected to the respective NREN in that country enabling nationwide interconnectivity. These NREN networks are currently based on individual (and therefore largely different) network architectures, technologies, functions, vendor equipment and network control/management. It is most likely that this heterogeneity and individuality per domain will be maintained in the foreseeable future.

Beside their national coverage, the NREN networks provide interconnectivity to the European research backbone network GÉANT2 enabling European scale connectivity and additionally long haul connections to non-European research networks. This is indicated in **Figure 2** with two example traffic flows across the network.

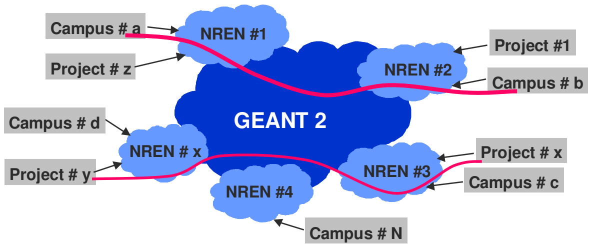

Figure 2: General NREN/GÉANT2 network scenario

To enable such pan-European interconnections, GÉANT2 has to interoperate with all the individual NREN networks and is always involved in a multi-domain network scenario, including mainly connection configuration and control.

Today, in most of the NRENs, the interworking is realised at the IP layer only. However, in future – thanks to additionally available technologies in the various domains and thanks to increasing demands for other types of services – it can be expected that interworking is required for various other network layers as well.

Interworking topics can be divided into data plane and control plane aspects. Already the seamless interworking on the data plane of different multi-layer networks might raise several new challenges. **Figure 3** represents some of the potential inter-working scenarios that will probably occur on the data plane. This interworking is especially challenging because in the involved network domains different technologies, network platforms, vendor equipment and operational processes might be used.

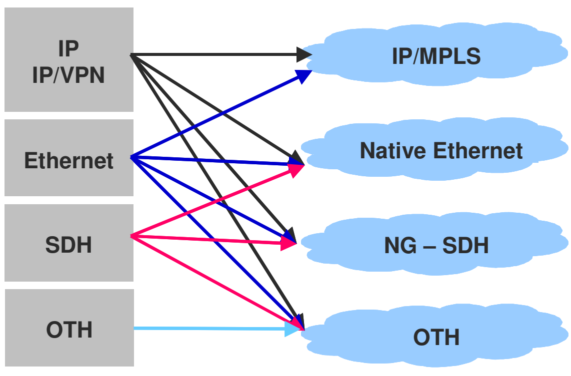

Figure 3: Schematic view of potential NREN – GÉANT2 data plane inter-domain interworking options

Although these interworking areas are based on standards, interoperability of different vendor implementations has to be ensured by specific interoperability tests. Another aspect is the interworking of future control plane solutions for these network technologies.

Inter-domain interworking related to the control plane is currently restricted to IP (BGP peering) and IP/MPLS layer (LSP interworking), only. Other layers are not control plane enabled.

For future upgrade of the control plane functionality to include lower network layers such as Layer 2 (Ethernet) and Layer 1 (SDH/OTH), the following essential requirements of the current and expected future scenario of the NREN/GÉANT2 networks need to be considered:

- Multi-domain environment: services require connectivity across multiple network domains
- Heterogeneity: the characteristics of the network domains can differ significantly with respect to transport technology, internal control and management, policies at external interfaces, etc.

These requirements mandate solutions which enable seamless inter-domain interworking while maintaining and supporting the individual approaches in each domain.

MUPBED contributes to both of the above mentioned working areas: interworking of data plane technologies, as well as interworking of future control plane solutions.

MUPBED Network Architecture

This section outlines the MUPBED architecture work, covering the range from a general architecture framework to specific detailed architectures that map exactly to the NREN/GÉANT2 situation. More information can be found in the corresponding MUPBED deliverables [3, 4].

The definition of MUPBED reference architecture is aiming at an overall framework that allows to reflect the NREN/GÉANT2 network situation and to describe each of the individual local test beds of the project and their interconnections as particular implementation option of the generic architecture model. The final MUPBED reference architecture will represent a common framework for all specific network architectures implemented in the local test beds involved in the MUPBED European test bed.

The general framework for the MUPBED reference architecture has been identified in Deliverable D1.1 [3] and is outlined in **Figure 4**. This architectural framework is considered as a starting point for the more detailed considerations on the reference architecture that are described later in this paper. The framework is based on the following generic principles:

- use of a layered approach
- separation between applications and network services
- separation of data transport, control and management layers
- identification of interfaces between functional entities
- partitioning of the network into (administrative) domains

The MUPBED architecture framework consists of four logical planes:

- application plane: providing application specific functions
- control plane: providing routing and signalling functions to enable the establishment and release of on-demand connections
- data plane: providing functions for the actual data transport, including both user data and control data transport
- management plane: providing management functions for both, data plane and control plane

The MUPBED multi-service transport network is the entity that provides end-to-end connectivity between application end-points.

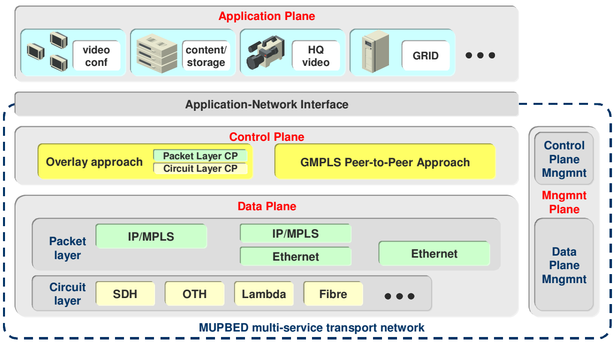

Figure 4: MUPBED reference architecture framework

Similar to the network scenarios of the European research networks, the MUPBED test network is composed of multiple network domains, based on different network layers, architecture, technology, vendor equipment and control. Additionally, applications are attached to these heterogeneous network domains. This overall scenario results in manifold horizontal (within one network layer) and vertical (among different network layers) interworking areas, summarized in **Figure 5**. The interworking areas are covering both, data and control plane topics. The data plane interworking scenarios covered in MUPBED are the same as described for the NREN – GÉANT2 networks above.

Horizontal inter-domain interworking issues could be identified at the control plane layer between the MUPBED test beds based on ASON architecture (TILAB, T-Systems/DT) and among the ASON and GMPLS (Acreo, PSNC, TID) based test bed domains.

Suitable, standardised inter-domain interfaces are needed to ensure interoperability within the MUPBED test network but also to other external network domains MUPBED is cooperating with.

Vertically there are two inter-layer interworking areas identified: Between the transport network layers (SDH) and the server/client layers (Ethernet, IP/MPLS), and between the applications and the network layers. To accomplish seamless interworking between different layers, suitable control plane interfaces could be used, maintaining at the same time the individual control and architecture of the different layers/domains. On the other hand, interworking between applications and networks could be achieved by appropriate Application Programming Interfaces (API).

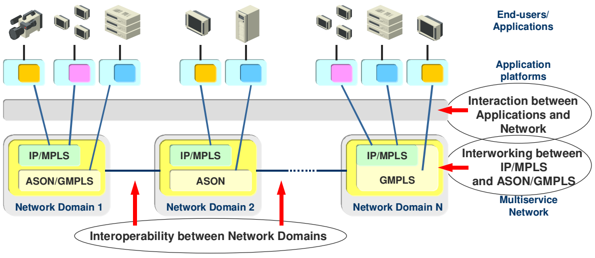

Figure 5: Key interworking areas investigated within MUPBED

Important goals of the MUPBED project within the network architecture area could be summarised as follows:

- prove of the MUPBED reference architecture concept within the MUPBED test bed
- close match of MUPBED architecture and test bed realisation with the real network situation of European NRENs/GÉANT2

Figure 6 shows the networks involved in the realisation of the pan-European MUPBED test bed: there are five test beds (so-called "local test beds") that are distributed across Europe and that use different technologies. In addition, the involved national research networks are shown that ensure the interconnection of these local test beds with the pan-European research backbone network GÉANT2. In addition, several partners providing broadband applications are interconnected via the NRENs.

The next section will describe in more detail how a fully meshed interconnection among all the local MUPBED test bed sites is achieved over these networks. The resulting test bed interconnections allow to implement different network architectures within the MUPBED test bed. These architectures at the same time represent potential future (European) research network architecture solutions.

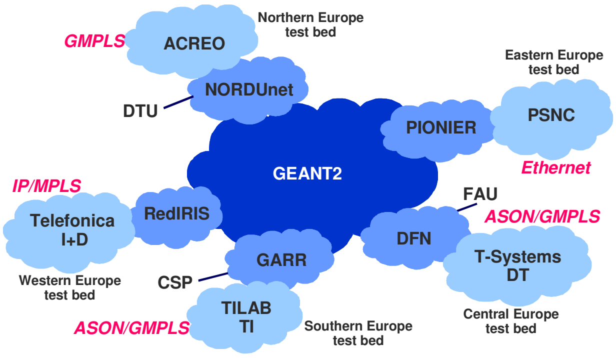

Figure 6: Involved networks and technologies for MUPBED network realisation

Figure 7 highlights a possible multi-domain network architecture with representation of several control plane interfaces. It can be seen from the general layout of the networks in this picture that such a scenario could be very well a representation of the NREN/GÉANT2 scenario in Europe, with the GÉANT2 network as "central" backbone, and the NRENs attached to it via different interfaces, depending on the available technologies within these networks.

In addition, an interconnection to another network is indicated, which could e.g. be a link to a research network outside Europe, or to any other network operator.

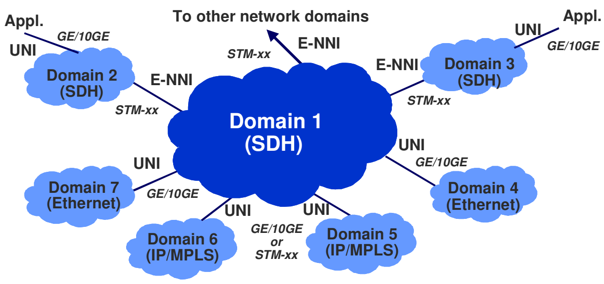

Figure 7: ASON multi-domain and multi-layer approach

Within the MUPBED project several different architectural approaches have been investigated and compared [4]. The conclusion for a near- to mid-term feasible solution for the European network environment has been a so-called "overlay model", based on standards currently available or under development.

Considering in addition that multiple transport network domains will be involved, including manifold customer/client network technologies and control mechanisms, a maximum degree of flexibility within network domains and well defined domain borders or reference points are needed. This has been leading to the ASON overlay model as the most suitable solution for MUPBED and the NREN/GÉANT2 architecture.

The MUPBED conceptual and implementation work is closely related and inline with the ongoing ASON/GMPLS standardisation activities. Several MUPBED partners are very active and supporting standardisation work related to ASON/GMPLS control planes, which has been leading to a tight relation between R&D efforts and standardisation efforts.

MUPBED Test Bed Implementation

The MUPBED test network implementation is following a roadmap focussing first on accomplishing the data plane interconnections among the five local test beds, and afterwards increasing gradually the interworking functions based on ASON/GMPLS inter-domain control plane interfaces, and finally the data and control plane integration.

The first step has been to provide connectivity among the local test beds based on transparent data links. With today's technologies, this could be best achieved with SDH/OTN interconnections between the five MUPBED test bed sites. However, such SDH interconnections were (and still are) not available.

Therefore, the MUPBED project had to find a solution for the challenging goal of "transparent" interconnections between all test bed sites, providing in the best case a full-mesh topology as shown in **Figure 8**. Such a topology gives highest flexibility to implement several network models by different inter-connections of the available test beds. In addition, the main "application partners" have to be connected to the network.

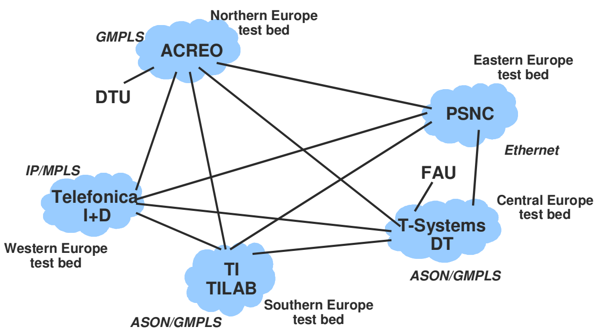

Figure 8: MUPBED targeted network topology

Since the technically simplest realisation of such a topology (via SDH links) is practically not feasible, MUPBED decided to implement "transparent Layer 2/ Ethernet" inter-connections between the test beds out of various reasons, such as:

- This data plane technology is available in all involved networks and therefore allows a homogeneous solution across all involved network domains.
- The functionality of these interconnections is sufficient for the main MUPBED purposes, such as high bit-rate data exchange and additional exchange of control information.
- Layer 2 connections over IP/MPLS networks are a service available at all involved NRENs and GÉANT2 networks. Operation of this fully meshed network is done in close collaboration with DANTE, the network operation centers (NOC) of the NRENs, and MUPBED.
- The selected approach also allows connecting the main application partners FAU and DTU in the same way, using the same mechanisms.

Figure 9 provides an overview of the implemented "real" MUPBED network structure. It shows the involved networks and partners as well as the full-mesh of inter-connections between the test bed sites realised over these various networks.

It has to be mentioned that thanks to this approach all switching capability of the MUPBED network is located within the different MUPBED test bed sites. In such a way a multi-domain network in a truly multi-partner environment with participants from industry and research community has been set-up.

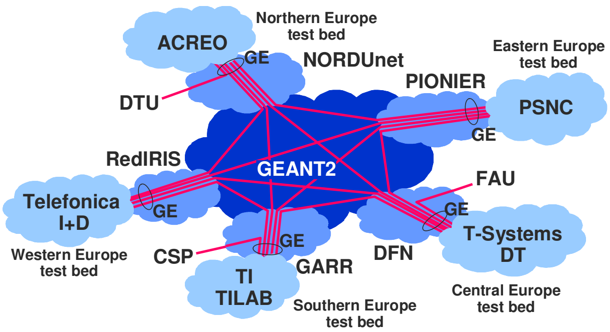

Figure 9: MUPBED layer2 network implementation based on a full mesh between test bed sites

The ASON/GMPLS inter-domain implementations are following a network architecture which is suitable to the current – and most likely that holds true for the near future European research network infrastructure as well – very heterogeneous network environment, with many separated network domains largely consisting of different technologies, network architecture, and operational mechanisms.

Therefore, solutions for seamless (automatic) interworking among these network domains are a key issue to be solved for next generation of research networks. The expected result is an increase in multi-domain connection configuration dynamics, on-demand customer oriented services, and significant reduction of manual configurations.

A similar heterogeneous network scenario is given in the MUPBED network, comprising five individual domains based on IP/MPLS, Ethernet, GMPLS, and ASON/GMPLS technologies and network control.

Given this network environment, MUPBED is aiming at providing solutions which could easily be mapped to European research networks (**Figure 10**).

The proposed solution maintains the individual architecture and technology approach in each of the five local test beds (therefore representing the independent network realisation of European NRENs) while enabling automatic interworking among the domains (therefore aiming at the important end-to-end communication requirement). Furthermore this concept allows using inter-domain interfaces, based on worldwide interoperable prototype implementations, as demonstrated at the OIF Worldwide Interoperability Demonstration 2005 [5].

At the beginning of 2006, between the test beds at TILAB and DT real multi-domain Ethernet Switched Connections (SC), Soft Permanent Connections (SPC), and virtual SDH-SC, SDH-SPC can be established. The ASON UNI2.0 Ethernet implementation at PSNC, TID, and Acreo is ongoing.

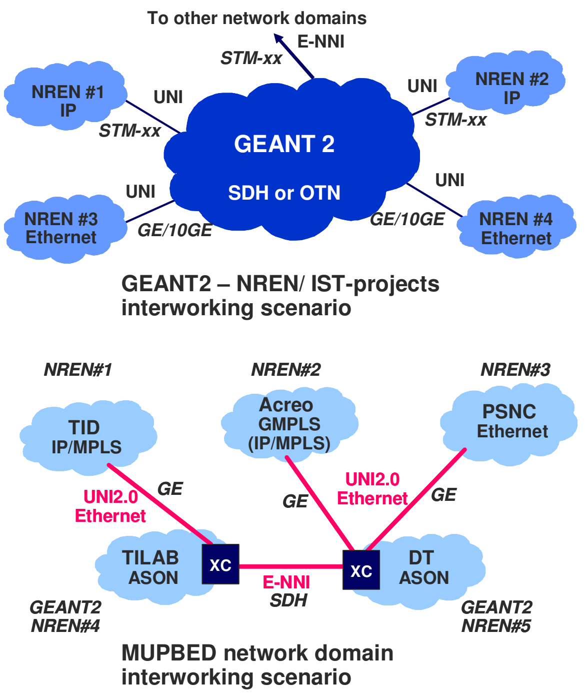

Figure 10: Planned MUPBED network architecture implementation and its relation to the European NREN network scenario

Conclusions

The MUPBED project is aiming at integrating and validating “telecommunication operator’s concepts” within the research network infrastructure, considering a heterogeneous multi-domain and multi-layer network environment, given in European NREN/GÉANT2 infrastructure environment, but also in carrier networks. The focus is on on-demand transport services, based on ASON/GMPLS control plane technologies, inline with the still ongoing standardisation activities. The close relation and cooperation with standardisation work ensures the highest level of interoperable implementations and eases significantly the manifold ongoing cooperation with other projects (GÉANT2, NOBEL/NOBEL2, MUSE2, VIOLA).

Acknowledgement

The work reported in this paper has been supported by the European Commission within the FP-6 project MUPBED (Multi-Partner European Test Beds for Research Networking) under contract number IST-511780.

The responsibility for the content of this paper is with the authors. The authors also thank all colleagues from the MUPBED project for their work, which has been the basis for this paper.

References

[1] Peter Szegedi, Zsolt Lakatos, Jan Späth: “Signaling Architectures and Recovery Time Scaling for Grid Applications in IST Project MUPBED”, IEEE Communications Magazine, p. 74 – 82, March 2006.

[2] http://www.ist-mupbed.org

[3] MUPBED Deliverable D1.1, “Preliminary Definition of a Reference Architecture for an Intelligent Optical Network Supporting Advanced Applications in Research Environments”, May 2005.

[4] MUPBED Deliverable D1.2, “Revision of the reference architecture according to the results of the project studies”, February 2006.

[5] OIF Worldwide Interoperability Demonstration http://www.oiforum.com/public/supercomm_2005v1.html.