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MUPPET

Multi-Partner European Test Beds for Research Networks

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Deliverable D0.1

Project Summary

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Marconi Communications ONDATA GmbH

Revision 1

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Dissemination Level		
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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abstract

The main goal of MUPPET is to integrate and validate, in the context of user-driven large-scale test beds, ASON/GMPLS (Automatically Switched Optical Network / Generalised Multi Protocol Label Switching) technology and network solutions as enablers for future upgrades to European research infrastructures. This goal will be pursued by creating a large experimental environment to assess the proposed network solutions, and that will be offered as an open test platform to other European research projects and users. The test bed will represent a multi-layer and multi-domain network based on IP/MPLS and ASON/GMPLS technologies. This European-wide field trial is designed to support the highly demanding applications of the research community and assess the impact of ASON/GMPLS technologies on future research network solutions.

MUPPET focuses on the application of innovative optical networking solutions to the evolution of research networking environments, specifically on the integration and validation of ASON/GMPLS technology. This goal will be pursued by creating a large experimental environment that will be used to assess the network solutions under investigation, and that will be offered as an open test platform to other European research projects and users. The test bed represents a multi-layer and multi-domain network based on IP/MPLS and ASON/GMPLS technologies (note that IP/MPLS is assumed to be common in all test beds; the other technologies may not be fully represented in all test beds). With reference to the considered network scenario, the project investigations aim at:

- Optimally defining the network architecture and services with respect to the research application requirements, and experimentally assessing the identified solutions;
- Optimizing the interaction of the application platforms with this generalized transport network from the perspective of both service performance and overall management;
- Efficiently integrating the ASON/GMPLS and IP/MPLS network layers.

Taking advantage of the strong asset of existing test beds, the MUPPET Project brings together leading European players from NRENs, operators, industry, research institutes and universities to ensure that all the aspects of advanced networking and emerging applications are covered. Different local test beds will be interconnected to create a Europe-wide field trial, allowing the assessment of different applications and the impact of ASON/GMPLS technologies on future research network solutions.

Document Information

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Table of Contents

1 Introduction

1.1 Purpose and Scope

This Deliverable provides an overview including the overall goal and the main objectives of the Integrated Project MUPPET ("Multi-Partner European Test Beds for Research Networking ").

1.2 Reference Material

1.2.1 Reference Documents

[1] R. Sabattino, ECOC 2004, “Dealing with emerging resource requirements: the evolution of GÉANT”, Invited Talk We2.2.2
[2] http://www.serenate.org
[3] E. Mannie et al., “Generalized Multi-Protocol Label Switching (GMPLS) architecture,” Internet draft, work in progress, May 2003
[4] ITU T Recommendation G.8080/Y.1304
[5] http://www.oiforum.com/public/supercomm_2004.html
[6] H.-M. Foisel, ECOC 2004, “Optical Internetworking Forum: World Interoperability Tests and Demonstrations”, post deadline paper Th4.5.2
[7] R. Sabatino, M. Enrico, ECOC 2004, “Dealing with Emerging Research Requirements: The Evolution of GÉANT”, paper We2.2.2

1.2.2 Acronyms and Abbreviations

AAA	Authentication, Authorisation and Accounting
API	Application Programming Interface
ASON	Automatically Switched Optical Network
ATM	Asynchronous Transfer Mode
DWDM	Dense Wavelength Division Multiplexing
E-NNI	External Network-Network Interface
GMPLS	Generalised Multi-Protocol Label Switching
IETF	Internet Engineering Task Force
I-NNI	Internal Network-Network Interface
IP	Internet Protocol
ITU-T	International Telecommunication Union - Telecommunication Standardisation Sector
MPLS	Multi-Protocol Label Switching
NGN	Next Generation Networks
NREN	National Research and Education Network
OTH	Optical Transport Hierarchy
OXC	Optical Cross Connect
PVC	Permanent Virtual Circuit
QoS	Quality of Service
RSVP	Resource Reservation Protocol
SAN	Storage Area Network
SDH	Synchronous Digital Hierarchy
TDM	Time Division Multiplexing
TE	Traffic Engineering
UNI	User-Network Interface
VPN	Virtual Private Network

WDM Wavelength Division Multiplexing
WP Work Package

1.3 Document History

Version	Date	Authors	Comment
0.1	23/09/2004	Jan Späth	Initial version
0.3	29/09/2004	Jan Späth, Ronald Müller	New text for 1.4, new text for WP descriptions, revised figure on testbed, revised figure on NOBEL rel., editorial changes
1.0	01/10/2004	Jan Späth, Ronald Müller	New title page layout, Section 1.2.2 completed, editorial changes, final release

1.4 Document overview

The document is structured as follows.

Section 2 provides a list of the members of the MUPPET project consortium.

Section 3 provides a detailed overview of the project main goal and objectives including the project context, the expected outcomes and innovations and the MUPPET Pan-European test bed.

Section 4 describes the technical approach and the work plan with the list of planned deliverables, followed by Section 5 on current and potential future co-operations of project MUPPET with other projects.

The final section provides a summary of the project data.

2 Project Consortium

Participant No.	Participant name	Participant short name	Country
1.	Marconi Communications ONDATA GmbH (Project Coordinator)	ONDATA	Germany
2.	Marconi Communications S.p.A.	MCSPA	Italy
3.	Acreo AB	Acreo	Sweden
4.	Telecom Italia	TILAB	Italy
5.	T-Systems / Deutsche Telekom	T-Systems	Germany
6.	TU Denmark	DTU	Denmark
7.	Telefonica I+D	TID	Spain
8.	Matav	Matav	Hungary
9.	DFN-Verein	DFN-Verein	Germany
10.	GARR	GARR	Italy
11.	CSP – Innovazione nelle ICT	CSP	Italy
12.	University of Erlangen	FAU	Germany
13.	RedIRIS-Red.es	Red.es	Spain
14.	Juniper Networks	Juniper	Ireland
15.	Institute of Bioorganic Chemistry - Poznan Supercomputing and Networking Centre	PSNC	Poland
16.	CoreCom – Consorzio Ricerche Elaborazione Commutazione Ottica Milan	CoreCom	Italy

3 Project Main Goal and Objectives

3.1 Project Context

During the last years Europe has considerably invested in the development of high performance research networks, taking the challenge of high capacity (Gigabit) networking. At the European level the GÉANT network [1] has been a significant step forward, offering interconnection both at 10 Gbit/s and 2.5 Gbit/s level; moreover, a number of National Research and Education Networks (NRENs) have introduced upgrades in their infrastructure up to Gbit/s levels.

A key issue in building very high bit-rate pan-European research networks is the availability of low cost high-speed networking and transmission technologies. The currently proposed network solutions are mainly based on the integration of the IP layer with a very high capacity optical layer, and are focused on offering very high bandwidth within a simplified overall network architecture.

However, research communities will not ask for mere connectivity to the European research networks, but application-related quality as well (i.e. low latency, no loss of data, good resilience, etc.). Therefore it is extremely important to clearly understand the real needs of research applications, both present and future, and find network architectures able to match these requirements by optimally exploiting flexibility features and control functions available in the different network layers.

Recently, the IST Project SERENATE (Study into European and Educational Networking as Targeted by Europe) [2] made some strategic studies about the evolution of research networking in Europe based on real needs of research communities and NRENs during a 5-10 year time frame, identifying the following requirements, relevant to the MUPPET Project activity:

- Terabit-per-second networking will be required everywhere, in the scientific community, by the end of the decade, but different groups of users will be looking for very different network solutions.
- Major drivers for higher bandwidth requirement in research networks will come from Grid Computing, High Quality Videoconferencing and Remote Visualisation of real or simulated data.
- User needs will also embrace security, privacy and confidentiality aspects.

It is generally recognised that, in almost all disciplines, scientific research requires permanently increasing computing power to solve problems of ever increasing complexity. Along with the demand for processing, also the volumes of exchanged data are rising. Furthermore, there is an increase in the dynamics of traffic requests. Today the provisioning of connectivity services still requires a significant amount of time and manual processing: this leads to the requirement for largely autonomous and dynamic bandwidth provisioning capabilities.

Finally, the network service provisioning usually involves multiple network domains, sometimes equipped with different technologies, as in most cases several research networks and network providers are involved in the provisioning of a pan-European broadband interconnection. Special attention must thus be paid to interoperability issues across different network domains and technological platforms.

Optical networking techniques have already been extensively deployed throughout the world to satisfy the increasing bandwidth needs and to facilitate the reduction of bandwidth costs. As a further step, intelligent and flexible multi-service optical networks will be introduced to support the additional requirements of the new and challenging applications currently emerging in the research environment.

The general working methodology of the Project is to evaluate and verify complete vertical solutions including applications, the different transport layers and their inter-working in European scale test-bed trials. Figure 1 depicts the multi-layer reference architecture that stays behind this methodology,

conceptually summarising the network vision of MUPPET. The following paragraphs explain in more detail the represented network layers and technologies.

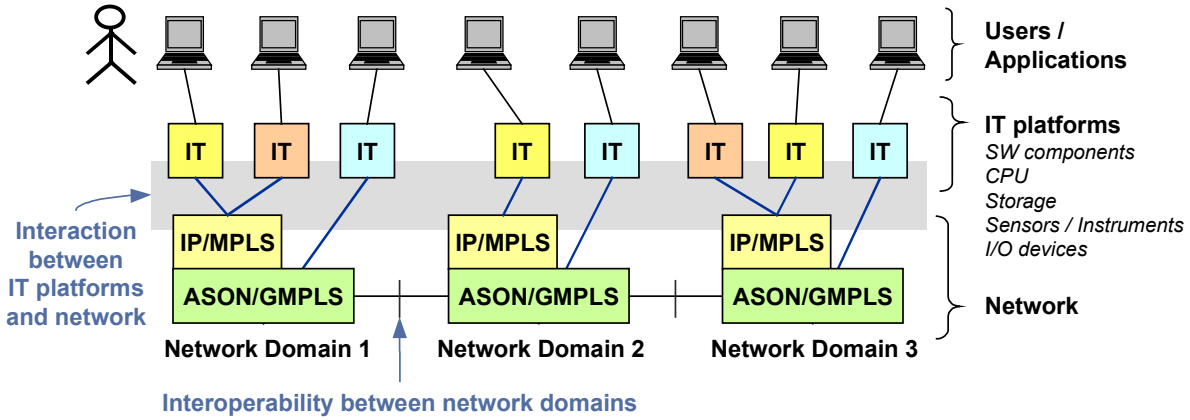

Figure 1: Multi-layer reference network architecture relevant for MUPPET

GMPLS is a set of protocols defined by the Internet Engineering Task Force (IETF) for distributed control planes that generalises the label switching paradigm to non-packet label switched paths [3]. GMPLS includes protocols for link management, routing and signalling. A key concept of GMPLS is to reuse the traffic engineering (TE) concepts, previously defined within the Multi-Protocol Label Switching (MPLS) framework, with a label-space generalised to time-slots, wavelengths, fibres, etc.

ASON is an automated control-plane architecture defined by the International Telecommunication Union - Telecommunication Standardisation Sector (ITU-T), which is applicable to different transport technologies and network environments, like Wavelength Division Multiplexing (WDM), Synchronous Digital Hierarchy (SDH) or Optical Transport Hierarchy (OTH) [4]. An important part of ASON is the definition of reference points in the network where control plane information is exchanged: User-Network Interface (UNI) between the user and the network, External Network-Network Interface (E-NNI) between networks or administrative domains, and Internal Network-Network Interface (I-NNI) between controllers within a single domain. These network interfaces are under specification within the Optical Internetworking Forum (OIF) whose protocols progressing towards large acceptance by the networking industry, as demonstrated by the encouraging results coming from the first multi-vendor interoperability tests [5, 6].

In order to fully exploit the ASON/GMPLS properties as enablers for efficient communication services in future research networks, the transport layer has to effectively inter-work with the upper network layers, in particular with IP/MPLS, and possibly also with the application platforms. In summary, an ASON/GMPLS enabled transport network will add a flexible and dynamically re-configurable transport plane to the existing IP/MPLS layer, today based only on static physical connectivity.

Concerning the inter-working between the transport layer and the data networking (packet-based) layer there are today two main approaches, usually indicated as the “overlay” and the “peer” models.

In the overlay model the IP routers can be seen as clients of the ASON/GMPLS layer. In parallel to the IP-routers there can be several other client networks requesting connectivity from the ASON/GMPLS layer, e.g. Asynchronous Transfer Mode (ATM) or clients that explicitly request specific Time Division Multiplexing (TDM) circuits. All the clients of the ASON/GMPLS layer, the IP routers as well as others, communicate with the control plane of the ASON/GMPLS layer via UNIs.

In the peer model the control planes of the IP/MPLS layer and the ASON/GMPLS layer are integrated into a common control plane.

The overlay model and the peer model represent two main streams and in many cases the difference between them is less clear-cut than described above. In fact there is a range of different integration

levels of the control planes of the IP/MPLS and the ASON/GMPLS layers, from communication via a UNI to full integration between the layers.

In the research community as well as in the standardisation bodies the discussion is still ongoing about advantages and limits of the different inter-working models. The choice between them actually depends on many different factors that finally come down to the requirements of applications and of network operation. As an example, important issues are whether the network should be designed for delivering TDM circuits or not, or whether the network consists of resources belonging to different owners who want to share only limited information about network resources and configuration.

Within the Project MUPPET there is not an "a priori" assumption on how to handle the control plane communication between the IP/MPLS layer and the ASON/GMPLS layer. The MUPPET test network will consist of multiple independent network domains with different architectures and technologies and therefore the Project will analyse the different options with an agnostic approach, evaluating their maturity level and their applicability to the different research networking environments. These investigations will be favoured by the availability of different implementations of the "IP over optical" scheme in the Project test-beds, following both the peer and the overlay model.

3.2 Objectives

The list below summarises key project objectives aiming towards innovations in the area of research networks.

Meeting the Requirements

- To identify service and network requirements of high-end applications for European research environments and the matching ASON/GMPLS network features.
- To identify solutions for an effective integration of the ASON/GMPLS network layer with the IP/MPLS one, on which the European research networks are and will be based.
- To identify solutions for the automatic activation of network services by the application, in order to simplify and optimize the provisioning of connectivity among the application end points and to offer a proper degree of network control to the user.
- To solve issues of interoperability between different network domains and of end-to-end provisioning across heterogeneous network environments, in order to enable true pan-European broadband services.

Investigations and Results

- To experimentally assess the ability of ASON/GMPLS solutions to support demanding research applications, through lab and field trials in real user environments and with a large user community, including European NRENs.
- To develop and integrate a pan-European multi-layer network test bed, equipped with application environments for testing purposes and open to other research projects & activities for joint experimental work.
- To develop design guidelines for the introduction of ASON/GMPLS technologies and of ultra-broadband on-demand network services in future European research infrastructures, collecting the practical experience of the project test beds.

Dissemination

- To disseminate the results to a broad user community in order to allow for a rapid introduction and broad acceptance of new networking services and broadband applications in the research community.
- To drive standardisation work by establishing a joint position for key issues, fostering the development of standards that take specific European needs and strategies into account.

3.3 Expected Innovations

The achievement of the MUPPET objectives will allow the introduction of several innovations in broadband research networks with respect to the present scenario. The following discusses some possible innovations:

Transport services are today statically provisioned, with a big amount of manual operations and time needed to interconnect research network domains or broadband users to the network. MUPPET will integrate and test a network with a distributed control plane, that allows a dynamic configuration of broadband connections with a significant reduction in manual processes and related costs.

Nowadays most IP networks, partially based on MPLS over a static transport layer (either on SDH or point-to-point WDM), provide only best-effort service. MUPPET will demonstrate true integrated networking where the IP/MPLS layer inter-works, e.g. through a UNI, with a dynamic optical layer based on ASON/GMPLS, in order to increase the transport quality of the network services offered to the users.

Currently, inter-working between different administrative domains is static and often limits network performance. MUPPET will investigate and demonstrate inter-working between different domains through E-NNI (including routing aspects) to enable an end-to-end connection set-up across multiple vendor and/or operator domains.

Today, there isn't integration between networks and applications. MUPPET will analyse and experiment the possibility to allow a certain control on network resources through open and application-independent interfaces.

Current QoS level provided by the IP network is not adequate to high demanding applications. MUPPET will experiment the automatic provisioning of on-demand dedicated circuits to support applications that require a more deterministic network service and large data transfers.

MPLS Virtual Private Networks (VPNs) are today manually provisioned. MUPPET will experiment automatically provisioned Optical-VPNs that intrinsically offer high security, low latency and guaranteed bandwidth.

3.4 The MUPPET Pan-European Test Bed

The pan-European research network test-bed is going to be one of the major outcomes of the Project. In this section, after preliminarily describing the main features of the final test-bed architecture, we will briefly survey the existing local test-beds that will be interconnected.

The final MUPPET test-bed will result from the internetworking of different local domains. The interoperability between "network domains" can in general refer to different basic scenarios:

1) connection of different administrative domains having similar network platforms;
2) connection of networks based on the same technology, but realised by different vendors;
3) inter-working of geographically separated networks based on different technologies and having different service capabilities (e.g., the inter-working of an ASON island with a Gigabit-Ethernet one).

The Project will take into account all these scenarios, but will focus its investigations mainly on the first and third ones. The above concepts are visualised by Figure 2. The figure generalises the reference architecture of Figure 1, including an example of case-3 interoperability: the domain on the right, in which the network is not based on GMPLS/ASON technology, seamlessly inter-works with the other GMPLS/ASON-based domains.

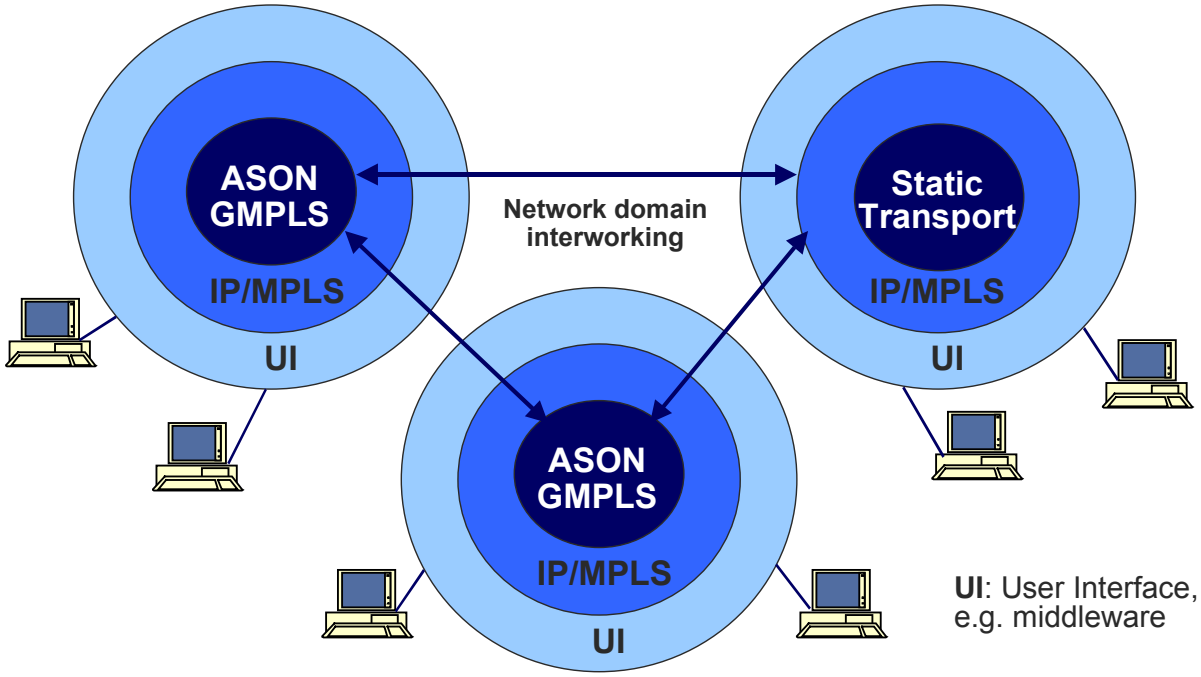

Figure 2: General Interconnection Scheme between different Network Domains

In Figure 3 the overall layout of the target MUPPET test-bed is depicted. The diagram shows the two ASON/GMPLS network test-beds (T-Systems, TILAB), a GMPLS network (ACREO), an Ethernet based network (PSNC) and an IP/MPLS network test-beds (TID), the participating and supporting NRENs (from Denmark, Sweden, Germany, Poland, Spain, Italy) and several academic institutions and private R&D centres that form the large "User Community" of the Project. Note that this figure represents the target test bed at the beginning of the project. MUPPET however does not restrict to this topology and will allow adaptations during the course of the project (e. g. if additional broadband users can be interconnected). Some of the institutions shown in the figure are part of the so-called planned "user community" and not part of the MUPPET consortium, but they agreed to investigate a collaboration with the Project in the experimental activities.

The Southern Europe test-bed focuses on IP/MPLS over ASON/GMPLS networking and is based on TILAB laboratory infrastructures. In addition to the already available equipment, optical cross-connects (OXCs) will be added to the test-bed, IP routers will be integrated and an interaction via UNI implemented. In a next step the complete integration of data- and control plane of the already installed TILAB OXCs and the new installed OXCs will be completed and an additional integration of equipment developed within the IST project NOBEL will be done on a data- and control-plane level.

The Central Europe test-bed is partly based on the existing resources and infrastructure of the "Global Seamless Networks Demonstrator", already covering networking test-beds on a metro-area and a wide-area network level and simple broadband applications. The ASON/GMPLS control plane features of the existing optical cross connects will be extended to provide additional E-NNI and advanced UNI functionality, necessary for an interconnection of different network domains..

The Northern Europe test-bed is based on further developments of the Acreo test-bed, and will follow the GMPLS architecture. In the Stockholm part of the network, at least three nodes will be equipped with transparent optical cross-connects (OXCs). IP routers will be integrated with the OXCs and an interaction via UNI will be implemented.

The Western Europe test-bed is based on two already available IP/MPLS test-beds at Telefónica I+D facilities in Madrid. The first one, called the Next Generation Network (NGN) test-bed, is an IPv4 facility, which aims to serve as a vehicle for demonstrating a convergent scenario with very high

quality services running on it. The second one is an IPv6 test-bed integrated in the broader network structure of the Euro6IX's FP5 Project.

The Eastern Europe test-bed is based on the PIONIER network already connecting sixteen cities in Poland. The PIONIER network consists of Ethernet switches, connected with 10 Gigabit-Ethernet backbone links and equipped with Gigabit-Ethernet access ports. The backbone connections use DWDM systems and dark-fibre infrastructure as its transport network. The test-bed will be used to assess the possibility of integration between ASON/GMPLS and an Ethernet-based network.

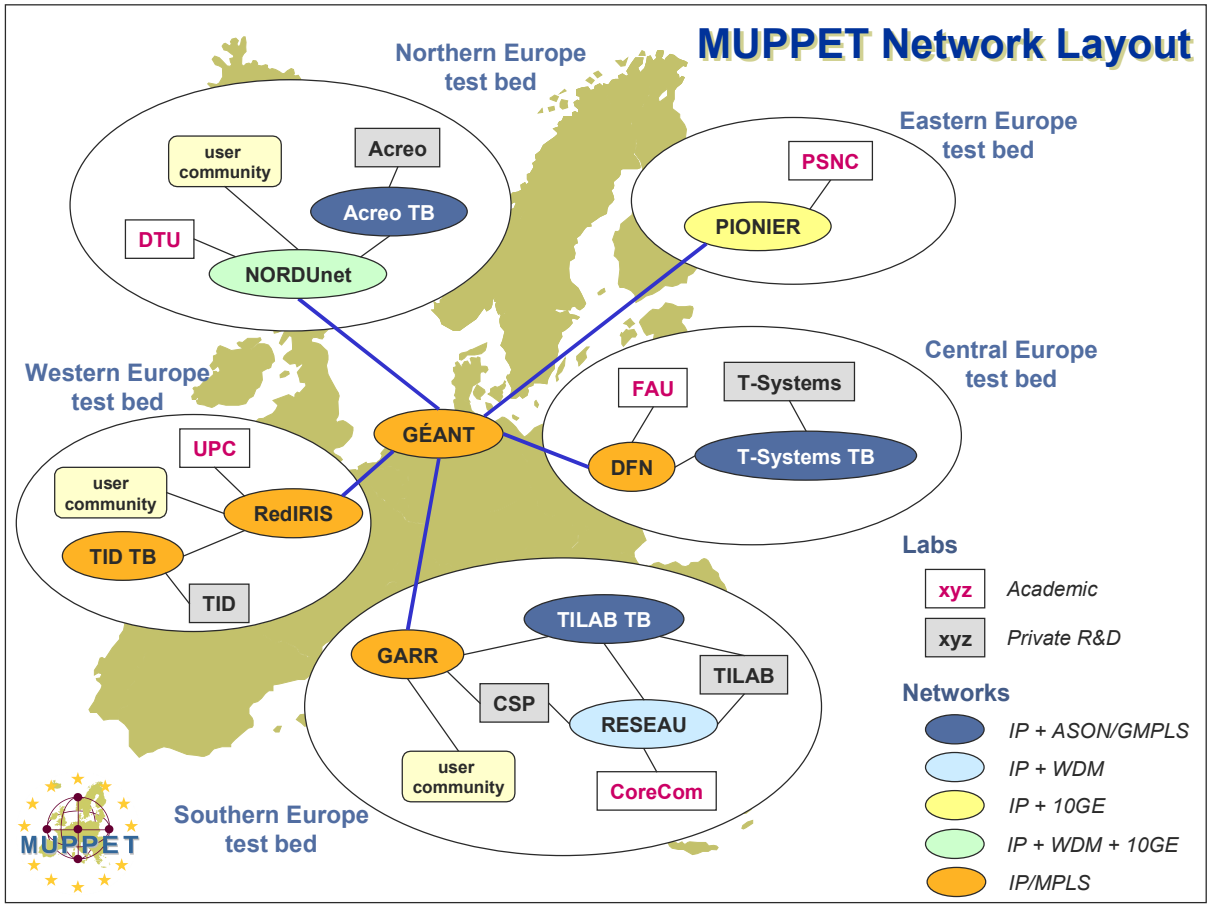

Figure 3: Overall Layout of the MUPPET European Test Bed

The European-scale connectivity on the MUPPET test-bed will be provided by dedicated circuit links among the three ASON/GMPLS networks and by IP/MPLS transport on the research backbone GÉANT [1]. The interconnection through GÉANT will be the first step in the Project schedule and will offer broadband connectivity among the regional test-beds as well as a way for members of the user community to access the experimental network platforms located in the partners' laboratories. The NRENs will play here a key role by offering their national infrastructures to interconnect partners' and users' sites and by supporting the experimental activities with the special configuration of the network services required to fulfil the specific requirements of the Project.

The transport services available on this infrastructure will be, at least initially, packet-based (layer 2 and layer 3). As a second step, the dedicated-circuit connectivity (SDH or WDM) could be added during the project lifetime in order to fully validate the ASON/GMPLS paradigm. These layer-1 links will be terminated at the digital/optical cross-connects at the edges of the ASON/GMPLS test-beds and directly controlled by the network control plane. This set-up will allow field experiments performed on a geographical scale where the connections across the network are dynamically configured according to the requests by applications and users. The availability of different kinds of network services within the MUPPET test-bed will offer the opportunity to compare different

networking models concerning their performance, configuration, ease of management and control, etc. This will be highly valuable in defining guidelines for future upgrades of the European research networks, and is one of the most defining features of the Project.

3.5 Selection of Planned Applications

Concerning the applications, the strategy of the Project is not to develop new application platforms but to use already existing applications and focus the work on interface adaptations for their efficient interaction with the ASON/GMPLS layer (be it directly or via the IP/MPLS network layer).

Applications to be used in the Project trials will be provided by the partners of the project: they could be standard platforms normally used in the partner activities as well as prototype solutions available through other projects in which the partners are involved. Moreover, the NREN partners will give a link to applications actually used within the community of their customers (research and academic institutions).

A selection of applications already considered for trials includes:

- **Transmission of uncompressed video.** Focus is on the transmission of uncompressed video in studio quality for interactive and distributed television production, an economical approach to support education and research (as suggested in IST Project SERENATE). This application is highly demanding as far as communication networks are concerned (low-latency and high-bandwidth) and requires a careful evaluation in test-beds. The application has the following requirements: remote controlled cameras; at least 300 Mbps of bandwidth for each camera signal; latency considerably smaller than 200 ms. Transmission with SDI-over-SDH and other advanced protocols will be evaluated, as well as QoS parameter enforcement (delay, jitter, loss) in the IP stack. The investigation will also include: video server signal transfer, video-file transfer (setting the compression degree according to the storage demands vs. network bandwidth requirement trade-off), possibly tele-medicine.
- **High quality video conference for distributed collaborative work and education.** The aim is the full utilisation of the high-performance MUPPET network to evaluate the advantages of deploying co-operative applications in research scenarios. In particular, distributed collaborative work and education trials will focus on person-to-person communication and acquisition and delivery of enriched media content (audio video). A videoconference platform with selectable quality levels will be integrated in the project test-bed using solutions for the activation of the underlying network services and the control of their characteristics. The platform will consist of multiple distributed components, including clients, servers and centralised video cross-connectors (reflectors) for multi-participant conferencing. Various codec and video formats will be tested.
- **Massive data transfer.** This application concerns the area of distributed storage infrastructures and Data Grids. Focus will be on the co-ordination of distributed storage resources on increasing the efficiency in moving large volumes of data (Terabyte datasets) over high speed and high delay (long distance) networks. Storage resources will be a critical component of future research infrastructures (e.g., based on Grid models) to access experimental and simulation data. An ASON/GMPLS network can enhance the performance of a distributed storage environment by enabling faster data transfers, on-demand reconfiguration of connectivity, transparent extension of Storage Area Network (SAN) architectures. The proposed applications will address the issues of storage synchronisation between data centres and of movement of huge data sets between archives and processing resources. New transport protocols (as GridFTP, FAST, Tsunami, etc.) for high rate data transfer will be tested in different network conditions (e.g. pure IP, IP with QoS control, IP with lambda shortcuts, dynamically provisioned circuits, etc.).
- **Grid platform and Virtual Organisations.** Current Grid research is evolving towards the model of "Virtual Organisations" which is the possibility of creating (virtual) on-demand collaborative environments over geographically distributed and multi administrative organisations. The lack of open standards for interoperability and network-performance limitations still prevents the real adoption of such scenarios. Mapping of Grid architectures on top of systems interconnected by

highly flexible, resilient and high performance networks – like the MUPPET network – provides a potential solution to enable the paradigm of "Virtual Organisations". The project plans to integrate some grid nodes with the test-bed to investigate the effectiveness of an ASON/GMPLS layer in supporting it.

The Consortium is open to introduce new applications, not presently identified, for evaluation during the Project lifetime. The partners intend to actively search for such applications by reviewing ongoing projects within the IST program and by establishing co-operation relationships with other research initiatives.

Although the project will rely on existing application platforms, it is expected that in most cases new application-network interfaces need to be defined and implemented by the project for the applications to properly interact with the network platform, in particular with the ASON/GMPLS layer. For the interaction between the applications and the network two service models can be distinguished:

- The "soft PVC model" where the application communicates its request of network services to the network via a separate tool, e.g. a web server. The tool can in turn communicate with the management system, e.g. for Authorisation, Authentication and Accounting (AAA) purpose, and then translate the request into the appropriate control plane signalling.
- The "UNI model", where the network control plane is accessible directly by the application. The application can get access to network services by sending proper signalling via a (generalised) UNI to the network control plane.

The Project has at this stage no preferred service model. It is part of the Project objectives to investigate this issue, to implement and test prototype solutions and finally to propose the most appropriate scheme with reference to specific user and network environments. This includes a number of activities; first, the types of applications in today's and future research networks should be evaluated by discussions with the NRENs. Secondly, for each type of application, the main requirements should be considered to identify similarities and differences between application requirements. Preferably, this results in a generic interface to the transport layer, but if this is not possible, the interface should be based on the applications in the testbed. Hence, an Application Programming Interface (API) or middleware should be developed or chosen, and modifications to the applications should be suggested.

4 Technical Approach and Work Plan

This chapter deals with the description of the technical work plan of MUPPET. In addition to an overall project plan for the whole duration, there is a more detailed plan for the first 18 months. Also for this period, the structure of the project (division into "Work Packages") and the list of planned deliverables are available. The second phase of the project will be planned in more detail at a later stage.

Project MUPPET's final achievement requires integration efforts in two orthogonal directions. On the "horizontal" plane, the pan-European test-bed will be built by interconnecting existing test-beds and national research networks: this will mainly require the solution of problems of inter-domain interoperability. In the "vertical" plane, the MUPPET test-bed will be a multi-layer network system comprising ASON/GMPLS, IP/MPLS and the application layer: the main issues in this direction will be the efficient harmonisation of the different layers and the provisioning of a comprehensive control-plane solution, offering to applications and users new ways for controlling the network functions and activating the network services.

To reach these goals, the work in MUPPET is structured into 5 Work Packages that are described in more detail in the following section. Work Package 0 is dedicated to project management activities, while the other work packages cover the technical work.

4.1 Description of Work Packages

4.1.1 Work Package 0 (WP 0)

In summary, the main objectives of WP 0 are project management, co-ordination with other projects and initiatives (within and outside FP6), co-ordination of standardisation activities carried out by WPs, co-ordinating and delivering the dissemination of results, and project administration.

The organisational structure of MUPPET follows a so-called "monolithic structure", with decisions being made and approved by the "General Assembly", consisting of representatives of all partners, and a project co-ordinator who is – in close co-operation with the leaders of the technical Work Packages – ensuring the overall project and consortium management.

WP 0 will also take care of the co-ordination of dissemination activities, which includes the contributions towards standardisation bodies. In addition, WP 0 will drive the co-ordination with other projects. This includes organising joint workshops and initiating technical discussions between MUPPET partners and other projects.

4.1.2 Work Package 1 (WP 1)

Work Package 1, "Specification of the reference architecture", lasts from month 1 to month 18 and will contribute to the architectural studies of the Project.

The architectural studies developed within MUPPET have a twofold goal: first, they aim at defining the general network vision subtending the Project activities and, second, they will integrate the experience gained during the development and operation of the project test beds into guidelines for the design of the future European research infrastructures. WP1 will aim at the first goal, the development of the Project's reference network architecture, while in the second phase of the Project a new Work Package will work on the definition of the design guidelines.

From a technical point of view, WP1 will focus its analysis on a multi-layer network based on IP/MPLS and ASON/GMPLS technologies, equipped with a unified control plane and designed to support the highly demanding applications that will be required by the European research community. In particular, the WP will identify ways to optimise the interaction of the application platforms with

this generalised transport network from the perspective of both service performance and overall management.

As the European national research and education networks and research infrastructures are and will be in the future heavily based on the IPv4 and IPv6 protocol stacks for data transport, WP1 analysis will specifically address the issue of an efficient integration between ASON/GMPLS and IP protocols. In this field, the technical issues identified for investigation include: multi-layer resiliency, restoration synchronisation, multi-layer routing, auto-discovery of network resources and services, and translation between IP QoS and ASON/GMPLS QoS, etc.

Moreover, the fact that NRENs are migrating towards simplified ultra-broadband transmission (i.e. 10 Gigabit Ethernet technology) makes it very important to investigate the issues related to the proper propagation of ASON/GMPLS control mechanisms across these non-ASON/GMPLS domains, and further towards end users, in order to enable a seamless end-to-end provisioning and configuration of connectivity services.

WP1 will start studying the application scenarios relevant to the European research communities in order to identify the network requirements for levels of performance and quality of service, flexibility and ease of provisioning, integration of network control with the application management functions, etc. At the beginning of its work, WP1 will also perform a review of state-of-the-art ASON and GMPLS, with specific reference to the test bed implementations, and of solutions for application-network interfacing, both already available or under study in research groups. These preliminary surveys will focus on the achievements of other research projects and initiatives, in order to leverage the existing know-how in the filed and select the still open issues (if any) for further studies within MUPPET.

According to the identified requirements, the available network functionalities, and the viable solutions for application-network interface, WP1 will define a reference model for the proposed architecture of an intelligent optical network supporting advanced application environments. The reference architecture will be defined in a preliminary way at the beginning of WP1 in order to guide the integration and experimental activities, and then refined according to the results of the project studies and the experimental activities.

Finally, in addition to the main activities and whenever it will be appropriate, WP1 will prepare technical contributions to standardisation bodies and technical fora.

As a general approach, the architectural studies of the Project will rely on validation by experiments in the test beds in a tight feedback loop, with the experimental work starting from day one and being carried out in WP2 and WP3, and WP1 working on the generalisation of the practical results and experiences.

4.1.3 Work Package 2 (WP 2)

The main objective of WP 2 is the vertical integration of the application layer with the transport layer. This is achieved by defining some kind of middleware between the layers that translates the resource requests from the applications to the dynamic resource allocations in the transport layer. The potential of such an approach is validated through tests and demonstrations in the MUPPET test bed.

Therefore, WP 2 includes a large number of activities ranging from definition of applications for trial, their requirements and middleware architectures to experimental validation and the establishment and maintenance of a forum for discussion between user communities, network operators and developers.

One activity considers which applications to consider for trial in the test bed. This is based on feedback from both the project internal and external NREN users and the network operators. This activity focuses on the current applications as well as future applications in the network.

In addition, activities are included to specify and group the requirements from the different applications to the network. Requirements of different applications are dissimilar, why it is important to group the applications and specify the similarities and differences in their network requirements.

A project internal core team will be settled with the main objective to elaborate on the application requirements and the feedback from the NRENs. This group is also essential for establishing lasting collaboration between user groups, network operators and developers. To improve these discussions, WP 2 will organise workshops for user communities and operators at larger European events.

Activities on the "glue" between the layers include specification of the middleware in question. The middleware should interface to the applications enabling communication of resource requests to the lower layers. Secondly, distributed policing functions are maintained by the middleware to balance the demands and to ensure fair distribution of available resources. Thirdly, the middleware communicates with the ASON/GMPLS control layer for establishing label switched path using, e.g., the Resource Reservation Protocol (RSVP).

The applications selected for trial are validated through the experimental test bed to demonstrate the advantages of the dynamic infrastructure. Furthermore, suggestions for modification of the applications to better facilitate a dynamic transport layer will be provided.

4.1.4 Work Package 3 (WP 3)

WP3 essentially covers the final planning and evolution of the five local test beds incorporated in the MUPPET consortium and their migration, by continuously improving the test bed interconnections bandwidth and functionality, to an unique European scale test network. Furthermore WP3 will cover the operation of this integrated European test facility.

The evolution of these five test beds embraces their domain internal enhancements in network functionality but also the functionalities supported at the external interfaces to the other networks. The MUPPET test network will be based on two ASON/GMPLS network test-beds (T-Systems, TILAB), one GMPLS network (ACREO), an Ethernet based network (PSNC) and an IP/MPLS network test-beds (TID), and on the network services provided by the participating and supporting NRENs (from Denmark, Sweden, Germany, Poland, Spain, Italy) and last but not least GEANT.

All these different network domains, local test beds, different connections types provided by the NRENs and GEANT, has to be integrated to an European test network. Therefore the local test bed interconnections will be gradually improved in terms of bandwidth, starting with IP based interconnectivity to allow first interworking tests and a preliminary implementation of applications. First initial experiments for the interconnection of the local test beds will be undertaken, including first tests of services on this level. The final goal is layer 2 or even a layer 1 test bed interconnection, based on the network functionality available at the corresponding NRENs and GEANT. In parallel an improvement on network functions of the interfaces between the local test beds will be pursued, to enable sophisticated interworking between these different domains and therefore building the bases for the networking functions of the whole MUPPET test network.

By accomplishing this, various aspects, topics and issues of horizontal integration via different domains and vertical integration via different layers of the network will be investigated, finally solved and pragmatic solutions implemented. Therefore WP3 will be instrumental to develop guidelines for the design of this future European research infrastructure by providing feedback to WP1, other projects and last but not least to the standardisation bodies and forums, gained from the experiences and validated results of the experimental- and integration activities.

4.1.5 Work Package 4 (WP 4)

Within project MUPPET, demonstration activities will play an important role to disseminate the results achieved in this project and "to achieve broader-scale up-take of technology across numerous user communities" as required in the IST work programme. To take the importance of this requirement appropriately into account, a separate work package (WP 4) has been dedicated to demonstration related activities within MUPPET.

The main objective of the demonstrations is to highlight selected project achievements to project external user communities, in order to promote ASON/GMPLS as an efficient service platform,

supporting first of all future research communication networks but also broadband networks with residential users. The specific objectives of the demonstrations are the selection of the proper test bed configurations for the public demos as well as the organisation and execution of demonstrations.

Demonstrations with different geographical extension are planned. Local test bed experiments, involving only one test bed site, can be used for demonstrating the interaction of applications with the ASON/GMPLS network layers as well as the interworking between different layers within a network domain. Experiments involving two or more test beds are required for demonstrating the control plane functionality over E-NNIs between different networks. European scale demonstrations will be important in generating visibility for the project and may be crucial for illustrating the benefits of ASON/GMPLS for specific applications and user communities.

An optical transport network by itself does not have a visual impact on any audience. The only thing that can be seen are the network elements situated in the locations and from a visual inspection there is little or no difference between a network with a ASON/GMPLS layer and any other network. Because of this an important part of the work will be to develop forms for presenting achievements of the project in an appealing way while emphasising the important results. The work can involve making presentation material for the demonstrations or e. g. to develop tools for visualising the network on computer screens, yet other ways can be to find visually attractive applications to demonstrate. Some demonstrations will specifically target limited user communities, Grid users, SAN users or residential users. The realisation of so called “show-rooms” will provide an important infrastructure for carrying out the demonstrations. A “show-room” can for instance contain a small exhibition area, a network node and a meeting room for presenting results to a small audience. The show-rooms can also provide a tool for dissemination and training activities.

Setting up the demonstrations can also involve integrating equipment and software from different sites, additionally to what is done in other work-packages. The demonstrations may also include connections to project external sites merely for demonstration purposes. Examples of European projects representing possible co-operations and where project partners already are actively participating are:

- Broadband telecommunication: IP NOBEL and IP MUSE
- Research network infrastructure: Geant, Geant 2, 6net
- Grid applications: GRIDLAB, CrossGRID, EGEE

A demonstration has been carried out on the Acreo test bed in Sweden in September 2004 at ECOC. The demonstration showed an interoperability test between Lumentis and Juniper Networks equipment on GMPLS.

4.2 Deliverables List

The following table gives an overview of the planned deliverables for the first project phase, covering the first 18 months.

Del. No.	Deliverable name	WP no.	Planned Delivery Date (Project Month)
D0.1	Project Summary	WP0	3
D0.2	Plan for using and disseminating knowledge for the first 18 months	WP0	4
D0.3	Plans for dissemination and horizontal activities	WP0	6
D0.4	Dissemination and horizontal activities in year 1	WP0	12
D0.5	Dissemination and horizontal activities in the first 18 months	WP0	18
D1.1	Preliminary definition of a reference architecture for an intelligent optical network supporting advanced applications in research environments	WP1	9
D1.2	Revision of the Reference Architecture according to the results of the project studies	WP1	18
D2.1	Definition of application needs and scale of dynamics in research network infrastructures	WP2	12
D2.2	Preliminary interface specification	WP2	15
D2.3	Specification on application enhancement procedures for selected applications to be verified in the MUPPET test bed	WP2	18
D3.1	Test bed overview	WP3	3
D3.2	Report on enhanced design and architecture of the local test beds	WP3	12
D3.3	Report on interconnection and integration of local test beds	WP3	18
D4.1	Preliminary plan for demonstrations to be performed in test bed experiments during the first half of IP MUPPET	WP4	6
D4.2	Demonstrations performed in the MUPPET test beds year 1	WP4	14
D4.3	Preliminary plan for demonstration to be performed in demonstrations during the second half of IP MUPPET	WP4	18

5 Project Cooperations

5.1 MUPPET – DANTE/GÉANT

DANTE (Delivery of Advanced Networking Technology to Europe) is a "not-for-profit" Limited Company, registered in the UK (based in Cambridge), and owned by a consortium of European NRENs (National Research and Education Networks). The main task of DANTE is the realisation of a common backbone to interconnect the various national research networks in Europe. This network is named "Géant".

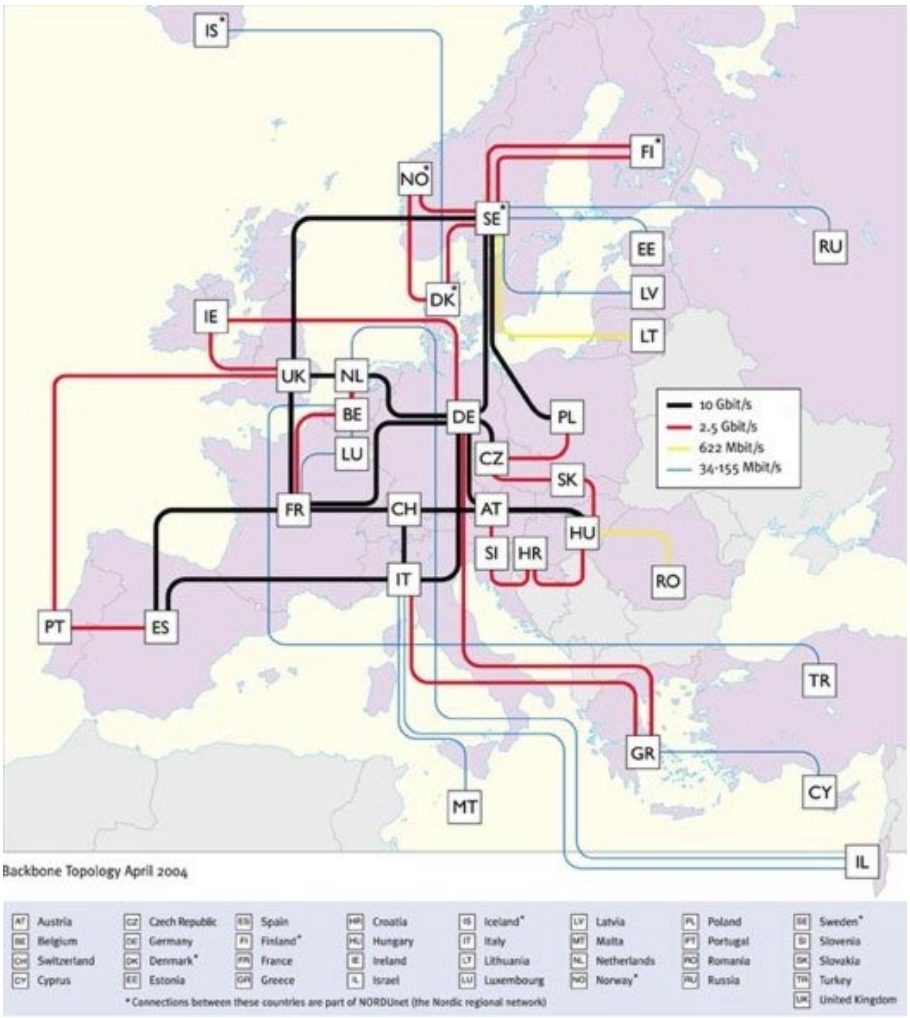

Figure 4: Géant Network as of 2004 (Source: [7])

The co-operation with DANTE is of importance for MUPPET in several ways:

- The Géant network is planned to provide the pan-European interconnection facilities needed for realising the MUPPET test bed.
- DANTE is organising in close co-operation with the NRENs a project (Géant2, GN2) to investigate the future direction of Géant. The topics studied in this project are of high relevance and importance for the activities within MUPPET, because both consider the future evolution of European research infrastructure.

- At a later stage of the project, the interconnection via NRENs and Géant will allow further users to be interconnected to the MUPPET test bed environment.

The co-operation between MUPPET and DANTE has already been set up at the beginning of the project. The first focus is on the interconnection capabilities between the local MUPPET test beds. In a second step, after DANTE and the NRENs finalised the work plan and objectives of GN2, a close alignment of theoretical research and investigation topics is agreed between the partners.

5.2 MUPPET – NOBEL

Integrated Project NOBEL "Next generation Optical network for Broadband European Leadership" is a big Integrated Project within the IST 6th Framework. The main goal of NOBEL is to find and to validate (experimentally) innovative network solutions and technologies for intelligent and flexible optical networks, thereby enabling broadband services for all. From this overall goal it can be seen that NOBEL is more focussing on residential end-users and network technologies for broadband core and metro networks, while MUPPET is specifically concentrating on research networks, their infrastructure and application requirements.

The relationship between MUPPET and NOBEL has multiple aspects, ranging from an exchange about network architecture concepts up to joint experiments and joint usage of network and test bed infrastructure. The relationship between these two IST projects is illustrated in Figure 5. Note that this diagram includes for NOBEL a second phase, which is planned but not yet confirmed.

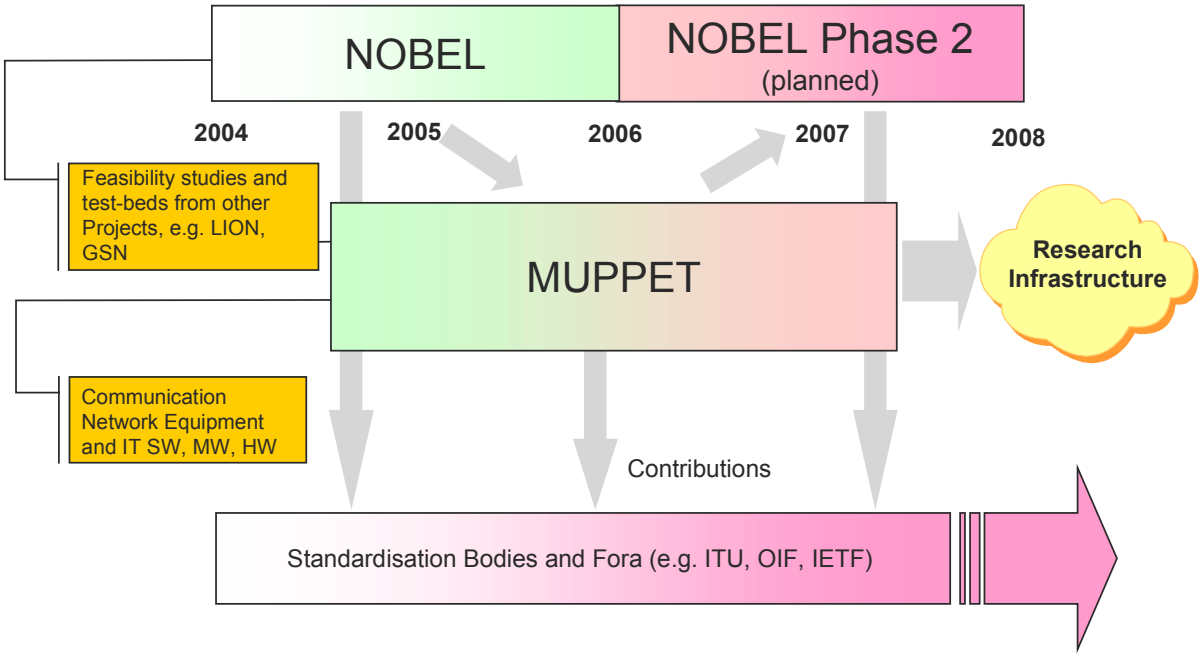

Figure 5: Relationship of IST projects MUPPET and NOBEL

At the current point in time, the following co-operation opportunities and plans have been identified. During the course of both projects, this matter will be further extended and refined in more detail.

Investigation of services and applications

The two projects NOBEL and MUPPET focus on complementary services and applications: NOBEL is focusing on “Broadband for All”, therefore having a focus on residential and business end customers and network services to support their applications. MUPPET is focusing on ultra-broadband research applications such as GRID computing or high-quality video transfer. An interesting aspect is that many applications may first occur in the research environment, but will later on transfer towards residential and/or business end users.

The network requirements that occur from these applications can be very different. The co-operation between the projects will lead to a comprehensive understanding of future services and network requirements. This is of high relevance for network operators because in many cases all services (residential, business, and research customers) need to be supported by a common transport network platform.

Definition of network architecture and network evolution

Based on the point above, it is obvious that also the derived network architectures and the corresponding network migration and evolution paths that will be derived by the two projects can be expected to cover complementary application scenarios. An interesting subject for co-operation between the projects will be to identify similarities and differences between these architectures and then to work on an overall framework, covering all aspects.

Requirements and solutions for a transport network control plane

A key enabler for future dynamic broadband networks is a control plane, efficiently using network resources while in parallel allowing a high flexibility for the users to access these resources. It is expected that within NOBEL the current state of the art for control plane technology will be further progressed and several open issues will be tackled and solved. The purpose of MUPPET is to investigate the applicability of such control plane technology in the framework of research network infrastructure, thus leveraging on the technological progress in NOBEL. This investigation shall be done in a Europe-wide experimental network. The results and experiences from these practical activities will on the other hand give a valuable feedback towards NOBEL to further improve control plane technologies.

Deployment and usage of network infrastructure

A key part of the MUPPET project will be the deployment of a network infrastructure, interconnecting multiple test beds across Europe. It is planned that this infrastructure can be used for experimental activities within NOBEL. The spectrum of such activities, probably being part of NOBEL Phase II, could cover a broad spectrum from providing interconnectivity between test beds up to joint experiments in the area of control plane and end-to-end service provisioning. The potential activities depend on the work plan and progress of both projects and have to be defined in detail during the course of NOBEL Phase I.

5.3 Other Co-operation Plans and Opportunities

In addition to the aforementioned co-operations, MUPPET is open for further collaborations. The extent of such activities has to be discussed and agreed on a case-by-case basis, but can in principle range from an active exchange of information up to interconnection to the MUPPET test bed and joint experimental activities.

Already, several other activities or bodies have been identified to which later contact looks very promising from a MUPPET perspective:.

- DRAGON (Dynamic Resource Allocation via Generalized Multi-Protocol Label Switching (GMPLS) Optical Networks Project) [http://dragon.east.isi.edu/]: This project is run by the Mid-Atlantic Crossroads, a consortium of universities and agencies that include NASA's Goddard Space Flight Center, the National Oceanic and Atmospheric Administration, and the National Institutes of Health. Other collaborators include the University of Southern California Information Sciences Institute, George Mason University, the University of Maryland and the Massachusetts Institute of Technology Haystack Observatory in Westford, Mass. The
- EGEE (Enabling Grids for E-science in Europe) [http://www.eu-egee.org]: EGEE will integrate current national, regional and thematic Grid efforts to create a seamless European Grid infrastructure for the support of the European Research Area. Since Grid computing is one of the most important applications to be supported by future research networks, the activities of this large IST project (with 70 partners) will be also important for MUPPET.

- TERENA (Trans-European Research and Education Networking Association)[http://www.terena.nl/]: TERENA's main goal is to promote and participate in the development of a high quality international information and telecommunications infrastructure for the benefit of research and education. Since this organisation includes many NRENs across Europe and has already established a close co-operation with DANTE, a co-operation looks also very interesting for MUPPET.

Some of the initial contacts have already been set up, while for others further information is needed and/or first MUPPET achievements should be reached before a productive co-operation could be made.

In addition to the above-mentioned activities, MUPPET will actively participate in horizontal activities within the 6th framework, such as IST workshops. It is expected that these activities will reveal various further collaboration opportunities.

6 Summary of Project Data

Web site for further material: http://www.ist-muppet.org

Call identifier:	FP6-2003-IST-2
Project reference :	FP6-511780
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