

# Delay Models for Different UNI Signalling Implementations in the Context of IST Project MUPBED\*

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## ABSTRACT

The concept of Intelligent Optical Networks (ION) nowadays is becoming reality. The GMPLS protocol suite of IETF, the ASON recommendation of ITU-T, and the reference points defined by OIF are existing standards. Real test beds, using these architectures and technologies across Europe and worldwide, are studied and improved. Today, the interaction issues (requirements, functions, protocols and interfaces) between the IP/MPLS client layer and the ASON/GMPLS server layer are being comprehensively researched. In this paper, delay models for simple implementation options of User to Network Interface (UNI) signalling are evaluated in the context of the EU project MUPBED.

**Keywords:** UNI signalling implementation, delay model, MUPBED Project

## 1. INTRODUCTION

Traditional Optical Transport Networks (OTN) have a huge amount of static transport capacity. The unexpected, dynamically changing traffic demands of the packet-based client networks have to be served by these transport networks, hence, implementation of intelligent control and management functions is required based on the Automatically Switched Optical Networks (ASON) concept. The main driver for operators to pursue and support this initiative stems from the generally accepted fact that the introduction of a control plane in a transport network significantly reduces the OPEX and CAPEX.

To be able to support the required dynamism, interfaces have been defined between the IP/MPLS and ASON/GMPLS layer with proper characteristics that can handle dynamic and automatic establishment of connections. An important part of ASON is the definition of reference points in the network where control plane information is exchanged: User to Network Interface (UNI) between the user and the network, External Node to Network Interface (E-NNI) between networks or administrative domains, and Internal Node to Network Interface (I-NNI) between controllers within a single domain. These network interfaces are under specification within the Optical Internetworking Forum (OIF) whose protocols are progressing towards large acceptance by the networking industry [1]. One of the main objectives of the MUPBED Project is to validate the interoperability of the existing European test beds using these interfaces. In this paper, the different UNI implementation options will be modelled and analysed in the context of signalling-based service provisioning delay. This work is part of my Ph.D. study and it has been done at the MATÁV, Hungarian Tel. Co. Ltd.

## 2. ON THE MUPBED PROJECT

The IST project “Multi-Partner European Test Beds for Research Networking” (MUPBED) is a European Union funded project within the IST (Information Society Technologies) priority. MUPBED started in July 2004 and will run over 3 years with an overall budget of 9.5 million € of which the EC is funding 5.3 million €. The MUPBED consortium consists of 16 partners from 8 European countries (see Table 1.), representing major network operators, system vendors, research and education networks, and research institutes [2].

Table 1. List of MUPBED partners.

Network Operators	Equipment Manufacturers
T-Systems Nova GmbH / Deutsche Telekom, Germany	Marconi Communications ONDATA GmbH, Germany (Project Co-ordinator)
Telecom Italia S.p.A, TILAB, Italy	Marconi Communications S.p.A., Italy
Telefónica Investigación y Desarrollo S.A., Spain	Juniper Networks, Ireland
Matav, Hungarian Telecommunications Co. Ltd, Hungary	
Research Centers	National Research and Education Networks (NRENs)
Technical University of Denmark - Education and Res. Center for Communications, Optics & Materials, Denmark	Institute of Bioorganic Chemistry - Poznan Supercomputing and Networking Centre (PSNC), Poland
Acreo AB, Sweden	DFN-Verein, Germany
CSP – Innovazione nelle ICT, Italy	Red.es-RedIRIS, Spain
University of Erlangen, Germany	GARR, Italy
CoreCom - Consortium for Research in Optical Processing and Switching, Italy	

The main objective of MUPBED Project is to integrate and validate, in the context of user-driven large-scale test beds, ASON/GMPLS 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

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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 network based on IP/MPLS and ASON/GMPLS technologies, equipped with a unified control plane and designed to support the highly demanding applications of the European research community [2].

### 3. REQUIREMENTS FROM DIFFERENT LAYER INTERACTION SCENARIOS

In the context of MUPBED Project, two possible layer interaction scenarios to exploit the UNI signalling functions of the Intelligent Optical Networks are supposed in this paper. Both of these scenarios based on the overlay model, where the client requests services from the server layer and the server satisfies the requests of the client layer without sharing detailed information.

- *Scenario 1*: In this case, the customer equipment (e.g. IP router, SDH cross-connect, Ethernet switch) acts as an individual client (user) and requests connection services from the ASON/GMPLS server layer through the User to Network Interface.
- *Scenario 2*: In this case, several customer equipments are represented by the edge node of the client layer. The edge node (e.g. IP router, SDH cross-connect, Ethernet switch) acts as a client (aggregated user) and requests connection services from the ASON/GMPLS server layer for its aggregated traffic stream through the User to Network Interface. (e.g. in case of carrier's carrier business model)

Considering *Scenario 1*, in case of specific user applications defined in MUPBED [3], the automatic and fast service provisioning is one of the main requirements. The emerging NREN's (National Research and Education Networks) user applications could be categorised as follows:

- *Transmission of uncompressed video*: Distributed television productions based on uncompressed SDI or HDTV signals do not allow network impairments and have strong QoS requirements due to their timing constraints.
- *High-quality, interactive multimedia*: The high-quality, bi-directional video communication with fast provisioning is required for example by medical applications and interactive entertainment/gaming.
- *Massive data transfer*: The connection requests can arrive frequently and dynamically from different applications (Storage Area Networking, mirroring of bank database, replication/snapshot of stock-market database, etc.) and directions, so we need fast connection set-up/tear-down capability (i.e. in order of milliseconds).
- *High capacity grid applications*: Parallel codes executed on massively parallel processors and clusters require fast and automatic connection set-up among the clusters to exchange large data of local results in the grid. The overall computing capacity of the grid can be scaled rapidly to the actual demands by the fast connection set-up/tear-down functions using UNI interfaces.

Considering *Scenario 2*, instead of the fast service provisioning the dynamic capacity upgrade and the fast, multi-layer resilience are the main requirements. (It can be noted that the duration of the capacity upgrade is not so critical, usually in order of seconds, because it can be predicted by the Traffic Engineering capability of the client layer.) In case of a network failure, the transfer of the aggregated client traffics means that a large number of client connections may need to be restored simultaneously, which implies a large number of signalling messages between the server and the client layer.

Regarding to the automatically initiated, fast service provisioning the overall service provisioning time contains several components, like: Call/Connection Admission Control (CAC) function delay, UNI signalling delay between the network layers, NNI signalling delay, route computation and allocation delay in the optical layer, etc. In the followings, only the UNI signalling implementations and their expected delay will be analysed.

### 4. IMPLEMENTATION OPTIONS FOR UNI SIGNALLING

The User to Network Interface is the access or reference point between the client and the optical transport network for data equipment, allowing controlled interoperability between the network layers. Over an UNI there is typically no routing information that is exchanged, which is fundamentally different from other interfaces, such as I-NNI, E-NNI. Among the number of UNI definitions proposed by different standardisation bodies and industrial forums (IETF, ITU-T, ATM, MEF, etc.) this paper based on the UNI definition proposed by OIF.

The OIF defines the UNI as the service control interface between the transport network and client equipment. Signalling over the UNI is used to invoke services that the transport network offers to its clients. The primary service is the ability to create and delete connections on-demand. Two service invocation models have been defined by the OIF, both follow the overlay model, where the UNI-N interface is on the network side and the UNI-C interface is on the client side [1]:

- *In case of indirect invocation model* an entity called the Proxy UNI-C performs UNI functions on behalf of one or more clients. The clients are not required to be co-located with the Proxy UNI-C. Based on this model, the first reference configuration of UNI implementation contains a centralised UNI functionality.

- In case of direct invocation model the client invokes transport network services directly, therefore the UNI-C functionality is present in the client itself. Based on this model, the second reference configuration of UNI implementation contains distributed UNI functionalities.

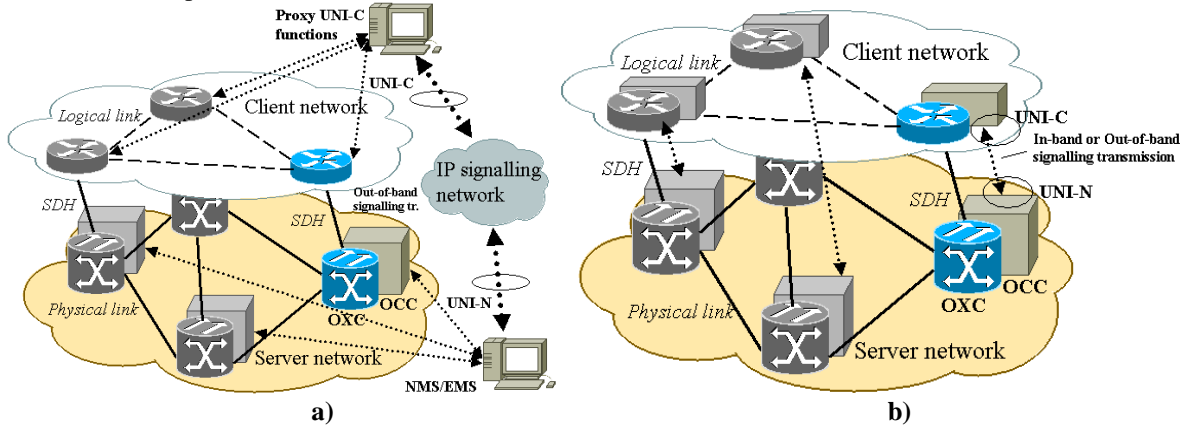


Figure 1. a) Centralized/proxy and b) distributed UNI implementations

The simplest step toward the exploiting of the UNI functions in a multi-layer network is the implementation of software based, centralized (Proxy) UNI functions. This centralised solution upgrades the software of network management systems with more sophisticated provisioning capabilities (Figure 1a). Out-of-band signalling transmission, where the signalling messages are carried over a separated signalling network (e.g. IP network) between the Proxy UNI-C and the UNI-N, is used. Software based signalling message processing can be used in the Proxy UNI.

The next evolutionary step is the implementation of distributed UNI functions, where the UNI-C functionality is integrated to the client equipment and the UNI-N functionality is distributed in the server network forming a Control Plane. In this case, both of the out-of-band and the in-band signalling transmission solution can be used. Beside the software based processing, the integrated implementation of UNI functionality allows the using of hardware accelerated signalling message processing in a later stage. The hardware acceleration provides lower delay. In case of in-band solution (Figure 1b) the signalling messages are carried over a communication channel embedded in the data-carrying optical link (e.g. using the Data Communication Channel (DCC) bytes of the SDH header). This solution provides same reliability as the data channel has.

## 5. DELAY MODELS AND ANALYTICAL RESULTS

In this section, simple mathematical models using basic queuing theories are proposed to analyse and evaluate the UNI signalling delay regarding to the aforementioned implementation options. Since this work is restricted only to the UNI signalling delay analysis, the delay components must be identified first then the initial parameters should be determined. The overall UNI signalling delay contains:

- *Message processing delay*: depends on the type of implementations (software based message processing: 200 job/s or hardware accelerated message processing: 2000 job/s).
- *Signalling transmission delay*: depends on the available bandwidth of the in-band (576 kbps) and out-of-band (10 Mbps) solutions.
- *Transport link delay*: this delay component is relevant only in case of out-of-band signalling (~15 ms).

A typical UNI message length is 500 bytes. The proposed queuing model of the UNI signalling is shown on the Figure 2. The assumptions on the statistical behaviour are; the signalling message's arrival process is Poisson, the message processing time is exponentially distributed, the message transmission time is deterministic and the link delay is constant. On the Figure 2 the first M/M/1 queue represents the processing delay, the second M/D/1 queue represents the transmission delay.

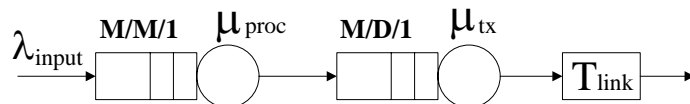


Figure 2. Simplified delay model of one-way UNI signalling transmission

Little's theorem [4] on the mean number of jobs in the system, and Burke's theorem [4] on the departure process of an M/M/1 queue are used to determine the overall UNI signalling delay in the proposed system with two queues in tandem. The expected delay of the system (Figure 2) can be calculated by equation (1). In case of centralised (Proxy UNI) implementation there are multiple  $n$  input queues. The modified model can be evaluated by equation (2).

$$E[T_s] = \frac{1}{\mu_{proc} - \lambda_{input}} + \frac{1 - \frac{\lambda_{input}}{2\mu_{tx}}}{\mu_{tx} - \lambda_{input}} + T_{link} \quad (1) \quad E[T_s] = \frac{1}{\mu_{proc} - n\lambda_{input}} + \frac{1 - \frac{n\lambda_{input}}{2\mu_{tx}}}{\mu_{tx} - n\lambda_{input}} + T_{link} \quad (2)$$

On the Figure 3a, the expected delay in millisecond is plotted on the vertical axis, and the arrival rate of the UNI signalling messages (job/sec) is plotted on the horizontal axis. The centralised implementation of the UNI signalling processes leads higher delay quickly as the arrival rate of the signalling messages increases. Using the same software processed out-of-band signalling solution, but changing the architecture from centralised to distributed, the expected delay will be lower, because we have more relative processing capacity. In case of hardware accelerated signalling process and out-of-band signalling the processing capacity does not restrict the overall UNI signalling delay, thus the curve is almost flat. Using in-band signalling transport instead of the out-of-band signalling we have no transport link delay, but we have not enough bandwidth. As it can be seen, in case of smaller arrival rate the in-band signalling solution outperforms the out-of-band ones, but as the arrival rate is increasing the overall UNI signalling delay is increasing quickly, because of the bandwidth restriction. In case of in-band signalling, the hardware accelerated processing solution also outperforms the software processing.

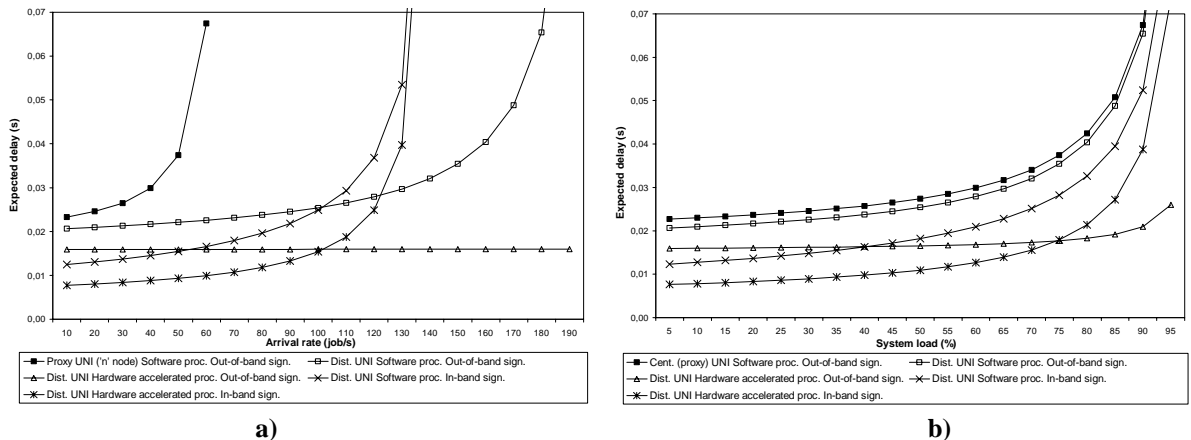


Figure 3. Expected delay of UNI signalling implementation options in a) absolute and b) relative scale

On the Figure 3b, the expected delay in millisecond is plotted on the vertical axis, and the system load (%) is plotted on the horizontal axis. The 100% system load means that the number of jobs (unprocessed messages) in either of the queues in tandem (processing queue or transfer queue) is starting to increase infinitely, i.e. the system is getting to an unstable state. As the relative tendencies show, all of the models following the distribute architecture outperforms the centralised solution in the context of overall UNI signalling delay. Under 40% system load, the software processed in-band signalling solution outperforms the hardware accelerated out-of-band solution because of the higher transport link delay of the out-of-band signalling. This limit of the system load can be extended to 75%, if the hardware accelerated in-band signalling solution is used.

## 6. CONCLUSIONS

The automatic and fast service provisioning and the efficient multi-layer resilience are the main requirements of the ASON/GMPLS based Intelligent Optical Networks. Inter-layer signalling delay is therefore crucial! It is shown that the distributed UNI signalling-intelligence provides faster reactions than the centralised solution. It is also shown in this paper, that the different signalling implementation options how effect the network response time. Finally, it is important to note that, in case of out-of-band solution the internal signalling network reliability is a main question. In case of in-band solution the reliability is given, but the limited bandwidth causes problems i.e. when software upgrade is needed. These issues are out of the scope of this paper and require further investigations.

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