Roadmap for emulation platform development and experiments

D50

Abstract:

TIGER2 is a continuation and an enrichment of the TIGER1 project which has set the bases of an integrated network architecture, combining the IP, GMPLS and Ethernet technologies in metropolitan, carrier-class environments. The purpose of TIGER2 is to build on the outcomes of TIGER1 and also to explore new horizons as WDM core networks, content optimised metro, self management.

This document aims at defining a realistic development roadmap for the emulation platform in order to demonstrate the new topics of TIGER2 with respect to TIGER1. It describes:

- the validation and performance analysis experiments to be performed on the emulation platform,
- the available building blocks, their capabilities and opportunities for integration,
- the missing building blocks, as well as the required modifications to the existing ones.

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### Abbreviations

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<tr>
<td>BRPC</td>
<td>Backwards Recursive Path Computation</td>
</tr>
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<td>CSPF</td>
<td>Constrained Shortest Path First</td>
</tr>
<tr>
<td>ELS</td>
<td>Ethernet Label Switching</td>
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<tr>
<td>FA</td>
<td>Forwarding Adjacency</td>
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<tr>
<td>GMPLS</td>
<td>Generalized Multi-Protocol Label Switching</td>
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<tr>
<td>IMS</td>
<td>IP Multimedia Subsystem</td>
</tr>
<tr>
<td>ISIS-TE</td>
<td>Intermediate System to Intermediate System - Traffic Engineering</td>
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<tr>
<td>KP</td>
<td>Knowledge Plane</td>
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<tr>
<td>L2SC</td>
<td>Layer-2 Switch Capable</td>
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<tr>
<td>LMP</td>
<td>Link Management Protocol</td>
</tr>
<tr>
<td>LOCARN</td>
<td>Low Opex and Capex Architecture for Resilient Networks</td>
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<tr>
<td>LSC</td>
<td>Lambda Switch Capable</td>
</tr>
<tr>
<td>LSP</td>
<td>Label Switched Path</td>
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<tr>
<td>MPLS-TP</td>
<td>Multi-Protocol Label Switching – Transport Profile</td>
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<tr>
<td>MP</td>
<td>Management Plane</td>
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<tr>
<td>MSTP</td>
<td>Multiple Spanning Tree Protocol</td>
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<td>NMS</td>
<td>Network Management System</td>
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<td>OBS</td>
<td>Optical Burst Switching</td>
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<tr>
<td>OCC</td>
<td>Optical Connection Controller</td>
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<tr>
<td>OSNR</td>
<td>Optical Signal to Noise Ratio</td>
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<td>OSPF-TE</td>
<td>Open Shortest Path First – Traffic Engineering</td>
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<td>PBB-TE</td>
<td>Provider Backbone Bridge – Traffic Engineering</td>
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<tr>
<td>PCC</td>
<td>Path Computation Client</td>
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<td>PCE</td>
<td>Path Computation Element</td>
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<td>PCEP</td>
<td>Path Computation Element Protocol</td>
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<td>PLSB</td>
<td>Provider Link State Bridging</td>
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<td>PSC</td>
<td>Packet Switch Capable</td>
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<td>RSVP-TE</td>
<td>Resource Reservation Protocol – Traffic Engineering</td>
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<td>RWA</td>
<td>Routing and Wavelength Assignment</td>
</tr>
<tr>
<td>SDH</td>
<td>Synchronous Digital Hierarchy</td>
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<tr>
<td>VNT</td>
<td>Virtual Network Topology</td>
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<tr>
<td>WDM</td>
<td>Wavelength Division Multiplexing</td>
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1. Introduction

TIGER2 is a continuation and an enrichment of the TIGER1 project. TIGER1, which ended in June 2008, has set the bases of an integrated network architecture, combining tightly and efficiently the IP, GMPLS and Ethernet technologies in metropolitan, carrier-class environments.

The purpose of TIGER2 is to build on the outcomes (specifications, evaluations, partnerships) of TIGER1 and also to explore new horizons. TIGER2 will capitalize on the architectural and functional specifications, plus the benchmarking of the “TIGER solution” designed during the TIGER1 project.

For this reason, TIGER2 is undeniably a continuation of TIGER1 but also a project that explores new networking issues. First, TIGER2 will address a wider scope. In addition to the metropolitan networks, the project will investigate the core network area and study how to apply and adapt the principles of the TIGER solution to the backbone network requirements. In order to provide a consistent end-to-end approach, the interconnection and inter-working issues at the boundary between the metropolitan area and the core area need to be investigated. Therefore, TIGER2 will cover multi-domain / inter-domain, as well as multi-region / multi-layer networks studies.

The main objective of this deliverable D50 is to define a reference network for the emulation platform, to implement it and to validate a few scenarios as per the output of the WP2, WP3 and WP4 work packages.

Section 2 of this deliverable aims to define the targeted scenarios for the experiment.

Section 3 of this deliverable overviews the blocks that are already existing, and that can be reused for the emulation platform.

Section 4 describes the extensions that have to be implemented in order to be able to demonstrate the experiments specified in Section 2, as well as defines a general roadmap.
2. Targeted scenarios for the experiment

WP5 aims to define the necessary emulation and test-bed infrastructure for supporting the required experiments needed to validate the proposed solutions in the other WPs and to analyze their performance.

Since it could be difficult to experiment end-to-end services themselves, it has been agreed to focus on end-to-end services from a protocol point of view: in other words, this means that we will focus more on the service provisioning aspect, more than on the service itself.

Also, an incremental approach seems relevant: in other words, to experiment a subset of the WP2/WP3 reference network (as for instance the metro core and core segments, since core network was not part of TIGER1), and then extend it to the other segments.

2.1 First experiment: Metro core & core

Overview

A first step is to experiment the metro core and core segments of the TIGER2 generic reference model (cf below) considering multi-domain / inter-domain and Ethernet and WDM switching capabilities issues.

![Generic reference model for the TIGER-2 project](image)

Figure 1: Generic reference model for the TIGER-2 project

Starting with a very simple topology as described below, the experiments could be enhanced by adding nodes and domains and validating the recovery and self-* managed procedures.
The purpose of this experimentation is to validate one of the proposed network architectures, defined at the core network segment, for the integration of GMPLS controlled Ethernet and DWDM switched transport networks.

The starting point is CTTC pure optical DWDM transport network (involving a single TE domain), and Marben Ethernet Switched transport network. Ethernet clients are assumed to be attached to the optical domain, typically, at a region boundary [L2SC, LSC] or [PSC, LSC].

In the proposed scenario, the client requests an optical lightpath via a UNI-like interface based on GMPLS. The optical network (Wavelength Switched Optical Network) provisions the end-to-end lightpath in the optical domain. Once the LSP is established, it is announced as a TE link in Marben (Ethernet) domain. In consequence, it is not really a classical Forwarding Adjacency (FA), since the TE link would not be announced in the same domain where the underlying LSP was instantiated. The scenario is based on [http://tools.ietf.org/html/draft-ietf-ccamp-lsp-hierarchy-bis-06](http://tools.ietf.org/html/draft-ietf-ccamp-lsp-hierarchy-bis-06), an internet draft (work in progress, subject to changes) where the GMPLS hierarchy is extended without the limitation that the FA needs to be announced in the same domain.

This scenario presents several highlights:

- Multi-Layer aspect: there are two layers involved: the optical layer and the Ethernet layer. The optical layer acts as a server layer where lightpaths are established as in a client server relationship. The Ethernet LSP is “embedded” in the optical LSP.
- Multi-domain aspect: this scenario covers two different domains, not only from a Traffic Engineering point of view, but also administrative domains.
- Testbed interconnection: to realize such scenario, two testbeds will be used: namely, the Marben and CTTC testbeds.

### Control plane features

This first experimentation will be performed with a unified GMPLS control plane managing:
• FAs creation
• Multi-domain provisioning, in which source-based and PCE-based approaches can be deployed and compared in order to provision an end-to-end service in a Multi-Layer domain, insisting on Backwards Recursive Path Computation (BRPC) and related procedures.
• Protection and recovery, at least, at the data plane level. This would cover protection (e.g. 1:1, 1+1) and restoration (e.g. “rerouting without pre-planned routes”). In the latter, the system is able to re-route a failed connection excluding part or all the failed connection (comparing, for example, fault detection-based and fault localization-based approaches).
• OAM functions
• Confidentiality in multi-domain recovery, which remains an open question. On the one hand, efficient recovery needs a detailed view of the network topology, including the failed resources. On the other hand, network operators are reluctant to provide details on the network topology. New solutions are needed to find a balance between these two seemingly opposed goals.

**Performance**

The experimentations will be carried out including, other than “proof-of-concept” and targeted demonstrations, exhaustive performance evaluations of the proposed systems. Several key performance indicators are meaningful in this context, such as

- The *Service provisioning delay* (as seen by the customer or NMS), including the setup delay, for both single and multi-domain architectures.
- The *Restoration time*, specifically when considering the “re-routing without pre-planned routes”.
- The *Blocking probability* for circuit-switched networks, defined as the ratio of failed attempts and total number of attempts.

### 2.2 Second experiment: Carrier Ethernet Metro Access

This experiment is based on a performance comparative analysis of different packet transport technologies for Metro Access Networks such as PBB-TE, MPLS-TP and PLSB.

![Experiment's segment scope](image-url)
In particular these experimental evaluations will be focused on the following functionalities:

- Protection and restoration capabilities
- OAM interworking with IP/MPLS technologies
- Point to multipoint support
- Scalability
- Service differentiation
- QoS assurance
- Synchronous Ethernet support
- Control Plane availability
- Multiservice traffic support (Ethernet, TDM, ATM...)

The main objective of this experiment is to evaluate the state of the art of current Carrier Ethernet technologies and identify those functionalities that might be improved in the future. A detailed description of the testbeds to be used in this study is provided in section 4.4.

2.3 Third experiment: LOCARN

This third experiment (aka LOCARN) is a new concept of transport networks for metro and/or core segments as specified by the Tiger 2 generic reference model. LOCARN stands as Low Opex and Capex Architecture for Resilient Networks. It aims to explore two concepts (namely, auto forwarding and enhanced broadcast), with the goal of keep the network as simple as possible and thus save both in the OPEX and CAPEX domains. For more information on LOCARN paradigm, please refer to the D40 document that describes its generic concepts and ecosystem.

The aim of this WP5 task is to realize a testbed able to emulate some functionalities of LOCARN network, in order to prove the feasibility of such a network.

The proof of concept network will be realized using standard Linux PC, equipped with enough Ethernet interfaces to be able to build different realistic architectures. Linux PCs are also equipped with Click, which acts as a plug between the physical interfaces and the network layer of the off the shelf Linux Operating System. We point out that the “Click Modular router” software package had been already successfully used for a physical realization of the TIGER1 Network (ELS+BFD protection) and presented during the CELTIC Event 2008 (Helsinki, 27-28 February, 2008). Click is distributed under an MIT/BSD-like license called "the Click license".

The main advantage of the Click package is its simplicity. An equipment is realized connecting "functional blocks" (elements) together as depicted in Error! Reference source not found.. Frames are processed inside elements. Many of elements are available in the package. Of course, it is possible to write (or subclass) new elements (C++) to fit specific behaviours.
Click offers the ability to manage the content of elements during the run using handlers (read, write or read/write). Handlers may be accessed from the outside using telnet connections. As a drawback, the frames are software-processed, which may have influence on performance.

The Hardware testbed itself comprises at least:

- 5 PC i386, with 4 Ethernet 100M ports
- 3 PC i586 dual core, with 2 Ethernet 100M ports and 3 Ethernet optical 1G port
- 1 external PC for development, downloading and management
- A video source (connection to a DSLAM)
- 2 video monitors (home gateways + setup boxes)

With the above hardware, we expect to build networks containing up to 8 nodes. Each node may run simultaneously two types of nodes: as Edge from a service point of view and as a transfer node. Orange Services (Video, internet, ...) accessible form the DSLAM may be transferred inside the network. Specific services between nodes (FTP, SSH, remote connections, ...) may be available on PC’s.

In a first time, the testbed will be located in Orange Lab’s Technical platform, in Lannion.
3. Existing building blocks

This section is the inventory of the existing building blocks of the Tiger2 partners.

3.1 Description of the CTTC ADRENALINE testbed

The CTTC ADRENALINE (All-optical Dynamic RELiable Network hAndLINg IP/ Ethernet Gigabit traffic with QoS) testbed is a GMPLS-based Intelligent Optical Network (ION) developed at CTTC laboratories.

For the purposes of TIGER2, and from a research point of view, one of the focus and goals of the ADRENALINE testbed is the performance evaluation of GMPLS-based traffic engineering algorithms and schemes. For this purpose, a set of 42 GMPLS-enabled controllers without associated optical hardware (i.e., the optical hardware is emulated) has been added. This set of GMPLS controllers introduces a new degree of flexibility in topology configuration, without restrictions regarding the targeted optical network topology or regarding the resources per link (e.g., number of available wavelengths, fibers, etc.). Thus, the GMPLS controllers can be interconnected following any devised topology, by means of Ethernet point-to-point channels carried over emulated optical links. The proposed solution allows the specification of control link parameters for realistic QoS constraints (fixed and variable packet delays, packet losses, bandwidth limitations, etc.). Additionally, 4 Virtualization servers with KVM/Xen virtualization software techniques have been introduced in the testbed, allowing the deployment of virtualized GMPLS-enabled controllers in just a single Linux-based physical host.

![ADRENALINE Testbed](image)

Figure 5: ADRENALINE Testbed®
Virtualized and Emulated Network
Each optical node is equipped with an Optical Connection Controller (OCC) for implementing a distributed GMPLS-based control plane, in order to manage automatic provisioning and survivability of lightpaths (RSVP-TE signaling protocol for wavelength reservation, and OSPF-TE routing protocol for topology and optical resource dissemination), allowing traffic engineering algorithms with QoS. The ADRENALINE testbed includes a Path Computation Element (PCE), which is a dedicated network entity responsible for performing advanced path computations. The PCE serves requests from Path Computation Clients (PCCs), and computes constrained explicit routes over the topology that constitutes the optical transport layer. As a main target, ADRENALINE is evolving from a single optical switching layer to a dual-layer architecture through the addition of Ethernet switching.

The operation of the ADRENALINE testbed relies on the ADNETCONF and ADNETGEN tools. These are two advanced and adapted software applications developed for the experimental research in ADRENALINE testbed, that allow the rapid operation and maintenance of the testbed, including common tasks such as the configuration and parameterisation of the network topology, the generation of client requests modelling the behaviour of network customers, or the monitoring, data-mining and statistical processing of obtained results allowing researchers to collect numerical performance data and to perform experimental research and quantitative comparative analysis.

Finally, the testbed also includes a diversity of client devices, which model network clients requiring a wide range of heterogeneous services offered by the network.

### 3.2 MARBEN™ GMPLS protocol suite and network emulator

The MARBEN™ GMPLS suite mainly consists of three controllers – Signaling controller, Routing controller and Link Resource manager. Such controllers are high-level libraries built on top of signaling, traffic engineering and path computation development kits. Such development kits are low-level libraries providing access to the RSVP-TE, OSPF-TE/ISIS-TE, LMP and PCEP protocol engines. The following schema highlights the different components and the multiple interfaces offered.
The MARBEN™ traffic engineering (TE) Development Kit allows to set and retrieve information from the local link state database that gathers all pieces of information exchanged through the dynamic routing protocol (either IS-IS or OSPF) and Link Management Protocol, provided by the GMPLS protocol stack.

The MARBEN™ Signaling Development Kit allows to establish, maintain and tear-down LSPs, according to the RSVP-TE signaling protocol provided by the GMPLS protocol stack. The same signaling Development Kit can also be used to implement the UNI interface, for both the client and NE sides, or E-NNI interface.

The MARBEN™ PCE Development Kit allows opening/closing PCEP sessions, building PathRequests/Replies and managing objects such as bandwidth, LSP attributes, metric load balancing stored in a transient database.

The MARBEN™ Signaling Controller mainly offers a set of standardized procedures leading to the setup and teardown of calls and connections. It invokes services from the Routing Controller and the Link Resource Manager to perform these tasks.

The MARBEN™ Routing Controller provides path computation capabilities e.g. cost-optimized link or node diverse path computation algorithms. It exposes its internal interface to the different path

Figure 6: MARBEN™ GMPLS components.
computation algorithms, so that it is easy to integrate other path computation algorithm(s). The Routing controller can also behave as a PCE server, or, based on policy configuration, as a PCE client.

The MARBEN™ Link Resource Manager performs local TE-Links management: TE-Links include local data-links, bundles and Forwarding Adjacencies (FAs). It uses the Traffic Engineering development kit (and its LMP development kit extension) to advertise local TE-Links through the OSPF-TE or ISIS-TE protocols. Bundling is driven by the user-application, or by provisioned policies. An interface to the transport plane has been defined to manage the resource allocation/de-allocation.

In addition, this GMPLS suite is embedded in the MARBEN™ network emulator such allowing to emulate a network of nodes running GMPLS-compliant control plane protocols. External GMPLS-enabled network elements can interact with the MARBEN™ GMPLS emulator.

An XML-based (IETF Netconf operations) management interface is available for the simulation of a management plane. External management systems supporting the same XML-based interface can manage the simulated nodes: each node hosts a management plane agent, which provides both for some control of each emulated node (triggering SPC, etc.), and also a mechanism to study the interactions between the control plane and the management plane. Furthermore, each emulated node hosts a transport plane simulation module to keep track of the allocation and release of transport plane resources, thus improving how realistic the emulation looks like (a node can run out of resource, resource contention can occur, explicit resource control requests can fail, etc.).
3.3 ALU testbed

The platform is used to make proof of concepts through the integration of new features on a mix of emulated and real network components. The platform covers technologies such as IP, G/MPLS and Ethernet, and includes control, data and management components.

ALBLF test-bed facility is based on a server farm linked to several test equipment by Alcatel-Lucent’s Omniswitch 6800 and 7700 series. The primary objectives of this architecture were:

- the virtualization of several “network control plane demonstrators” achieved during the past years
- the integration of FPGA-enabled or CAVIUM-enabled self-made nodes
- This test-bed facility is into the process of enriching its capabilities to host autonomic functions demonstration.

![Figure 7: Semantic and Autonomous Technologies test bed architecture](image)
Capabilities
ALBLF test-bed can host any demonstrator based or working on Linux OS. The virtualization guarantees the independence of the demonstrator with any other running demonstrator on it. The easy back-up and restore of the whole architecture by the storage of the OS including all software, developments, binaries and networks settings in an ISO file format stored on a dedicated server in an SVN project.

The facility has the ability to emulate a 36 nodes network with some 10GEth links.

Interconnection
Alcatel-Lucent premises host a large IMS demonstration facility that is customer oriented, the possibility of interconnection with ALBLF test-bed are being studied. The hosted demonstration on ALBLF facilities can be connected to external partners through internet connection, technical and legal constraints have to be defined in the consortium agreement. (This was done in the past on other ICT projects where ALBLF was involved).

3.4 TID testbed
Telefónica I+D has been working for the last four years on testing different multimedia services provided over IP/MPLS, Ethernet/L2 and SDH/WDM networks, according to the Next Generation Networks concepts. Currently, there are two different IP/MPLS test-beds at TID facilities located in Madrid (IPv4/MPLS and IPv6). In addition, TID testbed encompasses different L2 packet transport
equipment PBB-TE, MPLS-TP, PLSB and OBS. This test-bed is enhanced with fibre connections the Spanish NREN RedIRIS. This infrastructure permits to perform many network tests in an isolated or global way, verifying the different features related to the local and global routing in a complete network scenario.
This architecture allows also to test and deploy the high quality multimedia services (HDTV, broadcast and on-demand TV and music, high-quality multi-party videoconference, e-learning, etc), providing a whole scenario to verify the network and service interactions in an end-to-end environment. This test-bed is also used in Telefónica I+D as a main demonstration element.

**Figure 9: TID testbed for WP5 experimental evaluations**
4. Extensions and roadmap

The purpose of this section is to describe the extensions required to meet the requirements of the targeted experiments.

4.1 CTTC Testbed

Considering CTTC testbed, given CTTC know-how / expertise and targeted results, the roadmap is clearly focused on core networks and interfacing with metropolitan networks, defining specific "interfaces" which are at the edge of domains and at their boundary.

The following sections detail the roadmap for short, mid and long term, covering several lines of activity: recent evolutions in optical transport networks in general and in Wavelength Switched Optical Networks (WSON) in particular; the evolution towards a multi-domain network and the evolution towards a multi-layer (or multi-region) network.

Optical Core – Short Term (2009)

This covers the specifics for a single domain / single layer (optical) network, which are required for subsequent evolutions. As a non exhaustive list, the roadmap for the short term involves:

- Adaptation of CTTC Path Computation element (see figure) to the latest IETF normative documents. This includes the latest version of the PCEP protocol, the backwards recursive path computation (BRPC) of the objective function (OF) capability.

- The integration of the “exclude route” extensions, both for source nodes and the route controller at each node and / or the Path Computation Element. These extensions, covering the PCE, Route Controllers and Signaling Controllers are required for restoration, as detailed below.
The use of a generic wavelength (channel) label that unambiguously identifies the used resource. The work will be based on IETF documents (work in progress) that use G.694 identifiers. Previously, adjacent nodes needed explicit or implicit mechanisms to agree on label semantics and identifiers. The use of a generic label also enables centralized entities to operate on wavelengths regardless of any specific agreement between neighbour nodes.

\[
\text{Frequency (THz) = 193.1 THz + } n \times \text{channel-spacing (THz)} \\
- n \text{ is an positive, negative or zero integer} \\
- \text{Channel spacing: 12.5, 25, 50 y 100 GHz, convert to THz in order to obtain the label, that is 0.0125, 0.025, 0.05 y 0.1 THz.} \\
\]

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<td>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</td>
<td></td>
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</tr>
</tbody>
</table>

Grid (3b): ITU-T DWDM value: 1, ITU-T CWDM value : 2
C.S. (4b): 12.5 GHz (1) 25 GHz (2) 50 GHz (3) 100 GHz (4)
n (16b): index

The framework for the integration, at the control plane and management levels, of physical layer impairments that take place at the optical transport level, and affect optical signal quality. We believe this is needed to deploy a control plane to operate a carrier class transport network. For example, a physical layer attribute which may be managed by this particular extension is link OSNR.

**Multi domain / Inter domain - Short / Mid Term (2009)**

The short and midterm roadmap for CTTC ADRENALINE testbed aims at extending the network in the multi-domain aspects, considering TE domains such as Autonomous systems (AS) and / or OSPF-TE areas. The extensions are focused in both source-based and PCE based connection provisioning and recovery. In this sense, CTTC will extend the ADRENALINE testbed to add PCE-based path computation and provisioning using per-segment and BRPC methods, extending them when needed for optical constraints such as the wavelength continuity constraint.

In this context, definition of new path computation algorithms will also be required. We will consider both transparent and translucent networks.
Enhancements will also be required for protection and restoration at the optical level, for multi-domain scenarios, both at node, link and wavelength levels, using both source based routing and PCE based restoration. We expect to address the requirements by means of adapting and extending the Exclusion Objects (XRO). In addition confidentiality issues in the multi-domain recovery must be solved.
Multi Layer - Long Term (2010)

For the long term, the testbed will evolve with the integration of both layers, DWDM and Ethernet. The evolution in the long term involves, first:

- Details on TIGER1 approach and relationship with current status (MPLS-TP, PBB-TE), to identify label semantics and encoding (e.g. 60 bits worst-case)
- Preliminary studies on the migration of the control plane to a unified Multi-Layer control plane, addressing ADRENALINE specific issues.
- To define the best migration path and strategies for the ADRENALINE testbed in TIGER2 roadmap.
- Address the evolution of the Link Resource Manager to take into account Ethernet links (L2SC)
- Preliminary studies on the notions of Forwarding Adjacencies (FA), in single and multi-domain scenarios, and the role of “adaptation capabilities” for hybrid nodes having interfaces with both switching layers.

Please note that the evolution of the ADRENALINE testbed in the Multi Layer aspect is foreseen for the long term, but this does not preclude the realization of the targeted experiment, since the ADRENALINE testbed may act as a server transport network serving requests from client (e.g. Ethernet) layers, using a UNI or similar interface.

4.2 Marben Products GMPLS suite

The roadmap is focused on the multi-layer support during the first year of the Tiger2 project whereas year 2 will be more dedicated to the routing and wavelength assignment (RWA) topic. Both the GMPLS protocol suite and the GMPLS network emulator will benefit from the works conducted during this project.

Multi Layer - Short Term (2009)

For the purpose of the first experiment, Marben Products will implement the support of FAs and FA-LSPs based on RFC4206, and extended by http://tools.ietf.org/html/draft-ietf-ccamp-lsp-hierarchy-bis-06.

Three approaches will be studied:

1. Each FA-LSP is fully configured by the management plane: it provides the FA-LSP path, and triggers its establishment (and release) by the control plane.
2. A Virtual Network Topology (VNT) is initially configured by the Management Plane (MP), as in step 1. This virtual network topology is then used as a template by the control plane to dynamically trigger additional FAs and FA-LSPs whenever required (i.e., additional FAs are only created between two nodes if there already exists an FA between these two nodes in the VNT).
3. FAs LSP are dynamically created by the control plane. Policies shall be defined in order to determine which FAs need to be created to avoid a full mesh of FA-LSPs.

For steps 2 and 3, threshold-based policies triggering the setup (respectively the release) of an FA before the exhaustion of existing ones (respectively, once enough free resource exists in other existing
FAs) will be added to the implementation.

Last, for step 1 and 2, the use of soft-FAs will be experimented. As defined in draft-ietf-ccamp-gmpls-mln-extensions-06.txt (and introduced in RFC5212 and RFC5339), a soft-FA is advertised in an upper layer while the resources of its supporting FA-LSP are either not yet committed in the lower layer, or not even selected in the lower layer (they will be as soon as an upper layer LSP is established across the soft-FA).

In addition, Marben Products will carry on its participation in OIF and IETF multi-layer works.

**RWA - Mid Term (2010)**

During the second year of the project, Marben Products will work on the DWDM support with routing and wavelength assignment.

There are currently several approaches to be considered:

- Combined Routing and Wavelength Assignment: the same entity performs routing and wavelength assignment (PCE is a good candidate);
- Separate Routing and Wavelength Assignment: different entities perform routing and wavelength assignment (as a consequence, wavelength assignment may not be possible for the path provided by the routing entity);
- Routing with distributed Wavelength Assignment: Wavelength assignment is performed during signaling.

Some very first draft documents exist on these topics:

- draft-ietf-ccamp-rwa-info-02.txt: it separates static and dynamic routing information flooding to minimize the amount of advertised information;
- draft-ietf-ccamp-rwa-wson-encode-01.txt proposes efficient encodings;
- draft-bernstein-ccamp-wson-signaling-03.txt: it extends signaling to handle distributed wavelength assignment for bidirectional LSPs.

Marben Products intends to implement routing with distributed wavelength assignment.

### 4.3 BME

BME’s work until now consists in theoretical work (simulations) towards providing a unified control for both multiple spanning tree (MSTP) and constraint based SPF (CSPF) based domains. Nowadays there are well-engineered solutions to implement both MSTP and CSPF based traffic engineering in separate domains. Typically the STP is used in the aggregation networks and the SPF is used in the core networks. The work proposed the joint optimization of two domains, when each of the domains deploys different TE mechanisms. CELTIC TIGER2 project investigates several aspects of the joint control of aggregation and core domains under the umbrella of the Knowledge Plane (KP) and this work fits into this concept.

Until now we have demonstrated the advantages of such a solution by means of simulation. This work
mostly has been done within WP4 (T4.2). Nevertheless, the practical details of combining the solution with the KP structure could not be modelled. BME will provide an implementation in the CTTC Adrenaline emulator in order to test the feasibility of this solution and will evaluate the performance of the implementation.

**Short term – 2009**

KP implementation

BME plans to prepare a feasible emulation/test scenario together with CTTC. In the first part of the work we will have to solve the interaction between the two domains. We plan to deploy two PCEs, one in both domains, each of them being responsible with the control of the respective TE mechanisms. Since we consider that the CSPF runs in a distributed manner, the PCE of the core domain mostly will have a monitoring function. The PCE of the aggregation domain will have the role to adapt the MSTP to the optimal parameters. We have to solve the interaction of the two PCEs in such a way that it assures the promptness of the information-exchange and still does not affect the scalability of the solution.

**Long term – 2010**

Performance evaluation

The second part of BME’s activity in WP5 will be the evaluation of the performance of the proposal on joint MSTP-CSPF optimization. The solution will be implemented in the CTTC Adrenaline testbed, as described above. The performance evaluation of this control space-implementation will have three goals:

1. Provide feedback to the design of the inter-domain communication. Verify that the PCE implementation is efficient enough (i.e., can react in timely manner to the changes in the network state) and improve it, if necessary.
2. Test the feasibility of the solution. Provide measurement data on the performance of the control-plane operations, which are implemented in the PCEs.
3. Evaluate the performance of the solution. Provide measurement data from realistic emulation/testbed experiments on the parameters of data plane (traffic parameters during the transient period, comparison of parameters before and after a control-plane operation).

### 4.4 TID

Next figures show the specific testbeds to be deployed for the performance comparative analysis of MPLS-TP, PLSB and PBB-TE technologies described in section 2.2.
Figure 10: Testbed for MPLS-TP experimental evaluations

Figure 11: Testbed for PLSB and VPLS experimental evaluations
4.5 FT

**Modules and functionalities implementation**
While the testbed will implement only a little set of the LOCARN powerfulness, only some modules are expected to be realized and tested.
The main functionalities (stamped as mandatory) will be developed during the first half of 2010, in order to be able to present a first version of a demo before June of 2010. The implementation of a given set of "mandatory" functionalities and there integration in the test bed may give some results regarding the feasibility of a Network based on the LOCARN concept. The results achieved at the end of this period should give a realistic view of the "proof of concept".

Depending of man power availability, some modules (stamped as optional) may be added during the TIGER2 project life in order to improve the behaviour of the network, obtain more precise results about relevant use cases of a LOCARN Network and/or to fix some bugs or problem as well in term of specification and in term of realisation.

**List of functionalities to implement as"mandatory" and "optional"**
- Auto forwarding Data plane
  - LOCARN mapping and de mapping of incoming Ethernet frames
    - With fixed length of path (mandatory)
    - With variable length of path (optimisation, optional)
  - OAM for maintenance of end to end path
    - Basic HELLO frames (mandatory)
    - Enhanced HELLO frames (new functionalities, optional)
  - QoS management (optional)
  - Reordering of frames on path change (optional)
  - Security (optional)
- LOCARN Control Plane

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**Figure 12:** Testbed for PBB-TE experimental evaluations

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Basic PATH_REQUEST and PATH_DISCOVER frames (mandatory)
PATH_REQUEST broadcast policy (mandatory)
Enhanced PATH_* frames (for better optimization, optional)

LOCARN Service Plane
- Manual creation and deletion of services (mandatory)
- Automatic creation and deletion (optional)
- Links between Service plane, Control plane and Data plane (mandatory)
- Policy of path assignment for services
  - Basic Policy (min Hop + available Bandwidth) (mandatory)
  - Extended Policy (use Queue information, optional)
  - Double path protection (optional, depending of PATH_REQUEST Broadcast policy)

LOCARN integration and test
- Benchmarking modules (counters, queue analyzer, ...) (mandatory)
- Service creation GUI (optional)
- Reporting tool (optional)
- SNMP interfaces (optional, if needed)
- GMPLS partial integration (very optional, only if time and manpower are available)

**Specifications and framing**

As LOCARN claims to be a concept independent of the service Layer and the physical Layer, the specifications will be written at two different levels:

1. Generic specifications describe the behaviour of nodes, the interaction between LOCARN, the physical layer and the service layer, no matter what they are.
2. Implementation specifications, showing how these generic specifications are instanced on the chosen experiment: create and maintain "Carrier Grade" Point to Point Trunks using Ethernet connections between nodes.

In the same manner, two different levels of framing will be defined, a generic one defining the kind of information carried by each frame (it is not useful to have a too detailed frame format, only semantic description is need) and a physical framing dedicated for the test bed implementation. This "Test bed" framing entails all the needed information of the different fields identified in the generic frame's specification.

Generic specifications and framing will be available in February of 2010. "Test bed" specification and framing will be available in April of 2010. A first (draft) version will be available during January 2010.

**Benchmarking and expected results**

The main goal of the test bed is to prove the feasibility of networks based on LOCARN's concept. Expected results are mainly

- the prove of the used concepts
- the verification of Autonomic properties related to such a network
- the identification of lacks and problems encountered during the realization and the tuning of the test bed

Some conclusion about the actions and studies needed to advance through a real operational Network. Other results may be

- Identify problems to advance in a more realistic implementation
- Consequence of the flooding of PATH_REQUEST
- Comparison between observed and expected behaviour
Comparison between observed and expected performances

Compatibility
  - With other Ethernet networks
  - With some kind of services
  - MTU issues

Main of these results are expected between June 2010 and the end of the TIGER2 project, even some of them may be available in June 2010.
5. Conclusion

The planned scenarios are a well-balanced mix of unilateral and joint partners experimentations. They will extend TIGER1 results with comparative performance analysis of Carrier Ethernet technologies pointing out functionalities that might be improved in the future.

In addition, TIGER2 will experiment new features: for instance, the multi-layer and multi-domains aspects, with a test case combining two testbeds to validate an Ethernet over DWDM core network in a multi-domain environment. Studies on Path computation algorithms optimisation will also be conducted, taking into account this multi-domain challenge.

To end with, an innovative concept of transport network will be explored, whose final aim is to introduce self-management functions to reduce OPEX and CAPEX.

References