Integrating GMPLS in the OBS Networks Control Plane

Pedro Pedroso[1], Josep Solé-Pareta[1], Davide Careglio[1], Miroslaw Klinkowski[1,2]
[1)] *Universitat Politècnica de Catalunya, Jordi Girona 3, 08034 Barcelona, Catalunya, Spain*
[2)] *National Institute of Telecommunications, 1 Szachowa Street, 04-894 Warsaw, Poland*
Tel: (+34) 93 4016982, Fax: (+34) 93 4017055, e-mail: (ppedroso, pareta, careglio, mklinkow)@ac.upc.edu

ABSTRACT
The GMPLS set of protocols have been consolidated as the model for building up a Control Plane for WCS (Wavelength Circuit Switched Networks). GMPLS, which is an extension of the MPLS model adopted in IP networks to introduce traffic engineering, constrained routing and connection oriented facilities, includes extensions to introduce these facilities also to circuit switched networks like SDH and WDM networks. Now, adapting GMPLS to optical networks providing statistical multiplexing capabilities like Optical Burst Switching (OBS) networks means close the cycle, since we are coming back to the origins, a packet switched network. In this paper we first discuss the main characteristics of OBS networks and compare them with those of IP and WDM networks, then based on these characteristics we analyze the potential new requirements of building up a Control Plane for OBS networks, and finally we suggest how to integrate GMPLS the OBS control plane.
Keywords: OBS, Control Plane, GMPLS.

1. INTRODUCTION

The telecommunication's world has always been seen as a very interesting and attractive world, and a healthy run to achieve even better ways to support the dissemination of information and communication between people has been a constant since its beginning. Although we have developed new high-speed transmission technologies, a gap between the transmission speed and the switching capacity is present due to electronic device speed limitations. Next generation of network is defined by ITU-T [1] as a packet-based network able to provide telecommunication services and able to make use of multiple broadband, QoS-enabled transport technologies. Optical Packet Switching is the envisioned switching technology. However, is still facing significant cost and technological hurdles. Meanwhile, as an intermediate step, Optical Burst Switching is the best option as a trade-off between current available technology and performance. In an OBS network, each edge node aggregates and assembles the client packets into large burst units. An associated Burst Control Packet (BCP) carrying the information needed to do resource reservation at each intermediate node is transmitted out-of-band. It is delivered with some offset time prior to the data in such a way to those intermediate nodes have enough time to both process it and to reconfigure dynamically the switching matrix. When the data burst transfer is finished the optical path is usually released for other connections. Such a temporary usage of wavelengths allows for higher resource utilization as well as better adaptation to highly variable data traffic in comparison to WCS networks.

The fundamental premise of OBS based on the separation of the Control Plane (CP) and the Data Plane (DP) brings a high level of independency for both planes results in a fine network manageability and flexibility, i.e., different approaches and decision can be taken in order to exploit the best potentialities of both planes. In the latter, the data bursts are maintain in the optical domain end-to-end, avoiding the OEO conversion and buffering as they transit the core network. Hence, the achieved transparency allows the use of different format and transmission rate of the user data. For the CP since the BCP can only be processed electronically, it is possible to operate at lower data rate where economic and feasible network processors are available.

In order that such network can operate efficiently, it is essential to employ a CP able to respond to the higher control complexity demands by OBS network. Those demands are clear but, a well-defined CP for OBS is still an open issue. In this paper, we take GMPLS as a reference to design the OBS Control Plane. Besides the several points of convergence observed between the two technologies, such adaptation will speed up the process of developing and standardizing the OBS technology as allow for an easier migration from WCS to OBS networks in way that the former are already GMPLS controlled networks. Also, a normal coexistence between WCS and OBS networks can be achieved. In next sections we provide a more specific approach to this integration problem and come out with potential solutions for adapting GMPLS to OBS network.

The remainder of the paper is organized as follows. Section 2 reviews the GMPLS model. Section 3 presents the OBS Control Plane requirements. Section 4 discusses the model for integrating GMPLS in OBS. In Section 5 a tentative implementation of an OBS Control Plane is suggested. The conclusions are presented in Section 6.

2. REVIEW OF GMPLS MODEL

The well successful MPLS architecture in the electrical network of routers (IP network) has considerable improved the network operations and management through an efficient and automated end-to-end provisioning

This work has been funded by IST project NOBEL II (FP6-027305) and by MEC (Spanish Ministry of Education and Science) under the CATARO project (TEC 2005-08051-C03-01).

1-4244-1249-8/07/$25.00 ©2007 IEEE

of IP's connections, fast forwarding, TE based decisions and QoS provisioning. MPLS and the emergent need to have an alternative to the current complex, diverse and unadapted data traffic optical transport network models have created the fundamental motion's force to originate Generalized Multi-Protocol Label Switching (GMPLS).

The GMPLS is derived from MPLS: builds on the label switching model while adding features that enable it to work with optical networks [2]. It has grown out the development of MPLS and extended it to provide a flexible CP capable of handling a unified way multiple switching schemes. Such ability allows for an automated and full (vertical and horizontal) control of optical network supporting a wide range of services. GMPLS [3] is an IP-oriented architecture independent of the physical layer technology suitable for the envisioned paradigm: IP-over-WDM. A short/medium-term elimination of redundant protocol layers like ATM or SDH can be predicted for the backbone network. Hence, a consequent reduction of the operation cost is of several orders of magnitude (low time-consuming processes) [4]. GMPLS encompasses a suite of IP-based protocols that performs: signalling, routing, and automatic network discovery.

2.1 Signalling

GMPLS extended the two signalling protocols defined for MPLS-TE signalling, i.e., RSVP-TE and CR-LDP. The RSVP-TE was designated as standards track supported by nearly all of the vendors. It is responsible for the establishment of TE-LSPs, in a two-way process. Support the instantiation of explicitly routed LSPs, with or without resource reservation. Also support rerouting of LSPs, preemption and loop detection. The major enhancements are the label exchange to include non-packet networks (generalized labels); establishment of bidirectional LSPs and label assignment via suggested label (by upstream ingress node) which could reduce the LSP's setup time.

2.2 Routing

GMPLS also extends two traditional intra-domain link-state routing protocols, i.e., OSPF-TE and IS-IS-TE. We will focus on OSPF-TE protocol. At TE level, those extensions are needed to uniformly encode and carry TE link information which facilitates constrained-based SPF routing for LSPs. Two mechanisms were introduced to increase the scalability of the addressing and routing: unnumbered links and link bundling. Have a crucial importance since several hundreds of parallel physical links can now connect two nodes, becoming rather impractical to address, advertise or maintain link states for each one of these links. The auto-discovery of network topology and the resource state of all links in a routing domain is achieved by the above routing protocols. Public or private IPv4 and/or IPv6 addresses are used to identify both PSC (Packet Switching Capable) and non-PSC interfaces.

2.3 Automatic Network Discovery

A new Link Management Protocol (LMP) is introduced to provide control channel management and link connectivity verification among other functionalities. Moreover, provide an automatic configuration and control of the TE links. A unique feature of this protocol is that is able to localize faults in both opaque and transparent networks. Though, it is out of the scope of this paper, in the following we only consider signalling and routing.

3. OBS CONTROL PLANE REQUIREMENTS

Control plane issue is a further important topic, as a modern network like OBS needs to be capable to be rapidly reconfigured not only by the demand of an operator but also by customer request with the aim to achieving an efficient use of bandwidth, low latency and high degree of transparency. The OBS CP is just a packet-switched network, which controls the routing of data burst in the optical network based on the information carried in their BCPs. Such operations require high control complexity. In this section we describe the main OBS CP requirements and we also attempt to clear some open issues assign in OBS Signalling and Routing areas.

One of the most desirable features is the capability of a fast and dynamic provisioning of connections in response to the short duration of the burst transfer, i.e., it is claimed the same highly dynamic character of the OBS network to its CP in a way to have the ability to create, reconfigure or modify and tear down connections rapidly according to the traffic variations. Thus, an adequate signalling scheme to perform an efficient end-to-end connection provisioning without long delays and resource reservation is crucial. Furthermore, considerable functionalities should be provided by such control plane: a robust but simple routing method to forwarding the bursts with support of TE and QoS provisioning and to collect and distribute accurately the "current" information of the network's resource availability in order to provide acceptable burst loss rates; an efficient management of the offset time whose incorrect estimation may produce burst losses; facilitate the inter-working between legacy and OBS networks to be achieved the goal of having a horizontal and vertical control of the optical network. Even though it is out of the scope of this paper is no less important to refer that should implement burst assembly, contention resolution, QoS provisioning and protection and restoration mechanisms to ensure a well-built CP.

3.1 Signalling issue

Two different strategies have been proposed to OBS signalling: one circuit oriented with two-way reservation architecture or "Tell and Wait": Wavelength-Routed OBS; and other packet oriented with one-way reservation architecture or "Tell and Go": Conventional OBS. The former architecture is not acceptable for long-haul networks like OBS network due to the large latency in the establishment of the connections compromising the main advantage of OBS and so it is out of consideration. Our attention is then focused to the one-way reservation technique where inhabits the significant improvements to the current network.

3.2 Routing issue

The routing is a crucial functionality for optimal network performance. Good TE techniques and an adequate routing method are desirable to achieve that objective: how to have a simple but robust routing method that make the data burst safety reach the destination (low burst blocking) is still an open question. Another important issue related with routing is topology and resource information dissemination. That is what parameters should be use to define the current state of the links and core nodes in order to help the edge nodes routing mechanisms to decide the best route to assign and how to flood these information with accuracy.

The first normal approach is study the traditional IP routing in OBS networks. The traditional IP routing, or pure routing, generally employs destination-based shortest-path routing, e.g. OSPF. Even thought it can be easily scale when the network grows, this routing approach usually creates congested links and unbalanced traffic distribution, being a huge waste of network capacity. Though, forward the BCP as a datagram would increase the necessary signalling and routing information carried in it leading to a high core node time processing while each core node would have to determine the next hop according to the current network status, which seems impractical in a highly dynamic network like OBS.

Much more intelligent bandwidth utilization and a better burst block probability can be reached if the traffic is properly engineered by using explicit-routed paths. MPLS, or as a generalization covering a large fields, GMPLS controlled network offers TE capabilities and supports explicit routes by establishing LSPs. Labelled OBS (LOBS) suggested in [5] is the natural starting point to design an intelligent and efficient routing strategy.

A previous work [6] suggested the use of GMPLS features but no establish any LSP due to the signalling incompatibility between GMPLS and OBS (two-way vs. one-way reservation); every BCP is routed through the OSPF-TE protocol, under GMPLS framework. The dismissing of LSP has important consequences, which impacts the network efficiency. Indeed, many GMPLS features cannot be performed because are based on LSP. The BCP size is bigger since has to transport more information related with signalling. TE features are much less which difficult the traffic handling. A dynamic routing has to be performed. Therefore the sender edge node can define an explicit route, which means that the route has to be based on the current network resource availability. Such thing is not scalable because the time to treat such data and run a routing algorithm to define the optimal route is too large comparing to the dynamic state of the OBS network. At the time of transferring the BCP such network state have already changed. These are some of the reasons why we maintain the LSP establishment.

Consequently, using LSP is our bet to a scalable and realistic implementation. In the following section we introduce a full description of the scenario and add more motivations and advantageous of using LSPs in the OBS networks.

4. MODEL FOR INTEGRATING GMPLS IN OBS

In this section we present a GMPLS/OBS integration scenario and the correspondent advantages and drawbacks. Some questions are bringing up to a forward resolution. We consider the OBS architecture present in the Fig. 1*a* with a transparent all-optical data plane and a hybrid control plane (as considered in [6]). Such a hybrid control plane consists of a specific OBS control layer and a GMPLS control layer. How to perform this integration will be the focus of our study. Before enter in possible logical integration scenarios, the first problem approach is the physical implementation of the control channel for the control information exchange. In both architectures the data and the control plane are decoupled. However, while in OBS network such decoupling is mainly logical because the control packets and theirs corresponding data bursts use the same optical fibre, at GMPLS architecture that decoupling is not only logical but also physical, which means that GMPLS control packets can use a completely separate network of the data packets. That brings up the question: having two physical separate networks, Fig. 1*b*, or sharing the optical control channel, i.e., using the same dedicated wavelength channel, Fig. 1*c*, for GMPLS and OBS control messages exchange.

Some advantages and drawbacks are described. Having two separate networks alleviate the management and control processes at the control unit of each core node: unneeded different software or processors for distinguish the messages at the core nodes (less processing tasks); and eliminate the need of an additional encapsulation format definition for GMPLS messages. Furthermore, the utilization of a separate network, which is already implemented and where proper and less expensive resources (software and processors) are available, for no time constraints functions performance improves the optical resources availability and reduces the developing costs.

Also, allow the coexistence of WCS and OBS due to using the same GMPLS controlled network. Other advantage is the fault's isolation provision. However its importance is dependent of the signalling scheme. Possible drawbacks are the maintenance of two separate networks.

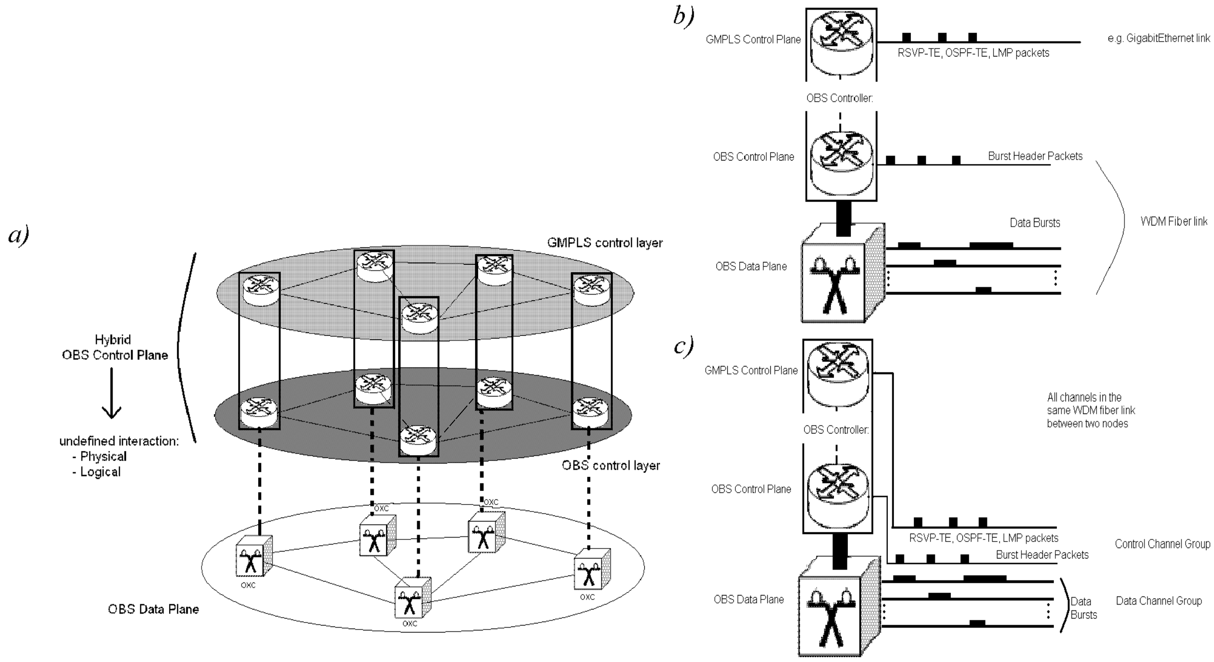

Figure 1. a) GMPLS/OBS overview integration: starting point, b) Two separate control planes, c) Sharing the control channel.

The use of the optical control channel for exchange both GMPLS and OBS control messages eliminate the last comment drawback but at the same time transform all the advantages of the previous solution into drawbacks. Thus, assign an entire wavelength for GMPLS messages might be waste of capacity. The decision of how to implement the control channel will not have influence in logical scenarios definition. Such decision is more related with technological availability and economic strategies.

A standard BCP format is also still missing. Although we think that GMPLS control packets can be adapted for such OBS control packet, attempt to use the GMPLS signalling packets as BCP it is out of question. They work in a different timescale and they were designed for different scopes. So, what will really be adapted is strongly dependent of the coming signalling solution. So we will let this topic for the further section.

5. TENTATIVE IMPLEMENTATION OF AN OBS CONTROL PLANE

A successful GMPLS/OBS control plane integration depends of an intelligent interpretation and delineation of the OBS tasks. The figure 2 shows our interpretation of the OBS control plane tasks. As GMPLS, we firstly separate the Signalling and the Routing Blocks and therefore we classify the OBS tasks into two groups namely OBS Specific Tasks and OBS Background Tasks. Such classification is based on time scale demands.

The OBS Specific Tasks are related with Resource Reservation and "Current" Network Resource Availability Information. Those tasks require a processing time in order of microseconds/milliseconds being performed at the OBS control plane. The OBS Background Tasks are related with the Virtual Topology Management and the Network Topology Information. Those tasks have variations in order of minutes/hours/days being performed at the GMPLS control plane.

	OBS Signalling Block	**OBS Routing Block**
OBS Background Task	Virtual Topology Management	Network Topology
OBS Specific Tasks	Resource Reservation	Network Resource Availability

Figure 2. OBS Control Plane tasks distribution.

The describe task division lead us to choose two separated networks to exchange the control information. The proposed OBS Control Plane will be a hybrid control plane not only logically but also physically: The OBS control plane for OBS Specific tasks at optical network (e.g., a dedicated wavelength in the links) and a GMPLS control plane for OBS background tasks at separate network (e.g. Ethernet network). With this we reduce the amount of information transmitted at the optical level as well the BCP's size (encapsulation format) and low the processing time in each OBS core node (unit control). Moreover, the fault's isolation is guaranteed. The maintenance of two networks is not a crucial problem.

5.1 OBS Signalling Block

The signalling block is divided in two modes, namely Virtual Topology Management Mode and Resource Reservation Mode. The separation of these functionalities allows the coexistence of the two-way reservation technique of GMPLS signalling protocol and the on-fly reservation technique of OBS signalling.

5.1.1 Virtual Topology Management Mode

This mode is responsible to set up, maintain and tear down LSPs between edge nodes. However no resource reservation is made in contrast to GMPLS signalling paradigm where a wavelength is assign at the LSP timescale. That feature is transfer to the optical level at BCP timescale. Such reduced version of GMPLS (without reservation) [7] establishes the LSPs in a two-way mode in order to distribute the label between the nodes of the path. The LSP set up follows an Explicit Route defined by routing mechanisms and TE requirements. No other modifications are needed.

However, the following question is bringing up: If this does not guarantee resource reservation why establish LSP. Maintain the use of LSP is of great importance. Beyond that allow the use of the other GMPLS features as protection, restoration, QoS, link management because all those features are based on LSP, the goal is to improve the traffic handling in a way to minimize the congestion on the links and reduce the burst block probability, which is crucial in OBS network with no or limited Fiber Delay Lines (FDL).

By establishing LSP without resource reservation we are constructing routes based on: shortest-path, traffic distribution planning, network operators' policies, and the type of available resources. Moreover it is possible to create not only one pre-established LSPs per pair of edge node, but a set of them. Thus, performing dynamic routing based on *Alternate Routing* is feasible. At the time of transfer the BCP, the sender only has to decide which LSP best fit to the incoming traffic requirements avoiding all other type of processes. Such decision is based on the "Current" network resource availability information about the nodes and links belonging to those LSPs. The explicit route of each LSP and how to flood and gather the current state information it is an issue of the Routing Block.

5.1.2 Resource Reservation Mode

On the other hand this mode is responsible to do the resource reservation, i.e., reserve the necessary bandwidth for data burst transmission. Its operations are performed at the optical level where the timescale is the order of microseconds/milliseconds. The BCP is the control message containing the necessary information for control the routing of data burst. Such information, process by the control unit at each core node, will configure the optical switching matrix to switch the burst optically. The on-fly resource reservation is done, i.e., the effectively wavelength assignment and the reserve of resources at the each core node is done hop-by-hop and at the transfer time but the path of the BCP is one of the pre-established LSP. With that we achieve simultaneous the desirable improvement in bandwidth utilization and end-to-end delays as the way to lower the burst block probability by given a connection oriented paradigm to the transmission. The BCP is labelled at the edge node. This label binds it to the path to take, i.e., select LSP and avoids the use of the destination address. At the moment there is no standard definition for BCP. The GMPLS signalling protocol, namely RSVP-TE, provide some interesting properties that might be adapt. In Figure 3 we compare the RSVP-TE message and the defined BCP message. In the latter, we consider common fields like label, offset time, wavelength of the incoming burst, committed data rate, and burst duration; and novel fields useful for the network resource availability. These fields can transport information on the percentage of the available bandwidth belonging to an LSP and explicit bandwidth availability requests.

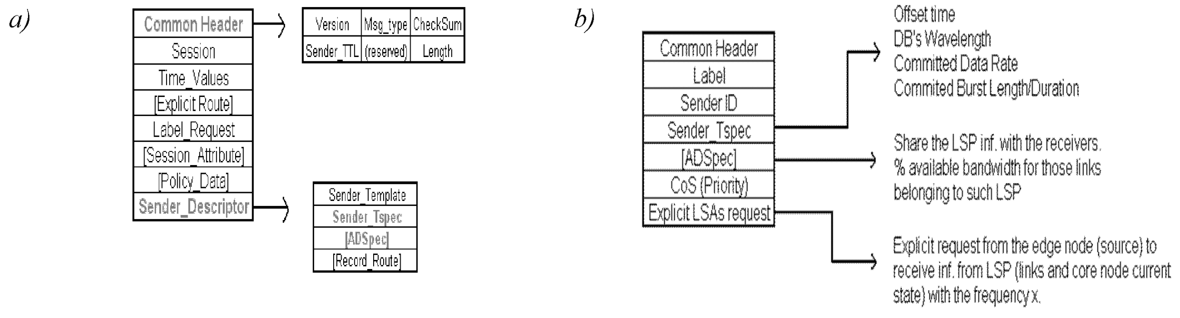

Figure 3. a) RSVP-TE message format and b) BCP message format.

5.2 OBS Routing Block

The routing block is a crucial feature for an optimal network performance. It is responsible for distributing topology and available resource information as the “current” state of such resources through the network. Our proposal divided the routing block in two modes, namely the Network Topology Information and Network Resource Availability Information.

5.2.1 Network Topology Information Mode

This mode includes two parts namely network information dissemination and constraint-based path computation

Information Dissemination: This sub-mode is related with the topology and the available resources information dissemination throughout the network. It can be done by the OSPF-TE protocol, under GMPLS framework, through the GMPLS controlled network, since the physical topology of an optical network is relatively stable. All functions do not have any critical time demand and no modifications are required.

Path Computation: The traffic distribution or balance in OBS network is of great importance. If it can be evenly balanced the Burst Blocking probability can be significantly reduced. Both explicit route and constraint-based routing support in the GMPLS leads to that objective. However, one of the main issues is how to compute them. In [8] one possible solution is presented. As explained in [8], to support dynamic routing the network may need to be flooded by frequent network-resource-update message, and additional signalling protocol or modifications of current signalling protocols may need to be developed. However, we think it is not necessary to add or modify the signalling protocol. We propose to provide that dynamism to the LSP selection at the BCP transfer time. Every explicit route is set based on a given traffic intensity matrix. An intelligent and careful network planning based on such traffic patterns and statistical behaviour (TE functions) helps us to better define a set of static, explicit routes and a set of limited dynamic, explicit routes for time-limited traffic demands. This approach does not require accurate network resource availability information and therefore does not incur in high instability. As explained before, the unpredicted behaviour can be managed by having more than one LSP for the each pair of edge node which are constantly supervised with “current” information. Hence, the usage of the pre-compute LSPs for one pair of edge node is not fixed: they may change according to traffic prevision and demands. The path computation is also operated in GMPLS control plane in a way that we do not have critical time demands due to our scheme and at the same time we preserve and can make use of all the advantages of GMPLS such scalability, protection and restoration, and management.

5.2.2 Network Resource Availability Information.

This mode has a crucial role in the overall operation of our proposed scheme. It is responsible to gather and disseminate the “current” network resource availability information. They are OBS specific tasks and so are performed at optical level. A proper and timely performance of those tasks helps the traffic balance and reduces the burst-loss probability. More specifically it is determinant to an efficient and accurate selection of the proper LSP at the BCP transfer time. The way to do it is not defined yet. We suggest the use of the LSAs provide by the OSPF-TE under the GMPLS framework. Specific extensions and modifications are needed. The LSA should be associated with each established LSP. The information contain into the LSA should resume the attributes that interfere with the LSP selection at time transfer. Such attributes must reflect the status of the links and the core nodes. This status cannot be exact due to the high traffic variation of the OBS network. Also, the information included in the LSA messages should be general because many decisions are local. Therefore only an estimation of a set of important parameters can be gathered and flooded. For example: mean converters availability, average free bandwidth of those links belongs to LSP (link bundling), average FDL availability (free capacity), and average burst losses of those links belong to LSP. The flooding dissemination can be decided and request at any moment by the edge node (source) to control his decision of maintain or change LSP (TE information). Another innovation is the use of the ADSpec object in the BCP message. Since the LSPs are commonly bidirectional, a BCP can collect the status of the node throughout an LSP and delivery it to the destination node. In the opposite LSP, this node is the source node; hence it is aware of its LSP status.

6. CONCLUSIONS

Try a full integration GMPLS/OBS is not easy, since GMPLS and OBS are not designed for each other. Here we have presented an overlay GMPLS-based control plane to perform the defined OBS background tasks that interworks with the OBS specific functionally allocated at the control units of the OBS switches. The task division suggested in this paper allows for the use of the best of both of these two worlds, GMPLS and OBS.

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