

# A Conceptual Framework for Object-Oriented Modeling of GMPLS Networks

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## Abstract

We present a conceptual framework for object-oriented modeling of GMPLS-based networks and the solutions to their associated problems. The framework is targeted towards a larger scale initiative by us for developing a modeling language that can help with conceptual modeling of typical GMPLS network design problems. While there are different pieces of literature available that provide modeling languages for other application areas, there are not many languages for use in modeling general networking problems. Our work is an important step forward to address this deficiency. Our proposed framework takes some existing modeling language notations and extends them to support the modeling of GMPLS networks.

**Keywords:** Modeling, UML, Networks, GMPLS.

## 1 Introduction

A consequence of migrating the existing Internet architecture to an all-optical one is that the network will consist of a mixture of equipment, ranging from electrical routers to all-optical packet switches. Hence, future networks will consist of multiple domains deploying different technologies. In this context, GMPLS is becoming increasingly widely used as a control plane in optical circuit-switched networks due to its capability to allow a seamless integration of a multitude of technologies, especially circuit-switched systems, with packet-switched networks.

In this paper we present a Unified Modeling Language(UML)-based framework to support model GMPLS-based networking problems. Our efforts are

targeted towards a larger scale initiative for providing a UML Profile for modeling GMPLS Networks. The Profile is based on an extension of core UML. Although UML is considered by many professionals as a *de facto* tool to aid in system modeling, the current versions of UML do not specify methodologies, modeling elements and tools to even address problems specific to the general area of Telecommunications. Other initiatives with UML Profiles address modeling issues associated with application domains such as Quality of Service in Distributed Systems [1,2], Business Modeling [4], Fault Tolerance [5], CORBA [6], Testing [7] and Schedulability, Performance and Time [8] and Agent Oriented Software [9]. Thus we see that although there have been UML Profiles developed for use in other application areas, there are no UML-based profiles *even* for use in modeling the fundamental networking problems. Since GMPLS-based networks are one of the most promising modern day communication technologies, we focused our work in this area.

## 2 GMPLS

GMPLS extends MPLS to provide the control for devices in any of following domains: packet, time, wavelength, and fiber. In this way, data from multiple layers are switched over Label Switched Paths (LSPs). As a result, GMPLS simplifies network operation and management by automating end-to-end provisioning of connections, managing network resources, and providing the level of QoS that is expected in the new, sophisticated applications [10,11,12].

One of the main architectural enhancements proposed by GMPLS is the complete separation of the control and data areas of various networking layers [12,13]. While the technology used by the control zone remains IP-based, the data area can be diversifying to include more varieties of

traffic (TDM, Lambda, packet, etc). In this way, this architectural change allows high performance, intelligent networking while simplifying networks by combining transport and multi-service switching into a single layered network. Its success depends on its ability to communicate with the many existing ATM or Frame Relay network infrastructures. Inter-working with ATM and Frame Relay networks allows transport of control and data plane information exchanged between two similar networks (e.g., two ATM networks) through a dissimilar network (e.g., GMPLS) [11,12,13].

Despite the complexity of issues, the basic operation of the GMPLS protocols is simple, as shown in the activity diagram in Figure 1. All the activities can be divided in three large phases:

1. Discovery

- (a) All nodes initialize and start communication with other link participants regarding necessary properties and attributes.
- (b) Topology protocol starts up and finally, every node knows about the entire network topology. This step also includes information distribution about resource usage at each node.

2. Path Calculation.

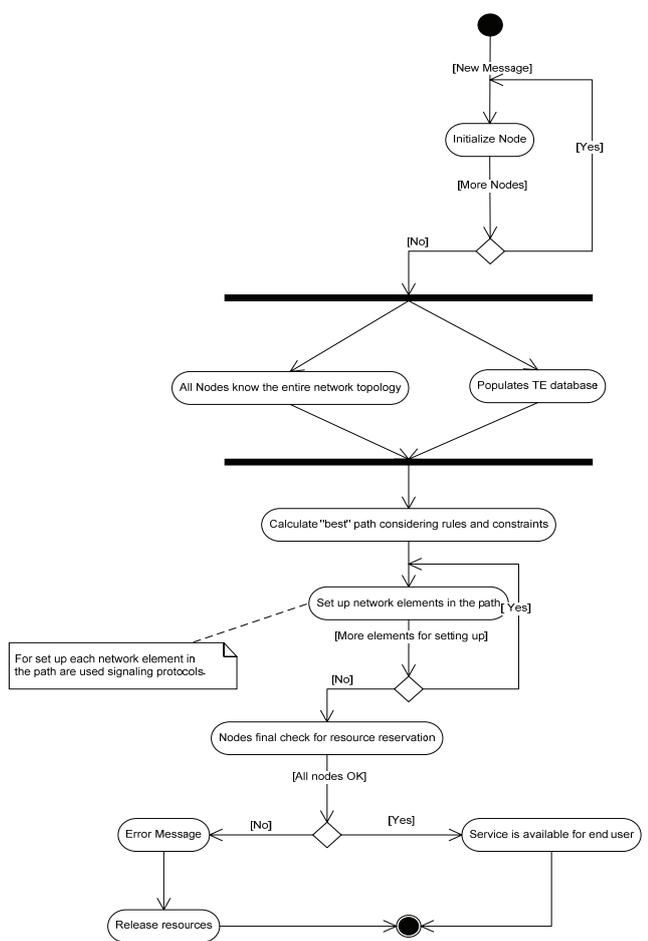


Figure 1 The basic operations of GMPLS protocols

- (a) The management software sends a service request to one of the end points of the network.
- (b) That node searches its traffic-engineering database to find the “best” path between the service end points.
- (c) The most important issue of this step is to respect rules and constraints specified by the user.

3. Service signaling

- (a) After the path has been selected, are used signaling protocols are used for setting up all elements of the path.
- (b) Each node along the path must perform a final check and reserve the requested service for the service.
- (c) If there exists at least one node that cannot fulfill the service requirements, an error is generated and all previous reserved resources are released.
- (d) If all are successful, at the end of this step, the service is available for the end user.

GMPLS requires close interaction between LMP, RSVP, and OSPF [15]. The sequence diagram in Figure 2 describes how GMPLS works. It uses standard GMPLS terminologies, which are not described here in this paper to maintain its brevity.

The diagram shown in Figure 2 is described below [13,14,15]:

- LMP notifies RSVP and OSPF of the control peer, the control adjacency, and resources for the TE link.
- GMPLS extracts the LSP attributes from the configuration and requests RSVP to signal one or more specific paths, specified by the TE link addresses.
- RSVP determines the local TE link, corresponding control adjacency and active control channel, and transmission parameters (such as IP destination). It requests that LMP allocate a resource from the TE link with the specified attributes. If LMP successfully finds a resource matching the attributes, label allocation succeeds. RSVP sends a PathMsg hop-by-hop until it reaches the target router.

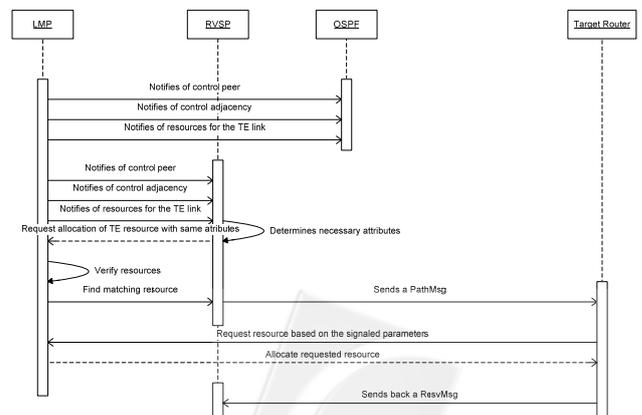


Figure 2 GMPLS sequence diagram

- The target router, on receiving the RSVP PathMsg, requests that LMP allocate a resource based on the signaled parameters. If label allocation succeeds, it sends back a ResvMsg.
- If the signaling is successful, an optical path is provisioned.

- Optical Connection
- Optical Path
- Optical Channel
- Optical Channel Segment

First element created for setting up a connection between two nodes is the optical connection (Figure 4). The *source* is the optical node that is trying to connect to the *destination*. This connection has some constraints defined in the *Quality of Service*.

### 3 Optical Connections Using GMPLS

Creation of an optical connection using GMPLS is a process that follows the following steps [12]:

- Creating of an optical connection object and its quality of service.
- Executing a routing algorithm that will try to compute one or more possible routes according to the quality of service requested.
- After the routing is done, executing a wavelength algorithm to create a light-path and reserving the resources.

The result of executing a routing algorithm on a connection is the creation of one or more possible routes, which are stored in the Vector *routes*. Once the routing algorithm has run, the wavelength assignment algorithm is using the information of the routes to create a *path*.

As a final point, before a connection can be used, a protocol must register to the path. Once a protocol registers to a connection, it becomes the owner.

The *Quality of Service* represents the constraints (like minimum bandwidth of the connection, the maximum delay) for the algorithms on the path in order to satisfy the requested connection. It also contains the name of the algorithms that must be used.

Once the route and the light-path have been computed, the resources have been reserved. The switches must also be setup along the path (using one of two possible methods: *Instantaneous setup of the switches* or *Dynamic setup of the switches*). A protocol has to register to the connection in order to get the right to send data.

Main components of an optical connection are (see Figure 3):

The Optical Path (Figure 5) is composed of a set of Optical Channels. Each of the channels is an end-to-end path from the source to the destination. It is possible to have more than one channel in order to have a higher bandwidth.

The Optical Channel (Figure 6) is an end-to-end connection that is composed of segments. Each of the segments represents the “lambda” that has been reserved by the wavelength algorithm for each link that composes the route. The role of a wavelength algorithm is to find the wavelength that can be used in all the links of the route computed by the routing algorithm, and to create the previous structure.

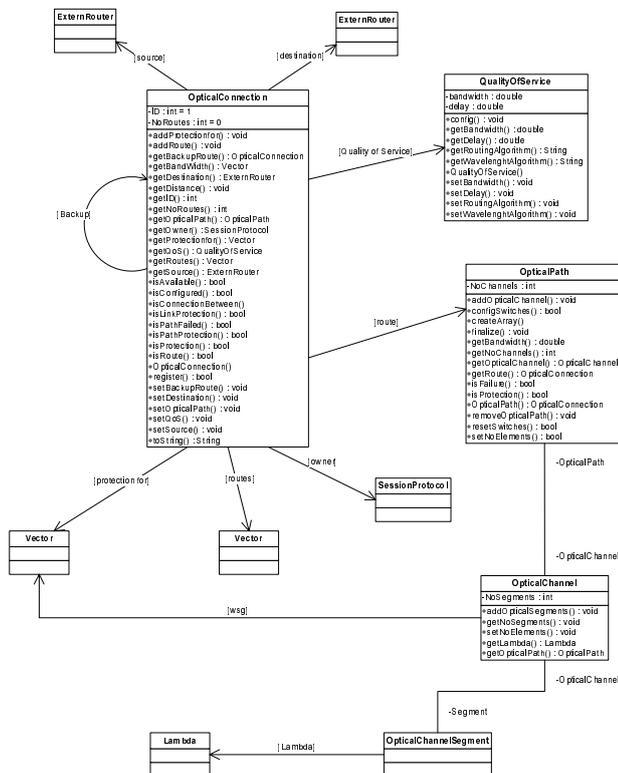


Figure 3 Connection Structure Overview

### 4 Extending Core UML to Support GMPLS: The UML Profile

An UML Profile takes a part of the UML and extends it with stereotypes for a particular purpose. It is defined in terms of three basic mechanisms: *stereotypes*, *constraints*, and *tagged values*.

- *Stereotype* is defined by the set of meta-model elements that can be attached to.
- *Constraints* can be associated to stereotypes, imposing restrictions over the corresponding meta-model elements.
- *Tagged values* have a *name* and a *type*, and are associated to a specific stereotype.