Network-element view information model for an optical burst core switch

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ABSTRACT

To natively support the bursty IP datagrams over all-optical Wavelength Division Multiplexing (WDM) networks, the Optical Burst Switching (OBS) WDM network has been proposed as a suitable architecture for future optical Internet backbone networks. However, managing the OBS network will be complicated due to the scale of the networks and the correlation between different technology layers. This paper presents an information model for the OBS core node, from the network-element view, to describe the management information flows between the optical burst layer and the traditional WDM transport layer, and how to model them using various Managed Objects (MOs). We also provide the structure of Management Information Base (MIB) used in SNMP management interface for managing the parameters identified at different layers.

Keywords: Optical burst switch, network management, information model, WDM, SNMP, MIB

1. INTRODUCTION

The Optical Burst Switching (OBS) has recently been proposed to achieve a balance between the coarse-grain optical circuit switching via wavelength routing and the fine-grain optical packet switching in building the next generation optical broadband networks.[1–6] In an OBS network as shown in Fig. 1, nodes are connected via links of typical Dense Wavelength Division Multiplexing (DWDM) fibers. Core nodes are usually meshed together to provide multiple backbone paths, while edge nodes act as concentration to a cloud of traditional IP routers, feeding packets in and out of the OBS cloud. Each transmission link carries multiple DWDM channels that can be dynamically assigned to user data bursts. One or several channels on each link can also be reserved for passing the control packet to announce an upcoming data burst. In this process, the control packet is interpreted by the control plane of the switching system, while the data channels are switched through transparently with no examination of the data. So the data can be transmitted at the full bandwidth of the wavelength channel without Optical/Electrical (O/E) signal conversion. This separation of control and data greatly simplifies the data plane of the switching system, and also makes the implementation of this all-optical switching potentially cost-effective.

However, to appropriately manage the configuration and operation of such a complicated OBS network, it is necessary to understand the information flows between various architecture layers of this network. This leads us to the creation of an information model for the OBS core node, from the network element view, to describe the management information at both the optical burst layer and the traditional DWDM transport layer.

Currently, most IP related data network elements are managed through the interface of Simple Network Management Protocol (SNMP), which is standardized by Internet Engineering Task Force (IETF). However, IETF does not have a specific model for either the optical switch/router or the WDM system, which greatly relates to information layers of the OBS network. Therefore, to model the OBS network more like a regular IP data network, the management information model and the structure of corresponding Management Information Base (MIB) presented in this paper follows and extends various IETF standards.[7–9] Requirements specified in the ITU-T Recommendations[10–13] are also adapted into IETF compliant MIB groups and tables to formulate an OBS private MIB structure combined with specific burst routing or switching control information.

This paper is organized as follows. In Section 2, different information layers inside an OBS core node are first presented based on the traditional layer model, and the functional architecture of the core node is illustrated

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Proceedings of SPIE Vol. 4584, APOC 2001, Beijing, China (2001)

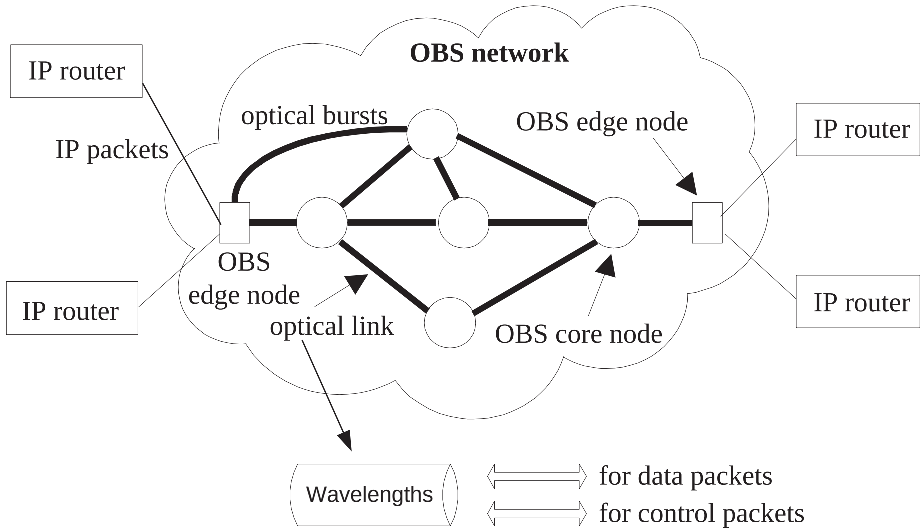

Figure 1. An optical burst-switched network

thereafter. Section 3 describes various components within the core nodes, and builds their corresponding managed objects using the Unified Modeling Language (UML).[14] In Section 4, we introduce the MIB structure appropriate for translating the management parameters identified at each information layer into SNMP compliant groups and tables. We finally conclude the paper in Section 5.

2. MANAGEMENT INFORMATION FLOW

This section presents the management information and functional architecture of OBS core nodes.

2.1. Management Information Layer

In an OBS network, multiple regular IP packets with the same destination are assembled into one data burst. The payload of this data burst, called Burst Packet (BP) is transmitted separately from the Burst Header Packet (BHP), its control header, and kept in the optical domain at the intermediate nodes. In this way, only the BHP needs to be converted to electronics in the process of routing and switching the data burst payload, and each BP can be transmitted at the full bandwidth of a wavelength without O/E signal conversion. Based on the traditional layer model used for defining network elements of the transport network, the flow of management information in an OBS core node can be described by four different functional layers as shown in Fig. 2.

The optical burst layer has three kinds of packets: (i) BPs, (ii) BHPs used to control the switching and routing of BPs, and (iii) Control Packets (CPs), which carries the control information necessary for the OBS network to complete Operation, Administration, and Maintenance (OAM) functions such as protection and restoration. These CPs are generated only when necessary and not associated with BPs or BHPs. Generally, BHPs and CPs are transmitted separately from BPs, and BHPs are transmitted ahead of BPs. BPs, CPs and BHPs can be in different wavelengths and in different fibers.

The Optical Channel (OCh) layer refers to the wavelength channels within each fiber and includes BP, BHP and CP channels (All wavelength channels in this layer are usually within the band of Erbium-Doped Fiber Amplifier for power amplification). The Optical Multiplex Section (OMS) layer contains the management information that will be terminated between the optical multiplexers. All control information about the links between any two segments will be represented at the Optical Transmission Section (OTS) layer.

Traditionally, WDM network uses the Optical Supervisory Channel (OSC) as the control channel for all optical data channels between link segments. However, in OBS network, the functions of OSC channels can be

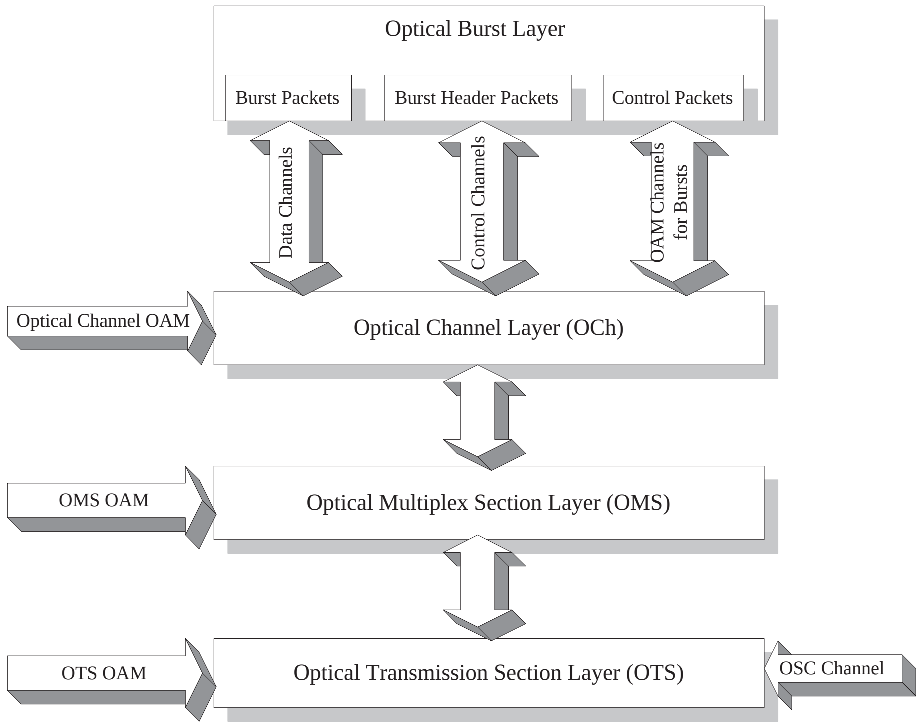

Figure 2. Management information flow in an OBS core node

completed by CP channels. In addition, the optical channel layer discussed here is not traditional OCh layer that can be found in the circuit switching network element, such as WDM or optical cross connect. Since OBS is based on IP-oriented burst routing, there is no fixed and pre-configured wavelength channel connection in the optical switching fabric. The reason this layer is still modeled here is that we may want to know the information about each wavelength port inside the optical switch fabric. A typical example is when one incoming BP is correctly forwarded to one output wavelength port based on the information of its BHP, but somehow that output port gets corrupted. In this situation, we may want to know the information about that output port.

2.2. Functional Architecture

Typically, an OBS core node needs to perform the following operations.

- Demultiplex the burst wavelength channels.
- Terminate BP channels and conduct wavelength conversion for passing through the optical switch fabric.
- Terminate BHP/CP channels and convert the control information from the optical into electrical domain.
- Schedule the incoming BPs and send the instructions to the optical switching matrix.
- Switch BP channels through the optical switching matrix.
- Re-generate new BHPs/CPs for outgoing BPs.
- Multiplex outgoing BPs and BHPs/CPs together into single or multiple fibers.

As illustrated in Fig. 3, the functional architecture of the OBS core node includes typical DWDM components such as optical receiver, optical transmitter, and wavelength converter. The Optical Receiver (OR) terminates

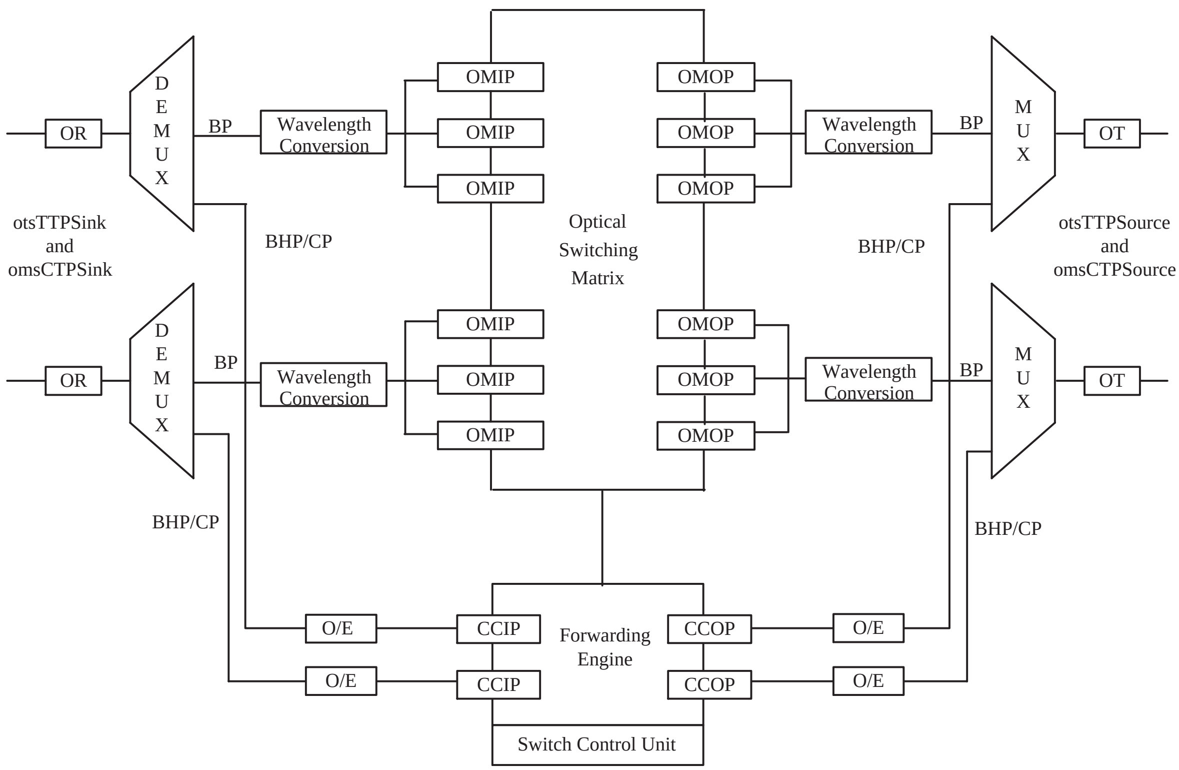

Figure 3. Functional architecture of OBS core nodes

all received optical channels and could be a preamplifier, acting as a termination point sink at OTS and OMS layer. The Optical Transmitter (OT) may be a power amplifier for the outgoing optical channels, acting as a termination point source. To accommodate multiple optical channels from and to other nodes with the same wavelength but in different fibers, the wavelength converter needs to be used at both input and output sides of the optical matrix.

Besides, one important component inside the OBS core node is the optical switching matrix since it determines the performance of the core node regarding how BPs are switched. The Optical Matrix Input Port (OMIP) and Optical Matrix Output Port (OMOP) refer to the input and output ports of this optical switching fabric. Another important one is the Switching Control Unit (SCU), which is responsible for the forwarding engine built on the routing protocols such as Open Shortest Path First (OSPF) or Multi-Protocol Label Switching (MPLS). This SCU also involves various scheduling mechanisms to correctly instruct the forwarding engine based on the control information from BHP channels after the O/E conversion.

3. MANAGED OBJECT CLASSES

Based on the management information presented in Section 2, Figure 4 shows the managed object classes that model the OBS core node and their inheritance from both equipment view and logic signal view. This presentation is a static view that gives the behavior entities of the core node, while the detail of its dynamic behavior such as messages will be left for the specific implementation. The description of relations between these object classes is consistent with UML version 3.0. All optical signals related information is extracted separately to formulate the Signal class. This logical abstraction prevents other classes that have pertinent signal information from being populated each time when this information is requested.

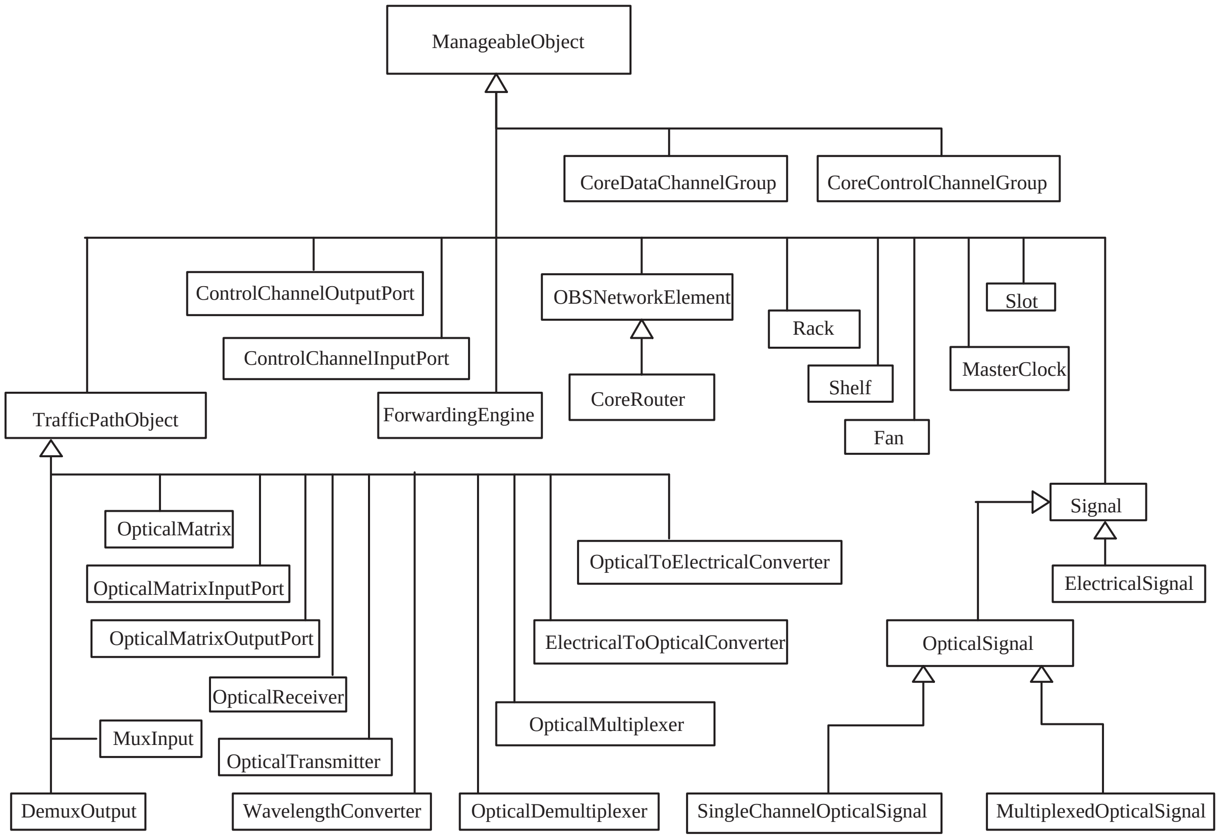

Figure 4. Inheritance of managed object classes

The brief description of some major managed object classes is as follows.

- TrafficPathObject: is an abstract class. An object that is instantiated from a class or a subclass of this abstract class is part of the payload data path. That is, either a burst packet or a burst header packet passes through this object.
- OpticalMatrix: routes bursts from OpticalMatrixInputPorts to OpticalMatrixOutputPorts. The OpticalMatrix is controlled by the ForwardingEngine.
- OpticalMatrixInputPort: transmits bursts into the optical matrix. It provides visibility of a single wavelength input signal. It collects statistical data on that signal, like burst error counts. It terminates overhead associated with the WDM OCh layer.
- OpticalMatrixOutputPort: receives bursts from the optical matrix. It provides visibility of the signal it receives. It also originates overhead associated with the WDM OCh layer.
- OpticalReceiver: receives an optical signal. It serves as a measurement point for the incoming WDM signal. It terminates overhead associated with the WDM Optical Trail Section.
- OpticalTransmitter: transmits the outgoing WDM signal. It originates the WDM Optical Trail Section overhead. It serves as a measurement point for the outgoing signal.
- OpticalMultiplexer: multiplexes incoming WDM signals. It originates the WDM Optical Multiplex Section overhead.

- OpticalDemultiplexer: demultiplexes an incoming WDM signal. It terminates the WDM Optical Multiplex Section overhead.
- WavelengthConverter: is an optical wavelength converter, also called transponder.
- ElectricalToOpticalConverter: converts an electrical signal to the optical signal of a single optical channel.
- OpticalToElectricalConverter: converts the optical signal from an optical channel into an electrical signal.
- ForwardingEngine: sends instructions to the optical matrix for routing BPs.
- ControlChannelInputPort: receives the incoming BHP/CPs and collects statistical data like BHP/CP error counts.
- ControlChannelOutputPort: contains the newly generated outgoing BHP/CP.
- CoreDataChannelGroup: is a container class for OpticalMatrixInputPorts or OpticalMatrixOutputPorts that go to the same neighbor node in the OBS network.
- CoreControlChannelGroup: is a container class for ControlChannelInputPorts or ControlChannelOutputPorts that go to the same neighbor node in the OBS network.
- CoreRouter: initially creates all the objects it contains, then it creates all the wires that connect those objects together.
- ElectricalSignal: is a signal carried on an electrical wire.
- OpticalSignal: is an abstract class. An object of this class is a signal carried on an optical fiber.
- SingleChannelOpticalSignal: is a single wavelength optical signal carried on an optical fiber.
- MultiplexedOpticalSignal: is a multiplexed signal carried on an optical fiber that consists of several wavelengths.

It is interesting to emphasize that the lines that connect elements together in Fig. 3 are also objects. For example, there is a line that connects an OpticalToElectricalConverter to an OpticalDemultiplexer. This line is actually represented by an object of the class SingleChannelOpticalSignal. The SingleChannelOpticalSignal contains two references (object instance pointers) named source and destination. Destination refers to the OpticalToElectricalConverter and source refers to the OpticalDemultiplexer. The OpticalToElectricalConverter has a reference named input that refers to the SingleChannelOpticalSignal, and the OpticalDemultiplexer has a reference named output that also refers to the SingleChannelOpticalSignal.

In addition, to better understand the relationship between objects instantiated from their managed object classes, Figure 5 and 6 demonstrate the object containment tree from both equipment view and logic view. For example, the OpticalTransmitter class, as described in Fig. 7, is defined to have a bi-directional association with CoreRouter for Multiplicity of 1. Such a relationship is illustrated clearly in Fig. 5 from the equipment view object containment tree. Besides, this class also has a uni-directional input and output association with SingleChannelOpticalSignal for Multiplicity of 1, which can be obviously seen from Fig. 6 of signal view.

4. MIB STRUCTURE OF SNMP MANAGEMENT INTERFACE

The management of an OBS core node relies on communications between this node and an external Operation System (OS). The core node receives operation requests from the OS, and sends operation results or event reports to the OS. It supports this information exchange by managing a virtual information store, called Management Information Base (MIB). The data in the MIB is an abstract representation of the resources and their roles in the network core node. Specifically, it is a collection of managed objects each of which is an instantiation of a managed object class in a management information model designed for this core node. Each managed object has attributes, generates event reports, and performs actions requested by the OS. The network element translates

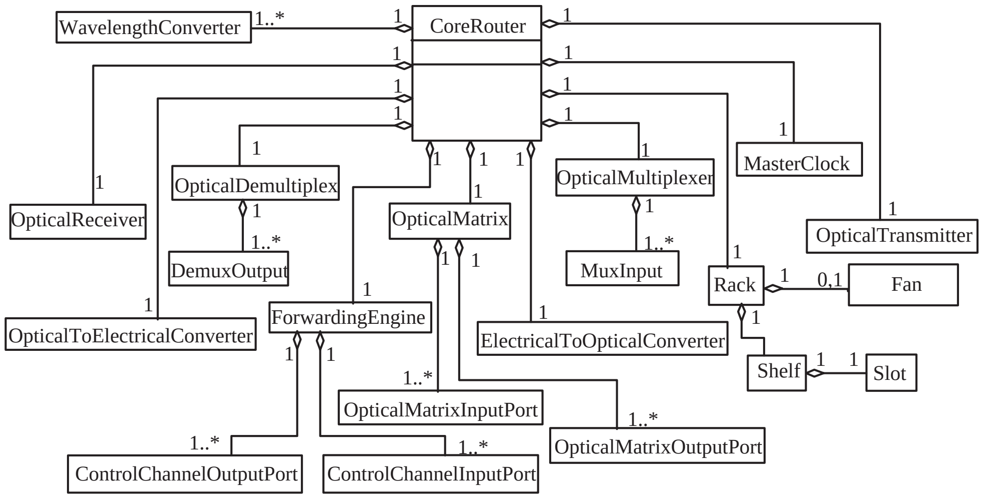

Figure 5. Object containment tree from equipment view

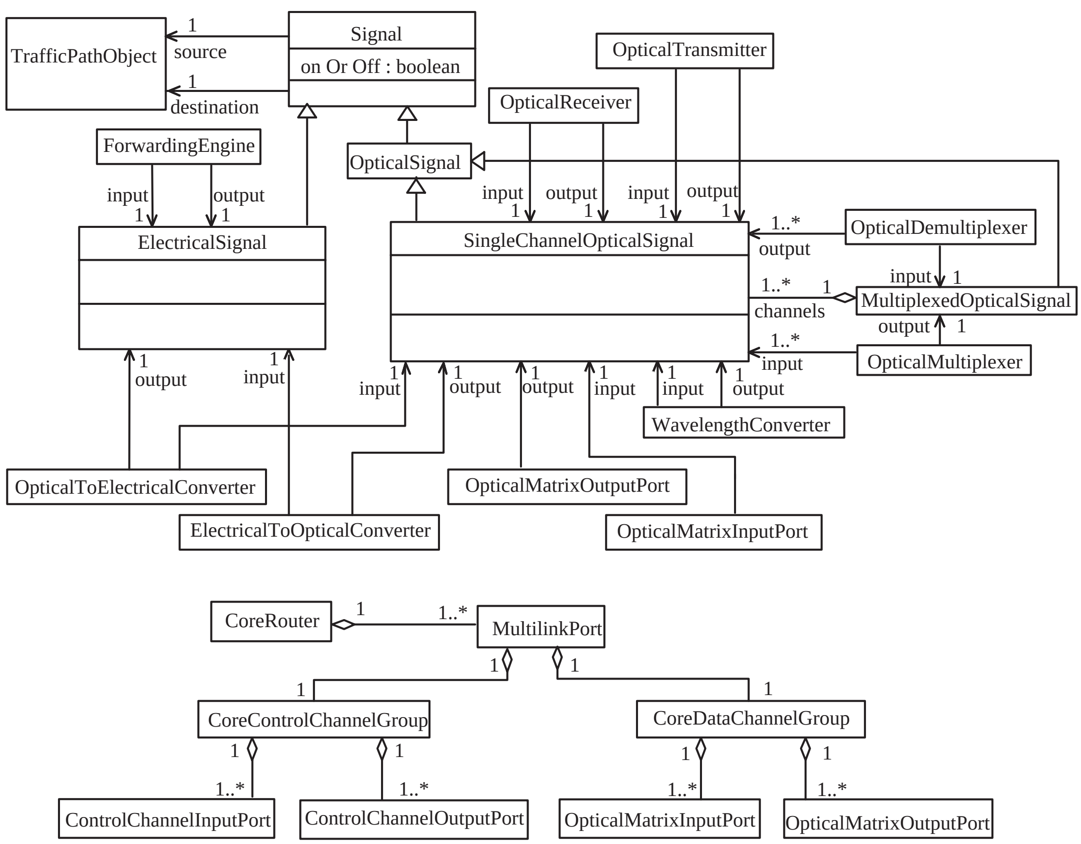

Figure 6. Object containment tree from signal view

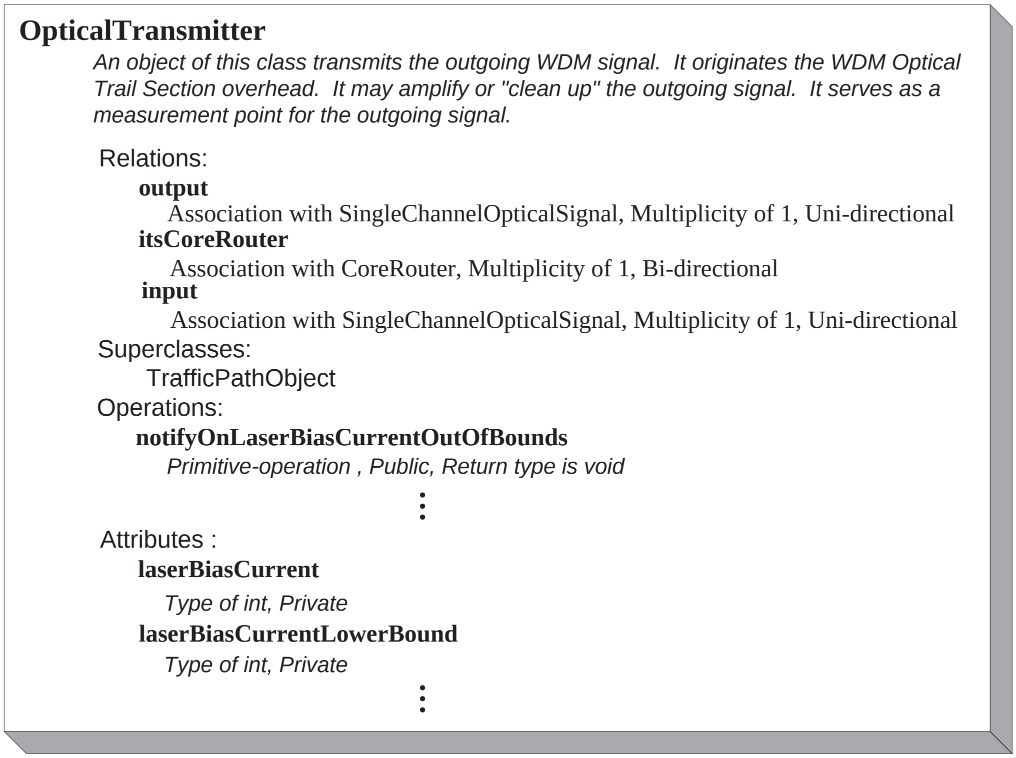

Figure 7. Definition of the OpticalTransmitter class

operation requests on managed objects in the MIB into real operations to be performed on the actual resources, executes these operations, and sends the operation results back to the OS.

The strategy for designing the MIB of OBS core nodes should take the following two considerations:

- OBS network core nodes behave mainly like traditional IP routers with the exception that their switching and transport components are in the optical domain.
- The separation of the burst payload from its header brings new challenges in the area of performance monitoring and fault management.

The general guideline is that the public MIBs should be used for the common components, of which the management information has already been standardized. The IETF has provided MIBs covering different layers of TCP/IP reference model through numerous RFC standards. However, for the components that exist only in OBS network such as optical switching matrix and objects related to optical burst layer, the private MIB needs to be utilized. A screen snapshot of one implementation on defining the MIB structure of OBS core nodes is shown in Fig. 8.

4.1. Public MIB

One common practice for managing the IP network is to provide a standardized MIB so that different management applications from different equipment vendors can complete some basic functions. This interoperability provides great convenience for end users to complete some common tasks, such as the system maintenance and contact information. Currently, the most-often used standard public MIB for managing TCP/IP-based networks is MIB-II defined in Ref. 15. Therefore, to assure interoperability, the OBS MIB structure needs to include the support

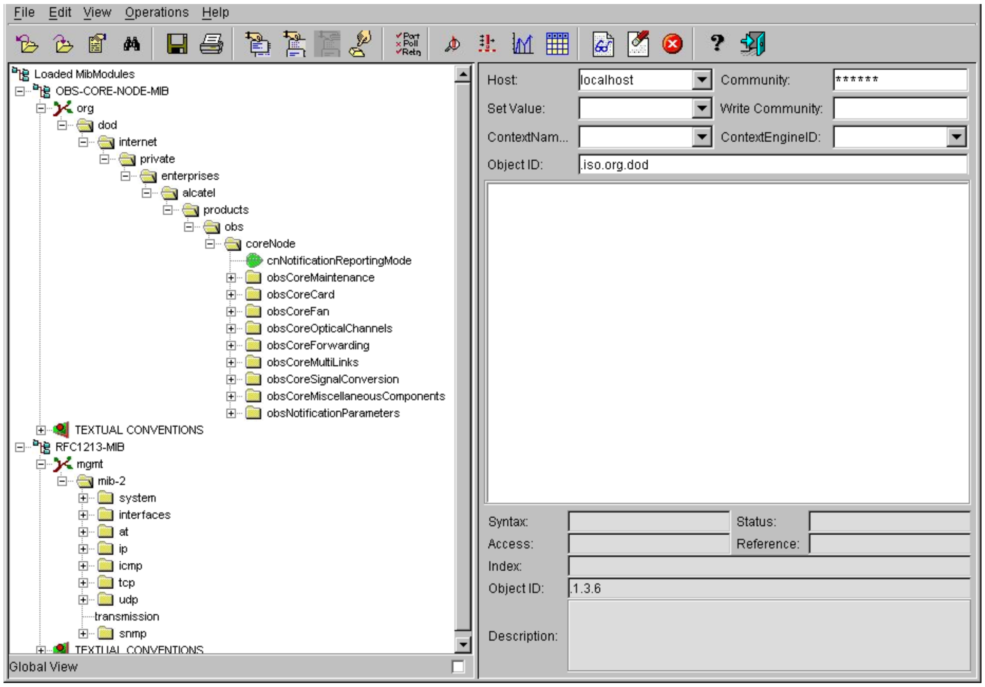

Figure 8. A screen snapshot of one MIB implementation

for MIB-II. For those parameters in public MIB-II not relevant to the OBS network, a simple *NULL* value is returned. In addition, some common MIBs that are related to optical channels[16] and various routing protocols are also adopted.

Another common practice in building the MIB of OBS core nodes is to adapt the parameters identified in various public MIBs of specific use and rearrange them into private MIB to have a better structure for that particular purpose.

4.2. Private MIB of OBS Core Nodes

The private MIB for OBS core nodes defines the managed objects that model the functionalities and resources that are specific to OBS network core nodes. To take advantage of the well-defined and well-known structure of MIB-II, one approach is to take the MIB-II structure as a template for building such a private MIB. As an example by using this approach, Figure 9 shows the first-level structure of private MIB for OBS core nodes. The description of groups contained in this private MIB is as follows.

- The Maintenance group tends to contain the same kind of information as the system group of MIB-II defines.
- The Card group is used to describe the interfaces specific to OBS with attributes like number, type, hardware and software version, as well as temperature.
- The OpticalChannel group gathers characteristics of optical components such as laser status, optical power of the receivers and transmitters.
- The Forwarding group presents the routing table, the address table as well as the burst information. Different counters report the performance data, such as the number of discarded input or output bursts because of insufficient router resources, the number of dropped bursts because of invalid destination field.

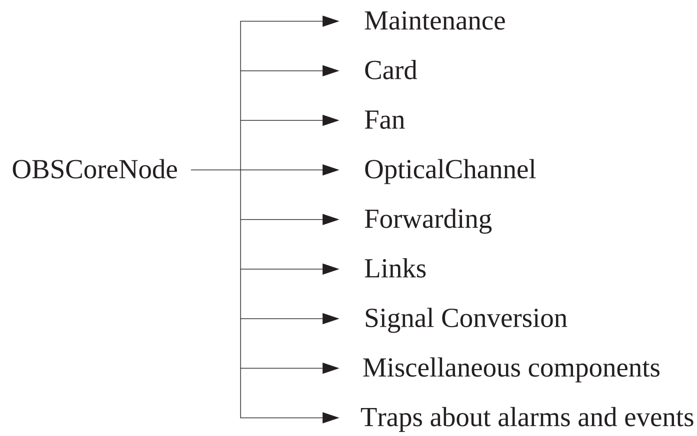

Figure 9. First-level private MIB structure of OBS core nodes

- The Links group deals with all parameters concerning with the logic channels such as DataChannelGroup and ControlChannelGroup. It also contains the mapping between logic channels and their physical wavelengths inside the fiber.
- The Signal Conversion group handles the parameters regarding the operations of O/E and E/O conversion.
- The Miscellaneous group refers to those management parameters that can be adapted from various public or other private MIBs. These parameters are relevant to OBS core nodes, edge nodes or both by a particular protocol or physical layer. It may include the parameters related to
  - DWDM at OTS and OMS layer
  - Generalized MPLS (GMPLS) or OSPF
  - SONET
- All alarm related event reports are arranged into the Trap group.

5. CONCLUSIONS

In this paper, we have proposed a management information model for the core node of optical burst switching network. We first describe the management information flow between different technology layers in the core node followed by the description of functional architecture. Then, we present the managed objects corresponding to the components and resources inside the OBS core node. The class inheritance and object containment of these managed objects is illustrated from both equipment and logic channel view using standard object-oriented United Modeling Language description.

Finally, the structure of management information base under the SNMP-based management interface is presented. It provides the virtual data structure for managing the requests, responses and alarms associated with the attributes and operations of the managed objects inside the OBS core node. It also translates the management parameters identified at each information layer into SNMP compliant groups and tables.

Our implementation demonstrates that this information model provides a clear methodology to understand the architecture and operations of OBS network core nodes. It also streamlines the design process from requirement specifications to the design architecture so that the development and deployment of a robust optical burst switching network can be facilitated. However, further work remains to be done regarding the edge nodes of optical burst switching network.

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REFERENCES

1. Y. Xiong, M. Vandenhoute, and H. C. Cankaya, “Control architecture in optical burst-switched WDM networks,” *IEEE J. Select. Areas Commun.* **18**(10), pp. 1838–1851, 2000.
2. S. Verma, H. Chaskar, and R. Ravikanth, “Optical burst switching: a viable solution for terabit IP backbone,” *IEEE Network* **14**(6), pp. 48–53, 2000.
3. C. Qiao and M. Yoo, “Optical burst switching – a new paradigm for an optical Internet,” *J. High-Speed Networks* **8**(1), pp. 79–90, 1999.
4. J. S. Turner, “Terabit burst switching,” *J. High-Speed Networks* **8**(1), pp. 3–16, 1999.
5. Y. Xiong, M. Vandenhoute, and H. C. Cankaya, “Design and analysis of optical burst-switched networks,” *Proc. SPIE* **3843**, pp. 112–119, (Boston), 1999.
6. F. Masetti, P. G. Morin, D. Chiaroni, and G. D. Loura, “Fiber delay lines optical buffer for ATM photonic switching applications,” *Proc. IEEE Infocom* **3**, pp. 935–942, 1993.
7. M. Rose and K. McCloghrie, *Structure and identification of management information for TCP/IP-based Internets*, STD 16, RFC 1155, May 1990.
8. M. Rose and K. McCloghrie, *Structure of management information for Version 2 of the simple network management protocol (SNMPv2)*, RFC 1902, Jan. 1996.
9. J. Case, M. Fedor, M. Schoffstall, and J. Davin, *Simple network management protocol*, STD 15, RFC 1157, May 1990.
10. *Network node interface for the optical transport network*, ITU Recommendation G.709, Draft Issue 0.8.3.
11. *Characteristics of optical transport network hierarchy equipment functional blocks*, ITU Recommendation G.798, Draft Issue 0.5.1.
12. *Transmission systems and media, digital systems and networks - digital transmission systems, digital networks, and optical transport networks*, ITU Recommendation G.872, Draft Issue 1.3.
13. *Management aspects of the optical transport network elements*, ITU Recommendation G.874, Draft Issue 1.4.
14. J. Rambaugh, I. Jacobson, and G. Booch, *The unified modeling language reference manual*, Addison-Wesley, Reading, MA, 1999.
15. K. McCloghrie and M. Rose, *Management information base for network management of TCP/IP-based Internets: MIB-II*, RFC 1213, Mar. 1991.
16. M. Stewart and K. Lam, *Definitions of managed objects for the optical interface type*, Internet Draft, Nov. 2000.