Information Model of an Optical Burst Edge Switch

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***Abstract*-Optical Burst Switching (OBS) has been touted as a suitable technique to support the bursty IP datagrams over the future all-optical networks. This paper presents an information model on edge nodes of such an OBS network to provide management information at both optical burst layer and traditional WDM transport layer to understand, operate and manage these edge nodes. Managed objects corresponding to various components and resources inside edge nodes are illustrated. The structure of Management Information Base (MIB) under the SNMP management interface for managing the identified parameters is also presented.**

I. INTRODUCTION

Rapid growth of the Internet traffic in the last decade has triggered the necessity of all-optical packet switching to eliminate the bottleneck of electronic processing involving header processing for routing and possible data multiplexing. This elimination of optics-electronics-optics conversion at the intermediate nodes in the end-to-end data path is critical to make emerging applications take full advantage of the transmission speed provided by the Wavelength Division Multiplexing (WDM) layer. However, due to a number of technological constraints such as the limited optical buffering that is currently implemented using optical delay lines or the difficulty in switching light pulses using light as control, Optical Burst Switching (OBS) has been proposed as a viable alternative to all-optical packet switches [1-6].

OBS allows switching of data channels entirely in the optical domain by doing resource allocation in the electronic domain. As shown in Fig. 1, the OBS network consists of edge nodes and core nodes. A control packet precedes every data burst. The control packet and its corresponding data burst are launched at the source edge routers and separated by a small time interval, which is determined at the time the control packet is launched at the source. The control packet contains the information required to route the data burst through the network, the length of the corresponding data burst, and the offset time value. Usually, the control packet is sent over an out of band wavelength channel and processed electronically at each of the intermediate nodes to make routing decisions such as outgoing interface and wavelength. Each node is configured accordingly to switch the data burst that is expected to arrive after the interval given by the offset time value contained in the control packet. The impending data burst is then switched entirely optically thereby removing the electronic bottleneck in the end-to-end data path.

However, the successful design and deployment of such an OBS network requires a solid management system to provision the network and manage the operations and parameters associated with OBS network nodes. Especially for the OBS edge node, the management involves not only the new optical

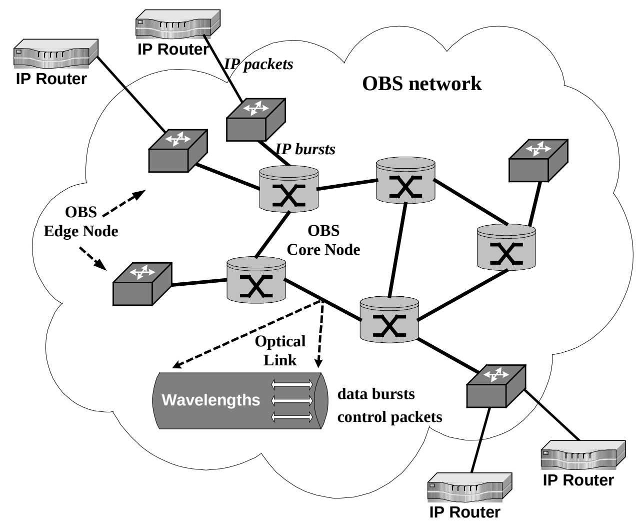

Fig. 1. An optical burst-switched network

burst traffic, but also the regular IP packets because the edge router, as an interface between the regular IP router and the OBS backbone, performs a series of burst/packet processing. This leads us to the creation of an information model on the edge node of this OBS network, similar to the one defined in [7] for OBS core nodes, to combine the management information at the optical burst layer with both the traditional transport network and regular IP 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, the 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 [8-10]. Requirements specified in the ITU-T Recommendations [11-14] 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. Section II reviews the functional architecture of the OBS edge node and describes its various management information layers inside. Section III illustrates the Managed Objects (MOs) corresponding to various components and resources within the edge node. The inheritance and object containment relationship of these

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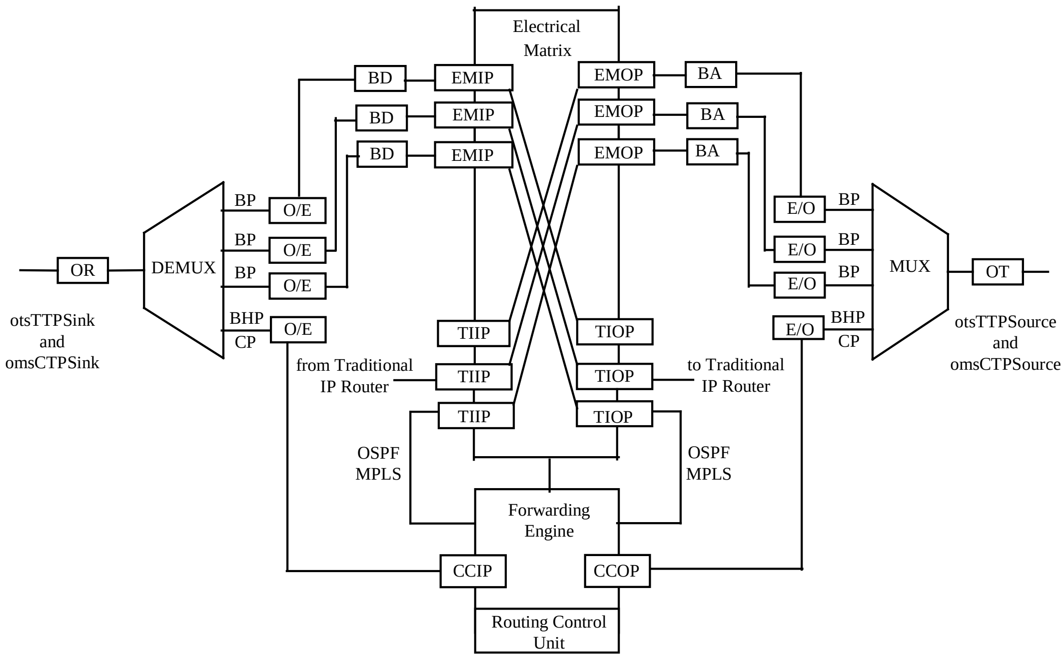

BA = Burst Assembler, BD = Burst Disassembler,
OR = Optical Receiver, OT = Optical Transmitter,
CCIP = Control Channel Input Port, CCOP = Control Channel Output Port,
EMIP = Electrical Matrix Input Port, EMOP = Electrical Matrix Output Port,
TIIP = Traditional IP Input Port, TIOP = Traditional IP Output Port,

Fig. 2. Function Architecture of OBS edge nodes

managed object classes is presented using the Unified Modeling Language (UML) version 3.0 [15]. In Section IV, 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 V.

II. Management functions and layers

This section presents the functions and associated architecture of one implementation approach of OBS edge nodes. The management information at each functional operation layer is analyzed.

A. Functional Architecture

In optical burst switching, multiple regular IP packets with the same destination are buffered in the source edge routers to form a data burst, also called the Burst Packet (BP). The control information of how to route and switch this data burst at the intermediate nodes is carried in a separate packet called the Burst Header Packet (BHP). The BHP is sent separately from the associated BP, and usually sent ahead by a small time interval to announce the upcoming of this BP. The control plane of the switching system then interprets the BHP, and routes the BP through transparently with no examination or interpretation of the data. In this way, only the BHP needs to be converted to electronics for the routing and switching information, and the BHP can be transmitted at the full bandwidth of a wavelength without Optical/Electrical (O/E) signal conversion. This separation of control and data greatly simplifies the data plane of the switching system since there is no O/E conversion involved any more. This also results in the elimination of the necessary line card for each data wavelength and makes the implementation of this all-optical burst switching potentially very cost-effective.

In addition, the implementation approach of the OBS edge node, discussed in this paper, also uses a special Control Packet (CP) to carry the control information necessary for the OBS network to complete Operation, Administration, and Maintenance (OAM) functions such as the protection and restoration. CPs are generated only when necessary and not associated with BPs or BHPs.

Considering the following operations that an OBS edge router needs to perform:

- Assemble regular IP packets into bursts based on some specific criteria such as the egress OBS edge node at destination field of the IP packets or the Quality of Service (QoS) based map channels.
- Generate and schedule the BHP for each BP.
- Convert the traffic outgoing to the OBS network from electrical signal into optical domain and multiplex them into WDM wavelength.
- Demultiplex the incoming wavelength channels and perform O/E conversion on the traffic received.
- Disassemble received bursts into regular IP packets.
- Receive and forward IP packets to the regular IP routers connected.

We can illustrate the functional architecture of the OBS edge node in Fig. 2. Like the OBS core node described in [7], the

OBS edge node has optical components related to WDM transport, such as optical receiver, optical transmitter, optical multiplexer and de-multiplexer. However, unlike the core node, in which the E/O or O/E conversion is performed for BHPs only, the OBS edge node converts signals between electrical and optical domain for both BP and BHPs.

There are several mechanisms for the BP assembly process of incoming regular IP packets. One possible implementation is to use the address of egress edge nodes that a specific IP packet goes to and the QoS parameter of this packet. The burst disassembly process is to recover regular IP packets from the receiving BPs and forward them to the destined traditional IP router connected. Therefore, the OBS edge node also has regular IP routing and forwarding engine modules.

The Routing Control Unit (RCU) is responsible for the forwarding engine built on the routing protocols such as Open Shortest Path First (OSPF) or Multi-Protocol Label Switching (MPLS).

B. Management Information Layer

As presented in [7], Fig. 3 shows that the management information in the OBS edge node can be described using four different functional layers.

The optical burst layer has three kinds of packets: BPs, BHPs and CPs. Generally, BHPs and CPs are transmitted separately from BPs. In the model presented in this paper, BHPs and CPs will be considered out-of-band signal, which means the BP, CP and BHP can be in different wavelengths within one fiber and in different fibers as well. There are also some other implementations for the signaling process, such as the In-Band-Terminator (IBT) of taking control packets as in-band signaling [16], the Just-In-Time (JIT) of processing and parsing messages in hardware [17], the Just-Enough-Time (JET) scheduling scheme [18], or using MPLS [5].

The Optical Channel (OCh) layer refers to the wavelength channels within each fiber, including BP, BHP and CP

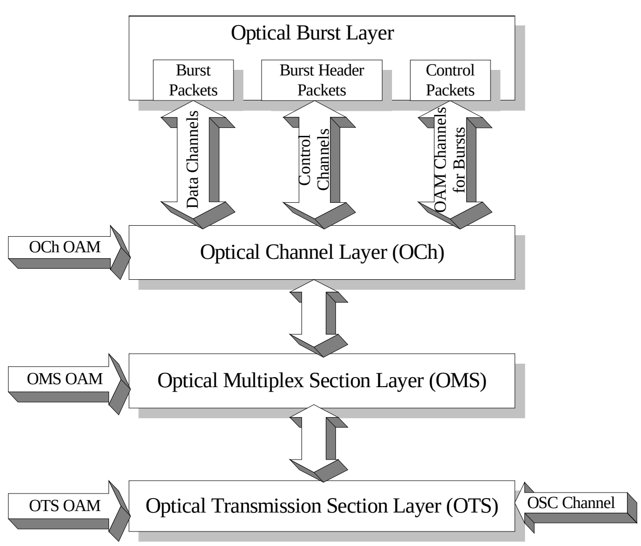

Fig. 3. Management information flow in the OBS network

channels. 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.

III. MANAGED OBJECT CLASSES

The management object class is an object-oriented abstraction of a specific physical or logical component that needs management function. Based on the functional architecture of the OBS edge node and the management information flow, Fig. 4 shows the classes of managed objects that correspond to the manageable resources or components inside the edge node. Their inheritance relationship from both equipment and logic signal view is illustrated to provide the static view of these behavior entities. All signal-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.

To model the dynamic behavior of the edge node, Fig. 5 demonstrates the object containment tree from equipment view, which gives the dynamic relationship between the objects instantiated from their corresponding managed object classes. However, the detail of this dynamic behavior such as the communication messages between these managed objects will be left for the specific implementation.

In addition to the common optical components defined in [7], the OBS edge node also contains the following major unique managed object classes.

- ElectricalMatrix: routes IP packets disassembled from bursts from ElectricalMatrixInputPorts to TraditionalIPOutputPorts, and ingress IP packets from TraditionalIPInputPorts into ElectricalMatrixOutputPorts. The ElectricalMatrix is controlled by the ForwardEngine.
- ElectricalMatrixInputPort: transmits disassembled bursts into the electrical matrix.
- BurstDisassembler: disassembles the ingress bursts into IP packets. It also collects statistical data such as burst error counts.
- ElectricalMatrixOutputPort: receives the IP packets from the electrical matrix.
- BurstAssembler: assembles the egress IP packets from ElectricalMatrixOutputPort into bursts.
- EdgeDataChannelGroup: is a container class for ElectricalMatrixInputPorts or ElectricalMatrixOutputPorts that go to the same neighbor node in the OBS network.
- EdgeControlChannelGroup: is a container class for ControlChannelInputPorts or ControlChannelOutputPorts that go to the same neighbor node in the OBS network.
- TraditionalIPInputPort: receives regular IP packets coming from various regular IP routers.
- TraditionalIPOutputPort: is a source for IP packets outgoing to regular IP routers.

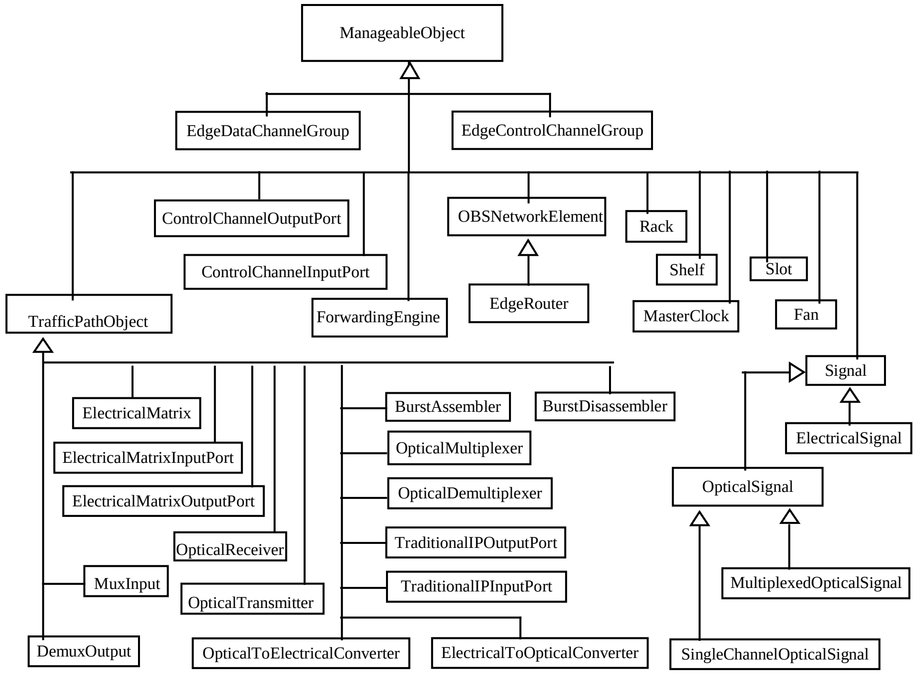

Fig. 4. Inheritance of managed object classes

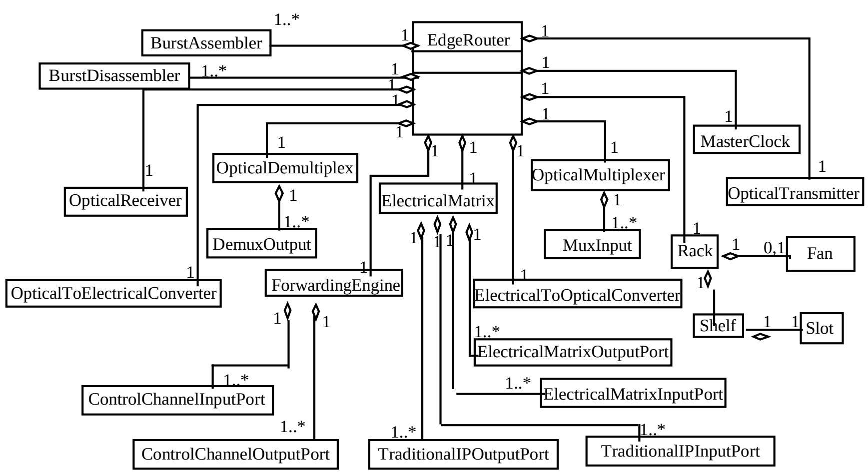

Fig. 5. Object containment tree from equipment view

IV. MIB STRUCTURE OF SNMP MANAGEMENT INTERFACE

The management of an OBS edge node relies on communications between this node and an external Operation System (OS). The edge node receives operation requests from an 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 functions in the edge node. Specifically, it is a collection of managed objects, each of which has attributes, generates event reports, and performs actions requested by an OS. The network element translates operation requests on managed objects in the MIB into real operations to be performed on the actual resources, executes these operations, and sends the results back to the OS.

A. Public MIB

One common practice for managing the IP network is to provide a standardized MIB so that various management applications from different equipment vendors can perform some basic functions. This interoperability provides great convenience for end users to accomplish some common tasks, such as the system maintenance and contact information. Currently, the most-often used standard public MIB for the management of TCP/IP-based networks is MIB-II defined in [19]. Therefore, to assure interoperability, the OBS MIB structure needs to include the support 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 the optical channel [20] and various routing protocols are also adopted.

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

B. Private MIB for OBS Edge Node

The private MIB defines the managed objects that model the functions and resources that are specific to OBS network edge nodes. The private MIB for edge nodes, as shown in Fig. 6, has the similar structure to that defined in [7] for OBS core nodes, and also uses the MIB-II structure as a template.

However, the Miscellaneous group in the private MIB of OBS edge nodes may also include parameters related to the following IP protocols for processing the regular IP packets.

- TCP — Transmission Control Protocol
- UDP — User Datagram Protocol
- PPP — Point-to-Point Protocol.
- IPv4 or IPv6
- BGP — Border Gateway Protocol
- IP forwarding
- MPLS or OSPF

V. Conclusions

In this paper, we have proposed a management information model for the edge node in an optical burst-switching network. After reviewing its functional architecture, we describe the management information flow between different technology layers in the OBS edge node. We also present the managed objects corresponding to the components and resources inside the OBS edge node. The class inheritance and object containment of these managed objects is illustrated using standard United Modeling Language description.

In the end, 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 edge 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 these edge nodes. However, the complete implementation of OBS edge nodes also requires considerations of other types of traffic at the optical burst layer such as Asynchronous Transfer Mode (ATM), Frame Relay, and Packets over SONET. Therefore, there are many further efforts remaining to be made to understand, enrich and complete this information model.

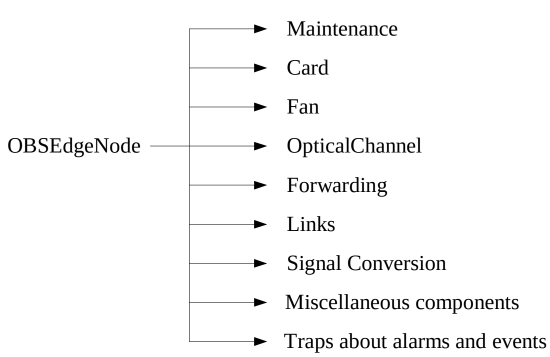

Fig. 6. 1st-level private MIB structure for OBS edge nodes

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