# An information model for the management of Optical Burst Switched networks

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***Abstract*— The Optical Burst Switching (OBS) paradigm proposes a new set of transmission protocols and network architectures that permits the high-utilization of the raw bandwidth available by Dense Wavelength Division Multiplexing at a moderate computational cost. Accordingly, it is necessary to extend the management plane of such networks to include the particular aspects of OBS, in order to guarantee the appropriate network operation. This paper analyzes the information required for the management of such OBS networks and proposes a new information model based on observed management use-cases. A simple data model is also specified to reduce the computational burden, but compliant with the modeled information.**

## I. Introduction

Optical Burst Switching (OBS) has been proposed as a cost-effective solution for the high-utilization of the raw bandwidth provided by the Dense Wavelength Division Multiplexing (DWDM) physical layer at a moderate computational cost [1]. However, the architecture and protocols involved in the operation of OBS networks are very different to those in traditional packet-switched networks. Then, it is necessary to extend the management plane to cope with the particularities of OBS.

Essentially, in OBS networks, there are edge nodes and core nodes connected together over the DWDM physical layer. The former aggregate incoming data packets (tens or hundreds of them) from the outer electronic domain building the so-called data bursts, which are switched at the core nodes all-optically. The all-optical treatment of data bursts removes the bottleneck of electronic switching, but brings many other difficulties, espacially those concerning the temporal allocation of data bursts when burst contention occurs, that is, when a data burst requests an output channel but all of them are already occupied.

At present, Fiber Delay Lines (FDLs), that is, a fiber segment of a given length, are the closest devices for temporal allocation of optical data, but they do not provide the same flexibility as electronic memories and are further expensive and hard to deploy. Hence, in the absence of FDLs, a set of solutions have been proposed to avoid contention at core nodes: reservation protocols, deflection routing and preemption.

In the most typical reservation protocol, Just-Enough Time (JET) [1], a Burst Control Packet (BCP) is sent ahead of the actual data burst to advertise the intermediate nodes of the imminent burst arrivals. The BCP informs the next hop in the path of the size and time arrival of its associated data burst, thus permitting the reservation of a time-slot at an output channel. After such reservation is made, the BCP is forwarded to the next hop in the path to do the subsequent reservation, and so forth.

When contention occurs, deflection routing is necessary to avoid data loss [2], [3]. Under this strategy, the BCP is given an alternative route to its destination, hence forwarded to a different node in the network. In this case, the network somehow acts as a buffering element. Clearly, the new route may have more intermediate nodes than the original one, thus requiring a higher offset time value. The network designer must take into account this aspect [3].

Finally, preemption techniques reassign to high-priority bursts the time-slot already reserved to earlier low-priority bursts reservations when contention occurs [4], [5].

As shown, the architecture and protocols involved in the operation of optical burst-switched networks are very different to those used in traditional electronic switching. Hence, the management plane must be extended to cope with their particularities, and a new set of variables need to be monitored and managed to keep the network at an optimal operation level.

Prior studies on the management of optical networks have mainly focused on configuration tasks, leaving a gap in other management functional areas, see for instance the projects DARPA MONET [6] and IST WINMAN [7]. Essentially, such works are mostly related to physical layer aspects, and OBS specific characteristics are not analyzed. Other works have considered the management of OBS [8], [9], but the information models presented only provide a description of the components in an OBS node, and do not define any concrete information to deal with the performance issues of OBS resources. Such information is indeed very meaningful since data bursts can be lost for several causes and each of them can help in detecting and identifying network malfunctioning.

Given the relevance of OBS technology in DWDM optical networks, this paper defines an information model that can be used by the network manager to check the performance of a set of OBS resources, including OBS burstifiers and OBS switches, as needed in current testbeds. The data model that implements such information model has to be simple, and must take into account the impact of the management on the overall performance of the resources.

The next sections define an information model and subsequent data model that include all the OBS aspects analyzed. The authors would like to note that this work has been defined within the Joint Project in OBS of the European Union e-Photon/ONe+ network of excellence.

## II. Management information model

This section presents a management information model for OBS networks, based on OBS-specific performance problems found in the literature. The following presents a set of experimental use-cases:

### *A. Number of burstification queues and classification algorithm*

At the OBS burst-assembler, the classification algorithm is in charge of dispatching the incoming packets to the different burstification queues. Typically, the algorithm follows a per-destination and per-Quality of Service policy. In this light, the information model must specify, for each queue, its size, the classification algorithm employed at the OBS edge node and the route or QoS label associated to that queue.

### *B. Burst assembly parameters at the OBS burstifier*

The way in which packets are assembled to generate a burst can be based on either a burst size threshold, a burst generation timer or a combination of both. Obviously, this assembly policy must be specified in the information model, together with its characteristic parameters, i.e. size and time thresholds. Note that such values must be specified per burstification queue.

Additionally, a number of statistics can be obtained during the assembly process, say number of assembled bursts per time unit, burst size and burst-assembly delay. This information may result useful on attempts to adjust the size and time thresholds, as well as the burstification algorithm.

### *C. Offset time and Quality of Service*

In OBS, the data burst follows its associated BCP with a given offset time of separation. Generally, this value is set to the network diameter (number of hops) multiplied by the maximum BCP sojourn time at the intermediate OBS nodes. The offset-time per queue should then be included in the information model.

Additionally, QoS differentiation can be provided by giving large offset-time values to high-priority bursts and vice versa, since the blocking probability decreases the larger the offset-time value is [1]. It is expected the cooperation between the information elements of the QoS-based classification algorithm and those concerning offset times.

### *D. Selective discard policies at the intermediate OBS switches*

At the intermediate nodes, selective discard policies can be implemented to resolve burst contention, according to some predefined priority policy. Indeed, high-priority bursts may even preempt low-priority bursts in service. Furthermore, if burst segmentation is activated, only the tail of the preempted burst is dropped, with significant savings in throughput [4]. Obviously, some QoS priority rank must be established before preemption occurs. The information elements that address these features are variables to enable or disable selective discards, preemption and segmentation.

Again, some management statistics can be derived: number of selective discarded bursts, number of preempted bursts and number of segmented bursts, all of them measured per unit of time and per priority level.

### *E. BCP sojourn time at intermediate switches*

In OBS, since BCPs are processed in the electronic domain, BCP buffering is sometimes required. This implies that BCPs can suffer *variable* sojourn time, which is a valuable piece of management information. If the reported sojourn times are too high, the network manager may proactively upgrade the Switching Control Unit (SCU) capacity. On the other hand, if upgrading is not an option, the network manager may increase the offset time values, as discussed in section II-C.

Rather than raw BCP sojourn-time measured values, it is more interesting to resort to other processed metrics, such as the minimum, the mean and the maximum sojourn times. Moreover, the authors have decided to use a delay histogram for this purpose, along with alarm thresholds for predefined maximum sojourn time values.

### *F. Burst loss due to insufficient offset time*

As previously stated, data bursts are switched all-optically, thus suffering only propagation delay. In this light, if the offset time value is smaller than the SCU sojourn time (including its buffering), it may well happen that data bursts actually "overtake" their associated BCPs. When this occurs, the data burst is obviously dropped.

Thus, a "burst overtake" may occur either by an overload situation in the SCU, or due to small offset time values. In any case, note that the burst is dropped *even though resources may be available*. Since this a major protocol fault, it is highly desired to include a variable in the management information model that counts the number of cases when bursts overtakes occur.

### *G. Burst loss due to occupancy or "retroblocking"*

Most losses in OBS networks are expected to happen due to output port occupancy. For constant offset times and bufferless OBS nodes, the burst dropping probability is given by the Erlang-B formula [10], if the number of sources being multiplexed is large enough to assume Poisson arrivals. However, it may also happen that a burst is dropped *even though the channel is empty by the time it arrives*. This is due to a previous reservation in the channel, from a burst that arrives after it. Such phenomenon is known as "retroblocking" [11]. Since both occupancy and retroblocking are different causes for burst loss, two different information elements are proposed, to count for both types of losses.

### *H. General performance statistics (dropped bursts, transmitted bursts, etc)*

Likewise other protocols, the management of an OBS node requires to keep track of general performance statistics at the

OBS layer. For instance, since OBS data bursts are transmitted transparently through the optical layer, there is no way to know if the burst payload has been corrupted on its way. However, such format transparency is a major advantage in OBS. Actually, any protocol data unit can be transparently encapsulated in an OBS burst, which is format independent.

In this light, counters for dropped burst (total) and transmitted bursts suffice. Another counter is also proposed for dropped bursts due to physical layer failures, in case the SCU cannot configure the switch fabric because of physical layer impairments. Note that this last counter may also be included in the physical layer group of the information model, instead of at the OBS layer.

### I. FDL statistics

Fiber Delay Lines are generally used to resolve contention in the time domain. A number of FDLs, with different lengths, may be present in the switch. The FDL utilization increases with the switch load. Thus, measuring the FDL utilization is important for network management purposes. As for the information elements, a counter per FDL is proposed, which stores the cumulative number of bursts using such wavelength.

## III. MANAGEMENT DATA MODEL

Once the information model has been defined in section II, this section deals with the design of a concrete data model. The information model and data model terms are used as defined in RFC 3444. For this, first of all, the design decisions are presented, based on the particular characteristics of OBS switches. Then, the data model is presented.

### A. Data model characteristics

To reduce the impact of the management on the OBS switches the data model has been defined in a way that takes into account its computational cost. The special characteristics of the OBS switches, which handle huge volumes of traffic, suggest that the load due to management tasks must be kept to a minimum.

To reduce the impact of management load, it is preferable to have counters and compute statistical values externally with respect to a time reference, instead of variables that automatically compute mean values or provide a probabilistic distribution. Obviously, the accuracy may not be as good as when the complete data is available, but this way provides a view of the behavior of the switches with low operational cost.

To obtain histograms easily, the authors propose the use of bins: a set of counters, each one related to a given interval, that counts the occurrence of an event in such interval. These bins can provide estimations of the distribution of burst sizes or sojourn times, in the same way an Ethernet frame size histogram is estimated in RMON MIB.

Another issue related to the particular characteristics of OBS networks is the use of large counters to avoid counter wraps due to the large volume of traffic. This is performed as in HCRMON MIB (RFC 3273), where 32-bit integer counters are replaced by 64-bit integer counters.

### B. Data model definition

At present, many different network management data models can be used to implement the described management information. Then, the data model has been defined by following an object-oriented approach in which some classes and attributes have been specified. The conversion to SMI tables or web service interfaces has been kept in mind. A way to convert classes to SMI tables has been defined following the ideas of [12]. Web service interfaces can be generated by defining XSD datatypes for each class, and providing operations to handle their instances. The object-oriented approach also allows an easy integration in the CIM model, leveraging its Metrics schema.

The defined data model is depicted in figure 1 as a UML class diagram. A plus sign (+) denotes a read-write property, whereas a minus sign (-) refers to a read-only property. Classes do not have methods to avoid conversion problems. Two main classes can be identified: *OBS Burstifier* and *OBS Switch* (shown in dark gray). *Histogram* (shown in light grey) is a helper class that allows the definition of bin-based histograms, as explained before. For this, nine bin upper bounds are included. These bounds are defined by a manager based on the statistics previously taken about maximum and minimum values. Once the bounds are defined, a *Histogram* instance starts to count the events of each bin.

The management information of an *OBS Burstifier* is contained in the following classes:

- *OBS Burstifier Queue*: It handles all the information related to each queue in the burstifier. There is one instance of this class per queue in the burstifier.
- *OBS Burstifier Queue Histogram*: It contains a bin-based histogram to measure the burst length and time taken to generate a burst. There are one or more instances of this class per *OBS Burstifier Queue* instance, which have to be instantiated by a manager.

On the other side, the management information of an *OBS Switch* can be modeled with the following classes:

- *OBS Switch* itself: It contains general settings. There is just one instance of this class per switch.
- *OBS Switch Statistics*: It includes statistical information on the lost and successfully transmitted bursts. There is one instance of this class per burst priority level.
- *OBS Sojourn Time*: It provides general statistics of the sojourn time of the BCPs.
- *OBS Sojourn Time Histogram*: It handles a bin-based histogram to measure the BCP sojourn time in the switch. There is one instance of this class per switch, and it has to be set up by a manager.
- *OBS Switch FDL*: It contains the information of the FDLs included in the switch. There is one instance of this class per FDL.

Two more classes have been defined, to handle alarms:

- *Delay Alarm*, which is generated when the sojourn time of a BCP reaches the defined threshold.

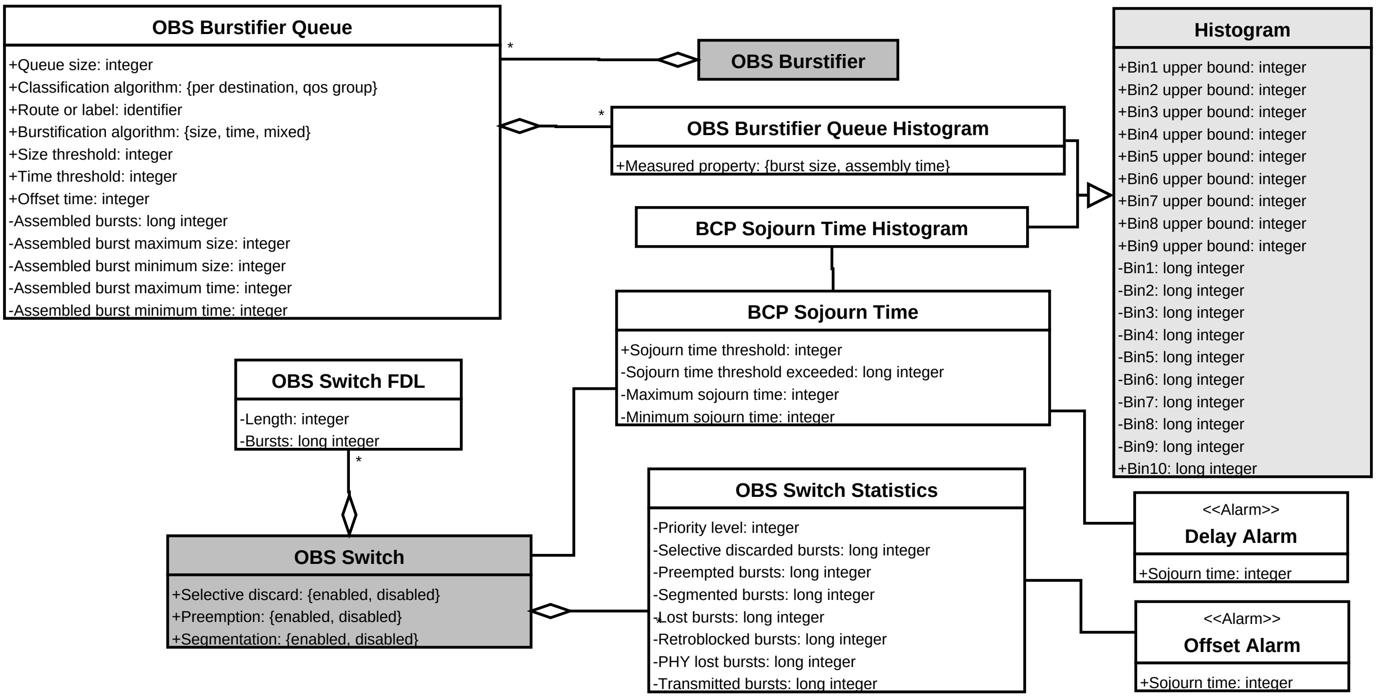


Fig. 1. Defined data model

- *Offset Alarm*, which generated when a burst is lost due to insufficient offset time.

It is expected that a manager can perform the tasks defined in section II by modifying and retrieving instances of the specified classes.

## IV. Conclusion

This paper presents a management information model for OBS networks based on common management tasks found in such networks. For this, OBS networks have been presented, providing the use-cases for a manager. From these use cases, the management information has been extracted. This information has been used later to define a data model. The data model is adapted to such networks, where the computational capacity of the switches has to be mainly used to schedule incoming bursts. Given the speed of these networks, polling of defined classes can be useful to detect and correct long-term network behavior. However, short-term behavior cannot be corrected in this way. Thus, other solutions based on autonomic networking principles should be defined.

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