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General Switch Management Protocol (GSMP) v3 for Optical Support

Status of this Memo

Abstract

This document describes the GSMPv3 for the support of optical switching. GSMPv3 controller SHOULD control optical label switches and manage optical resources on them. This document describes the extended functions of GSMPv3 for optical switching and explains operational mechanisms to implement them. It SHOULD be referred with [1] for the complete implementation.

Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119.

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1. Introduction

This document describes the extended functions and their mechanisms of GSMPv3 for the support of optical switching. The GSMPv3 is an asymmetric protocol to control and manage label switch. The label switches that are used for optical switching are all optical cross-connects (optical-optical-optical), transparent optical cross connects (optical-electrical-optical, frame independent), and opaque optical cross connects (optical-electrical-optical, SONET/SDH frames).These OXC (optical cross connect) systems can be IP-based optical routers which are dynamic wavelength routers, optical label switches, or burst/packet-based optical cross connects, and so on[2]. In this draft, we do not limit specific OXC systems, but aims to provide the general functions of optical switching and services for connections in general optical switches.

GSMPv3 is a label switch controller and provides a control interface to optical switches. Therefore, it SHOULD define and add services for optical switching and resource abstractions. The basic optical resources used in connection setup are different with them of legacy networks. In optical switching, basic connection units are a fiber, a wavelength, or a burst and they are assumed to be processed in optical domain without optical/electrical/optical conversion. It is impossible to define services, traffic control, and QoS guarantee in packet or cell level. New messages are needed to process optical services, optical connection management, and so on, in real time because optical switching requires real time process with low message processing overhead. This draft describes optical resources, connection management, optical services, and switch configuration which can be applied in optical domain generally.

One of the important OAM functions is protection and restoration functions. In the current situation where a single fiber delivers several Tb/s through several wavelengths, when even a single link gets cut it makes a huge turbulence. Therefore GSMPv3, as an optical switch controller, MUST have protection and restoration capabilities of switches and connections. By extending the management messages of GSMP, this function will be implemented. This draft also deals with several recovery capabilities of the GSMPv3.

For the complete implementation this document MUST be referred with [1].

2. Common Definitions and Procedures for Optical Support.

Common definitions and procedures which are not mentioned in this document follow [1].

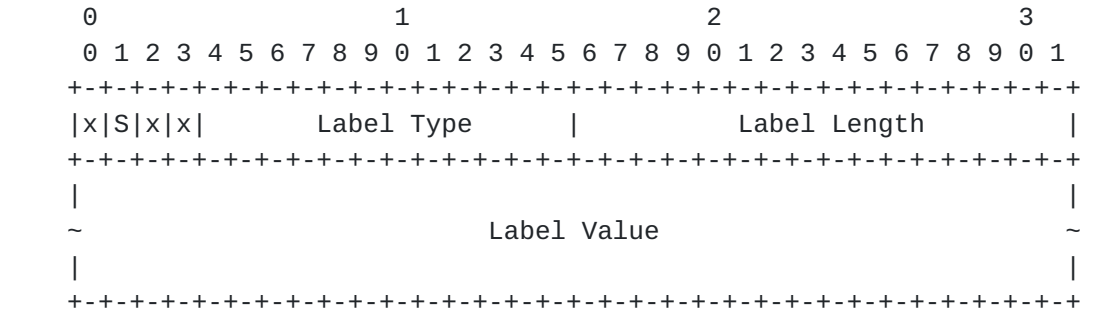
2.1 Labels

Labels are the basic identifiers for connections. In order to setup connections in optical switch, new labels MUST be defined. Newly defined labels identify entities that are to be switched in optical switches. GMPLS defines packet switching capable, TDM switching capable, lambdas switching capable, fiber switching capable interfaces, and it introduces needs of generalized labels to support them [3][4]. So far, GMPLS does not defined labels to be used for optical switching (label formats and encoding schemes), but GSMPv3 MUST support all types of label that to be defined in GMPLS. The following lists, especially related to lambda/fiber switch capable interfaces, are the labels to be supported in optical switching [2][3][4][7][8][10].

- a single fiber in a bundle
- a single waveband within a waveband (or)fiber
- a single wavelength within a fiber
- an optical burst within a wavelength

These labels can be encoded in a common structure composed of three fields, a Type, a Length, and a Value [1]. TLV types for optical support in GSMPv3 are not defined yet.

All labels will be designated as follow:



S: Stacked Label Indicator
S field is not used in this extended version of GSMPv3 because labels for optical support only carry a single level of label [4].

Label Type: 12 bit

Label type for optical support MAY be identified with the above four types of optical switching.
Label type for optical support is TBD.

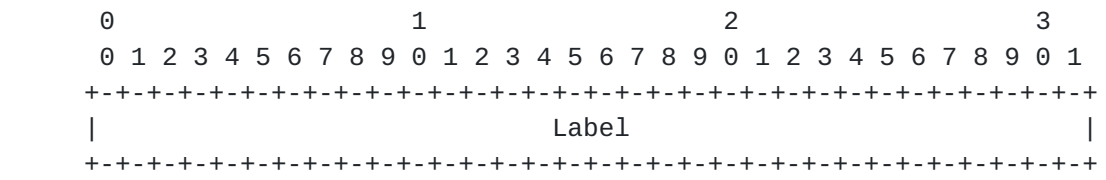
Label value: Variable
Carries label information. The interpretation of this field depends on the type of the link (or the type of connection) over which the label is used. Label value for optical support is TBD.

The other fields are defined in [1] and referred in it.

2.1.1 Labels for Fiber

This label indicates a fiber to be used for a connection establishment in optical switching. The label value only has significance between two neighbors, and the receiver MAY need to convert the received value into a value that has local significance.

If the label type = labels for fiber, the label MUST be interpreted as labels for fiber and the label for fiber has the following format:



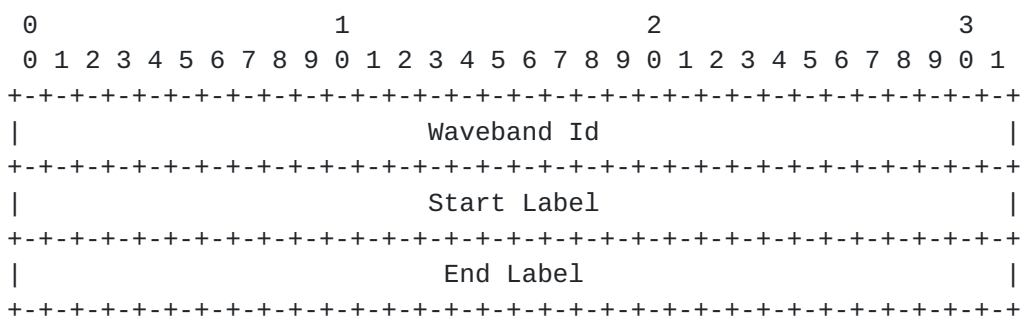
Label: 32 bits
Indicates a label for fiber to be used.
Label encoding is TBD.

2.1.2 Labels for Waveband

A waveband is a set of contiguous wavelengths which can be switched together to a new waveband [3][4]. It MAY be desirable for an optical cross connect to optically switch multiple wavelengths as a unit since it MAY reduce distortion on individual wavelengths and MAY allow tighter separation of individual wavelengths. Waveband switching introduces another level of label hierarchy and as such the waveband is treated the same way all other upper layer labels are treated. The waveband label is defined to support such a waveband switching. The waveband label can be encoded in three parts; waveband ID, start label, and end label. The start label and the end label represent the lowest value of wavelength and the highest value of wavelengths.

If the label type = labels for waveband, the label MUST be interpreted as labels for waveband and the label for waveband has the

following format:



Waveband Id: 32 bits
A waveband identifier. The value is selected by a sender and reused in all subsequent related messages.

Start Label: 32 bits
Indicates the lowest value of wavelength in the waveband.

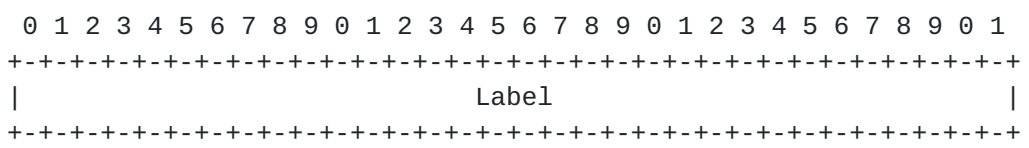
End Label: 32 bits
Indicates the highest value wavelength in the waveband.

The start/end label are established either by configuration or by means of a protocol such as LMP [6]. They are normally used in the label parameter of the Generalized Label one PSC and LSC [3][4].

2.1.3 Labels for Wavelength

The label indicates a single wavelength to be used for a connection establishment in optical switching. The label value only has significance between two neighbors, and the receiver MAY need to convert the received value into a value that has local significance.

If the label type = labels for wavelength, the label MUST be interpreted as labels for wavelength and a format of the label for wavelength is given as the below:



Label: 32 bits
Indicates label for wavelength to be used.
Label encoding is TBD.

2.1.4 Labels for optical burst switching

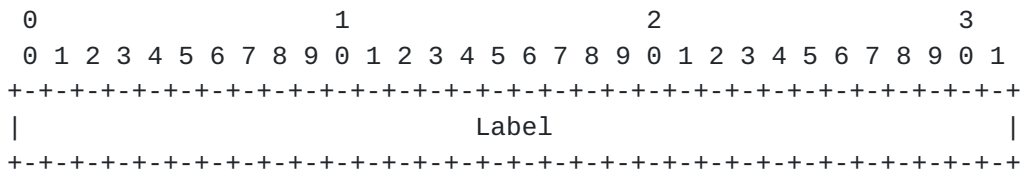
The label for optical burst switching represents a label for

switching optical burst data.

Optical data burst switching, which utilizes finer granularity in time domain in a coarse granularity such as a wavelength, is a new connection entity in optical domain [7][8]. Connection setup for optical burst includes reserving time on the transport medium for the client.

This time is characterized by two parameters: start time and duration of data burst. These values define a fast one-way reservation. Upon a request for setup of a burst connection, the GSMP controller MUST perform appropriate Connection Admission Control for the start time and duration of data burst specified. If the connection is allowed, it MUST signal these parameters to the burst switching device to reserve the exact bandwidth required [7][8]. The burst switch MUST perform the switching operation autonomously, using the synchronization methods prescribed for the burst network it is operating in.

If the label type = labels for optical burst switching, the label MUST be interpreted as labels for burst switching and a format of the label for optical burst switching is given as the below:



Label: 32 bits
Indicates label for a burst level connection.
Label encoding is TBD.

2.1.5 Label Range

The basic label range to be used in each port is specified by the Port Configuration or All Port Configuration message. The Label Range message allows the range of labels supported by a specified port to be changed. The controller MUST allocate the label range with consideration of optical characteristics when assigning the labels for a connection because a connection is established per optical burst, wavelength, waveband, and fiber in optical domain. Since the basic label range varies in switches and the labels for the connections can be different due to the optical characteristics, GSMP does not treat them. However, the following lists SHOULD be considered and the available label ranges SHOULD be applied in the Label Range message.

- When allocating a label for a wavelength, the label SHOULD be allocated with consideration of wavelength continuity. For

satisfying requirement of wavelength continuity in a connection, the label SHOULD be allocated to maintain the same wavelength for

it. The controller MUST manage the available labels and support the constraint.

- The labels to be used for waveband switching MUST be contiguous, because the waveband switching is possible only in a set of contiguous wavelengths. The decision mechanism for the available label range is out of scope of GSMPv3.

- GMPLS supports bi-directional symmetric LSPs setup [3][4]. To setup a bi-directional LSP two unidirectional paths MUST be independently established. For doing so, the presence of an upstream label in the appropriate signaling message indicates the bi-directional LSP setup and two labels are allocated for them. The GSMPv3, therefore, SHOULD allow appropriate labels for them. In order to avoid contention for labels, much care SHOULD be taken in choosing the two labels. To choose the labels to avoid contention is out of scope of GSMPv3.

3. Connection Management Messages

Connection management messages, which are used for establishing, releasing, modifying, and verifying connections across the switch by the controller, SHOULD operate for optical switching. Since the GSMPv3 does not process each packet in optical domain, traffic related fields used to specify connections in the messages are not dealt with and then it makes possible to process the message faster. Connection management messages also SHOULD support restoration capabilities of optical switch and these are mainly dealt with in the following sub-sections.

The general message definition and semantics in this section follow [1] and the other untouched items are dealt with in it.

3.1 Add Branch Message

The Add Branch message is used to setup a connection. Especially, it SHOULD support restoration capability in optical switches. For 1+1 dedicated recovery, it is required to make an additional connection as a backup connection to protect an original connection against a failure. Additional fields are not required in the Add Branch message to support the restoration capability since two connections are used for delivering data traffic simultaneously and an egress node selects one of them. Since the two connections are established for one connection, connection-related fields, such as input port/label, output port/label, SHUOLD be carefully set in order to distinguish them. The controller SHOULD know the whole status of the switch and

manage the information base.

3.2 Delete Tree Message

The message format and semantics in this section follows [1].

3.3 Delete All Input Port Message

The message format and semantics in this section follows [1].

3.4 Delete All Output Port Message

The message format and semantics in this section follows [1].

3.5 Delete Branches Message

The message format and semantics in this section follows [1], and optical switching related contents will be added.

3.6 Move Output Branch Message

The Move Output Branch message is used to change the current output port label to the new output port label for re-establishing the existing connection. It can be used to support restoration capability. Since to re-establish output port of a switch at an ingress node is to change a start point of the current connection, it can be used for 1:1 dedicated recovery or 1:N (M:N) shared recovery where an ingress node begins a connection and it takes responsibility for recovery of the connection. Upon a fault occurring, in order to setup a new backup connection for the failed working connection, the new port in upstream node SHOULD be connected to the current connection by using this message.

For configuring a new backup connection, the following fields of Move Input Branch message SHOULD be set as following.

- Old Output Port = failed working connection's output port ID
- Old Output Label = failed working connection's output label ID
- New Output Port = newly configured reserved backup connection's output port ID
- New Output Port = newly configured reserved backup connection's output label ID

This message is additionally used to move back to the original connection from the backup connection in revertible mode after a recovery completed. In this case, Old Output Port/Label are for the currently used backup connection, and New Output Port/Label are for

the restored working connection

3.7 Move Input Branch Message

The Move Input Branch message is used to change the current input port label to the new input port label for re-establishing the existing connection. It is also used to support restoration capability. For 1:1 dedicated recovery or 1:N (M:N) shared recovery, the message can be used to configure backup connection at an egress node. By setting Old Input Port/Label as a failed working connection and New Input Port/Label as a reserved backup connection, recovery of the failed working connections is achieved.

It is also used to move back to the original connection from a backup connection for the revertible mode after a recovery completed. The new port/label in this message sets that of the restored original connection.

The other untouched items and fields in these messages are dealt with in [1] and referred in it.

4. Reservation Management Messages

The GSMPv3 allows a switch to reserve resources for connections before establishing them through Reservation Management messages. Reservable resources are bandwidth, buffers, queues, labels and etc. In this extended version of GSMPv3 for optical support, the resources imply optical resources, such as data burst, wavelengths, fibers, and so on.

With these messages, restoration capabilities of a switch are supported. Especially, in 1:N (M:N) shared recovery scheme, a spare connection is reserved for N working connections. The GSMPv3 SHOULD use the reservation request messages for reserving a backup connection. The GSMPv3 controller SHOULD have mapping information between a shared backup resource and N working connections. Whenever the GSMPv3 uses the reserved resource for a failed working connection Add Branch message is used to establish a new connection with New Port/Label of one of N working connections.

Or any other cases, the reserved resources are used as followed in [1]. The message format and semantics in this section follow [1] and the other untouched items are dealt with in it.

4.1 Reservation Request Message for optical burst

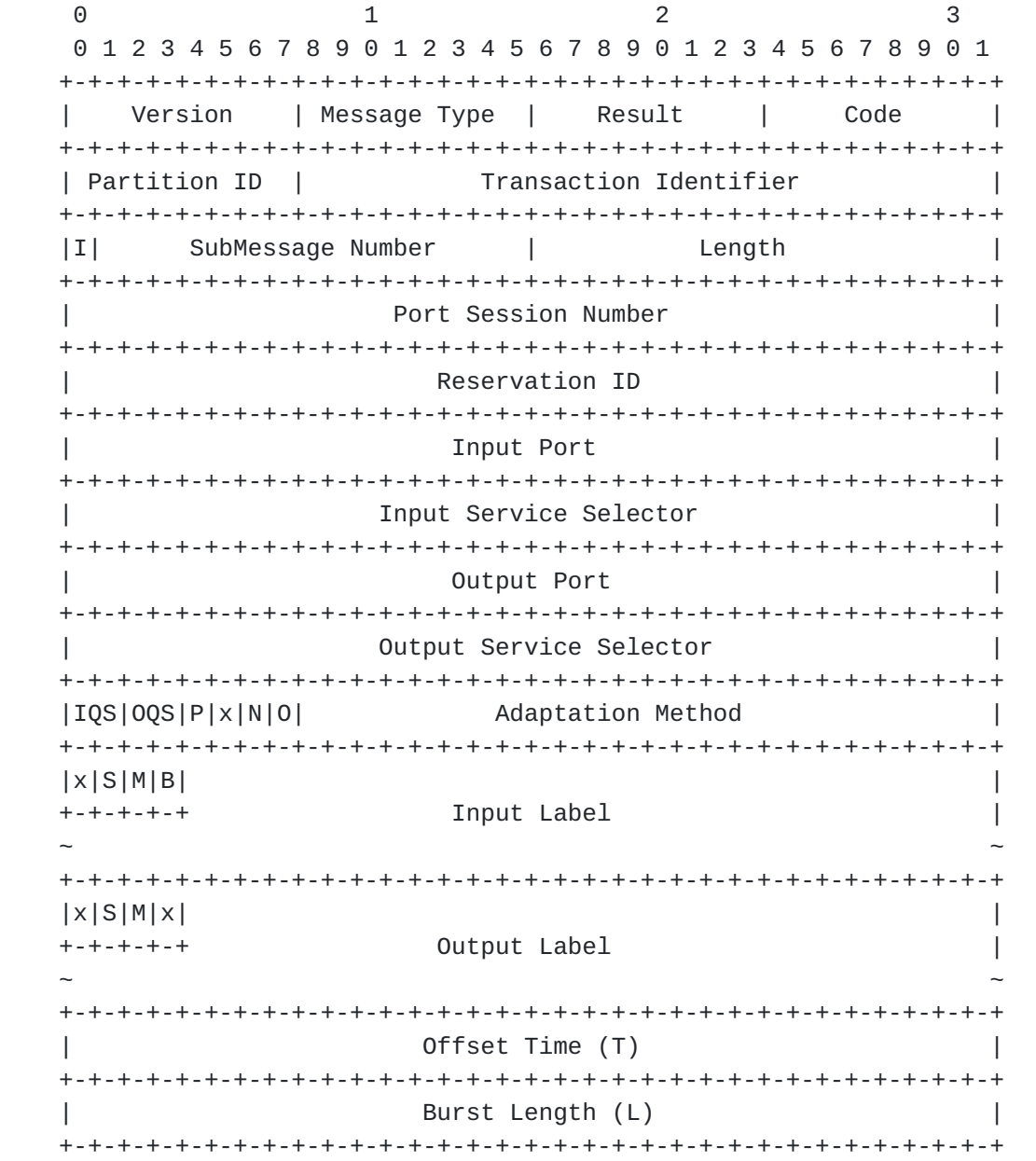
Reservation Request message SHOULD support new connections per data burst, based on time-delayed reservation in optical domain. In order

to configure connection per burst, two parameters, offset time and burst length, SHOULD be add on the message. When a controller

receives a request for a burst connection setup it sends a Reservation Request message with the two fields. The switch then waits for offset time to establish the connection and then automatically set it up. After burst length time, it releases the connection.

Message type = TBA

The Reservation Request message for optical burst has the following format.



Note: Fields and Parameters that have not been explained in the Subsection follow [1].

Offset Time (T); TBD

This field is the time between a connection request reception and the start of the connection for the data burst.

Burst Length (L); TBD
This field is the time duration of data burst

4.2 Delete Reservation Message

The message format and semantics in this section follows [1].

4.3 Delete All Reservations Message

The message format and semantics in this section follows [1].

5. Management Message

5.1 Port Management Message

The message format and semantics in this section follows [1], and optical switching related contents will be added.

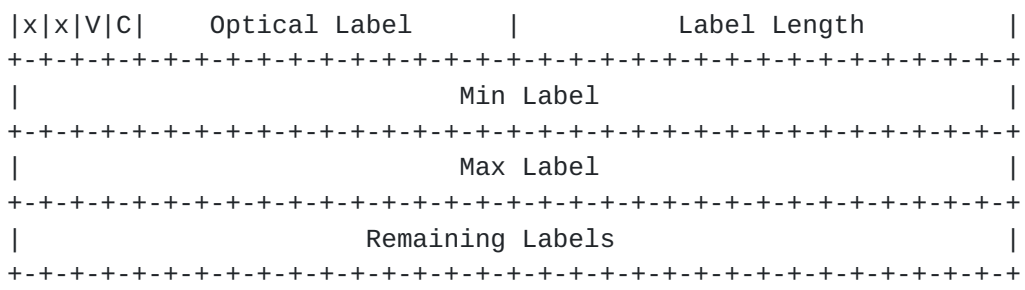
5.2 Label Range Message

The label range, which is specified for each port by the Port Configuration or the All Ports Configuration message, can be specified to the range of label supported by a specified port and to be changed by using Label Range message. Since the granularity of each connection is different in optical domain each port SHOULD allow the label range changeable in ports. In addition, a port MAY have wavelength converters with full or limited capability so that each port MAY have different limited labels. In case of waveband switching, a single label for waveband connection is used for a set of wavelengths in the band. To support these cases, the Label Range message is used.

The general usage and massage format of this message follows [1].

5.2.1 Optical Label

If the Label Type is equal to optical label, the label range message MUST be interpreted as an Optical Label. Label Range Message format follows [1] and the Label Range Block has the following format:



V: Label
The Label flag use is port type specific.
TBD.

C: Multipoint Capable
Indicates label range that can be used for multipoint connections.
This field is not used in the draft.

Min Label: TBD
The minimum label value in the range.

Max Label: TBD
The maximum label value in the range.

Remaining Labels: TBD
The maximum number of remaining labels that could be requested for allocation on the specified port.

6. State and Statistics Messages

The State and Statistics messages allow a controller to request state and statistics of connections of a switch. They SHOULD be extended to monitor the statistics related to ports and connections for optical transmission.

6.1 Connection Activity Message

The message format and semantics of the message follows [1], and optical switching related contents will be added.

6.2 Statistics Messages

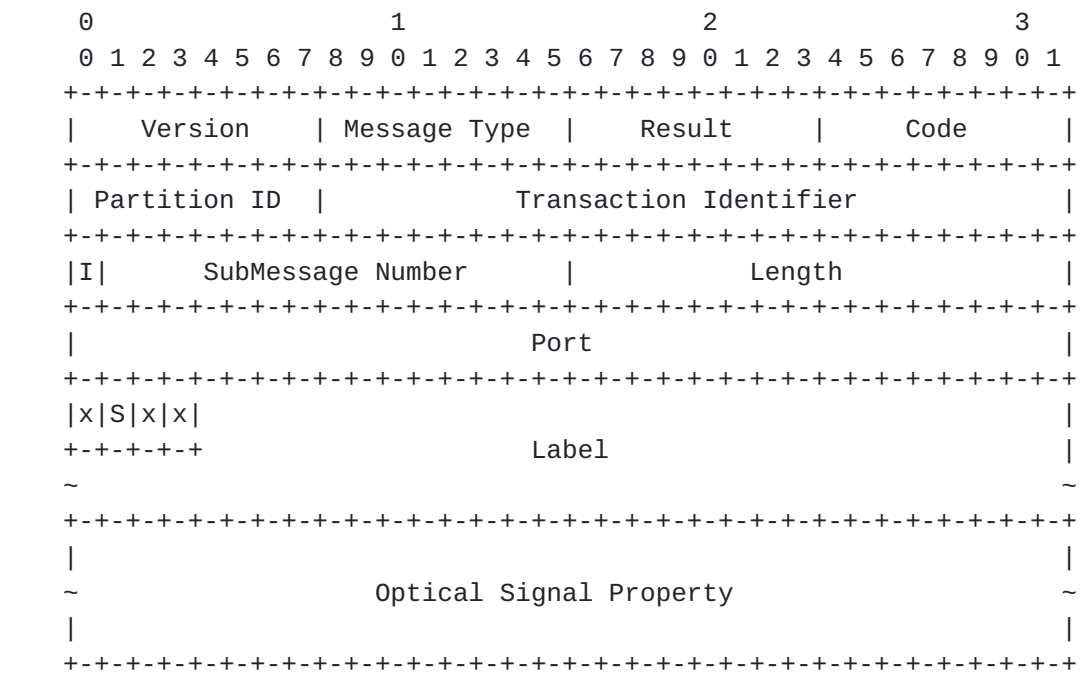
6.2.1 Optical signal statistics Message

The statistics messages are used to query the performance statistics related to ports and connections for optical transmission. Since the current statistics messages in [1] report the statistics related to

traffic states per cells, or frames, new fields SHOULD be added into the message for querying optical support. The statistics contain

optical transmission characteristics which specify transmission QoS of connections. Transmission performance is typically defined in terms of signal performance with reference to noise level, or by the signal-to-noise ratio (SNR), and spectral occupancy requirement or signal power level. Optical Signal Statistics message SHOULD contain Optical Signal Property which specifies the transmission property of connections as shown in the below.

Optical Signal Statistics Message Type = TBA



Optical Signal Property; variable
This field implies quality of transmission signal in a connection so that it informs a controller signal degradation or loss of signal. This field MAY consist of several sub-TLVs which specify the optical signal statistics in detail and they will be further added on this message. This information MAY result in an alarm of link failure.

The format and semantics of Optical Signal Property is TBD.

The other statistics messages are not dealt with in the section follow [1].

6.3 Report Connection State Message

The message format and usage in this section follows [1], and optical switching related contents will be added.

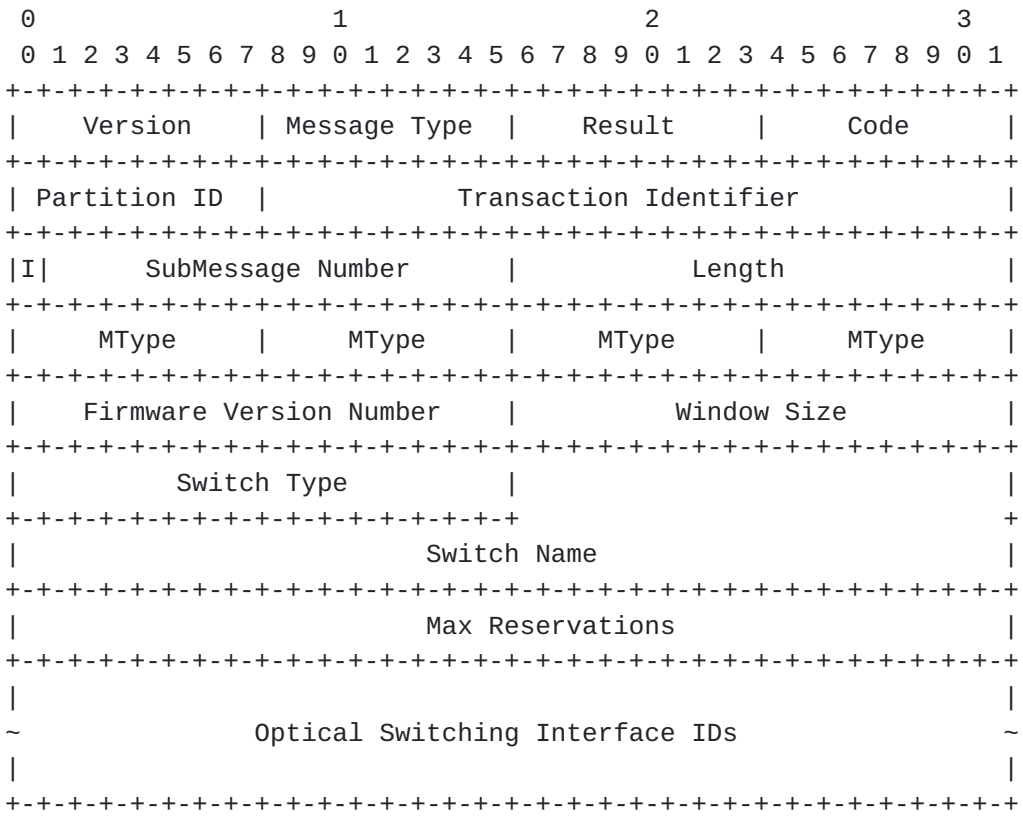
7. Configuration Messages

The configuration messages allow a controller to discover a capabilities of optical switch. Switch configuration, port configuration, and service configuration messages are defined for these functions.

7.1 Optical Switch Configuration Message

Since an optical switch MAY be able to provide connection services at multiple transport layers, and not all switches are expected to support the same transport layers, the switch will need to notify the controller of the specific layers it can support. Therefore, the switch configuration message MUST be extended to provide a list of the transport layers for which an optical switch can perform switching. For supporting various types of switching capable interfaces, Optical Switch Configuration Message SHOULD contain the Switching Interface ID.

Message Type = TBD



Optical Switching Interface ID: variable
TBD

The following lists are the possible switching capable layers.

- switching per optical burst
- switching per a single wavelength
- switching per a waveband

- switching per a single fiber
- switching per a fiber bundle

7.2 Port Configuration Message

The port configuration message informs a controller configuration information related to a single port. Ports in optical switches differ from those in electrical switches. The ports defined in GSMPv3 imply a single physical link and several connections are specified with labels in a port. However, a single port does not identify a single link in optical domain. A port can imply a set of fibers, a single fiber, or a single wavelength. Therefore different types of port SHOULD be identified in GSMPv3. Moreover, OXC can have many bays which contain hundreds of shalves which have tens of thousands of port. Therefore, physical bay and shelve identifiers also SHOULD be defined and encoded in the port configuration message.

The basic format and usage of Port Configuration message follow [1]. The following new port types are defined. In optical domain, PortType can be classified into per fiber bundle containing several fibers, a single fiber containing several wavelengths, or a single wavelength.

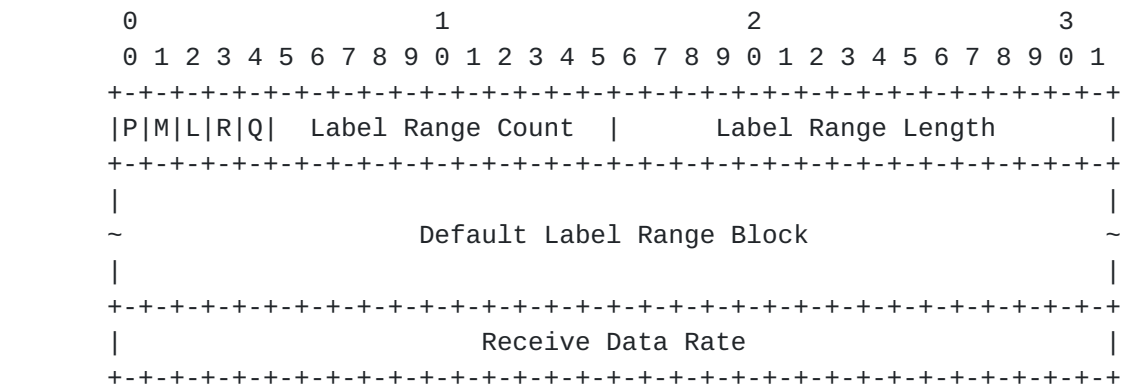
PortType = optical switching (TBA by IANA)

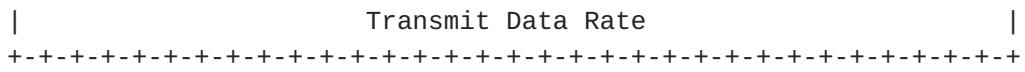
This port type further can be classified into several types as following.

PortType = fiber in optical switching
PortType = wavelength in optical switching
...

7.2.1 PortType Specific Data for Optical Switching

The format and usage of Port Specific Data in Port Configuration message depends on the PortType value and the basic format of it is given as following [1].




Transmit Data Rate

```
|  Port Status  |   Line Type   |  Line Status  |  Priorities   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Physical Slot Number      |     Physical Port Number      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Note: Fields and Parameters that have not been explained in the Subsection follow [1].

In this section, we specify some fields for supporting optical switching as following. If PortType is equal to optical switching,

Receive Data Rate
The maximum rate of data that may arrive at the input port (interface) in;

Bits/sec for PortType = Optical Switching

Transmit Data Rate
The maximum rate of data that may depart from the output port (interface) in;

Bits/sec for PortType = Optical Switching

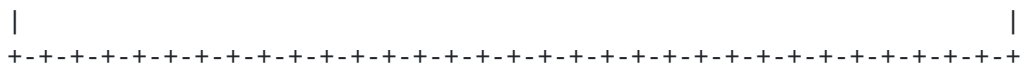
Line Type
The type of physical transmission interface for this port. The line type for optical support depends on switching interface for each switching entity, such as for wavelength-related port or fiber-related port. This field MAY define bit rate of wavelength, fiber type. The following values can be identified for optical support.

PortType = Optical Switching: TBD

Physical Slot Number
The physical location of the slot in optical switching (or OXC). Since the OXC systems can have many bays which contain hundreds of shelf which have tens of thousands of port this field SHLOULD identify the slot. For doing so, the field MAY be partitioned into several sub-fields to define bay, shelf, and slot.

The default label range block for optical switching has the following format.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|x|x|x|x|       Label Type      |          Label Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
~                         Label Value                           ~
```



Label Type: 12 bit
Label type for optical support. Each encoding type of the labels is TBD.

Label value: Variable
Carries label information. The interpretation of this field depends on the type of the link (or the type of connection) over which the label is used. Min Label and Max label value imply the range of available optical labels. Each encoding type of the labels is TBD.

7.3 All Ports Configuration Message

The message format and usage of it follows [1], and optical switching-related contents follow section 7.2.

7.4 Service Configuration Message

The Service Configuration message requests an optical switch report the configuration information of the supported services. The requested services are identified in service ID in the Add Branch message or the Reservation Management message. The service model is defined with traffic parameter, QoS parameter, and traffic control elements in [1], but these parameters can not be used to specify the optical services. Therefore this message SHOULD be modified to support optical services with newly defined capability sets. The services supported at optical switches SHOULD be defined for dealing with optical burst, wavelength, waveband, and fiber connection.

7.4.1 Optical Service Configuration Message

TBD.

8. Event Messages

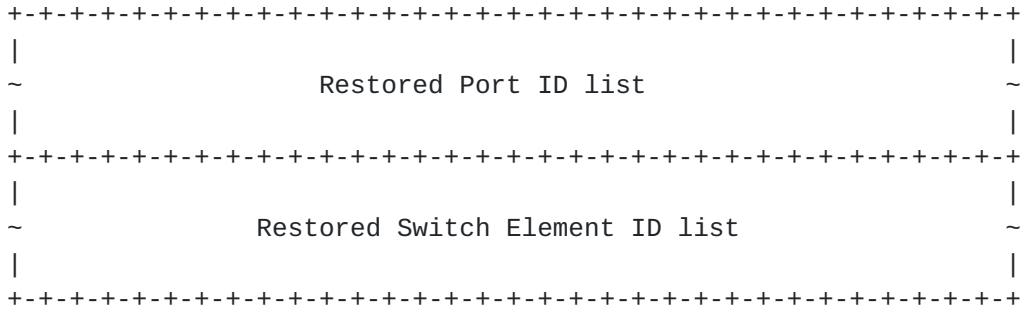
The Event messages allow a switch to inform a controller of certain asynchronous events. In this version of GSMPv3, asynchronous events mainly deal with recovery-related events. The indication of these asynchronous events related to ports and switch elements can inform failure of them to the controller and it can initiate a fault recovery mechanism. The basic message format and usage of it SHOULD be referred to [1]. The two messages, Restoration Completion message and Fault Notification message, are used to notify a controller fault-related events of a switch.

8.1 Restoration Completion Message

For 1+1 dedicated recovery, a failed working connection is switched over to another dedicated connection without a controller's recognition. This message is used to inform the controller restoration completion of the switch. This message contains failed working connection ID and restored backup connection ID.

Message Type = TBA

If a message type is equal to Restoration Completion message the following sub-TLVs SHOULD be added on the message in order to notify restoration completion to a controller.

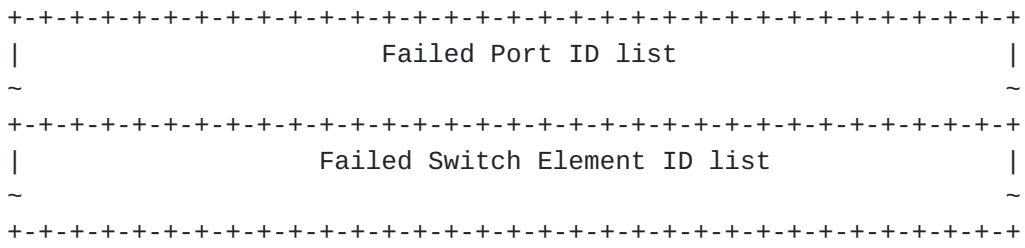


8.2 Fault Notification Message

This message is used to inform a controller a fault occurring in a switch. The possible faults are link failure from cutting off (affecting wavelengths, fibers, fiber bundles), port failure, or switch modules. For the notification purpose, the following sub-TLV SHOULD be added in Event message.

Message type = TBA

If a message type is equal to Fault Notification message the following sub-TLV SHOULD be added on the message in order to notify a fault in a switch to a controller.



Failed Port ID list; variable
This field describes the failed port ID which contains different types of port which indicate wavelength-related port, fiber-related port, or fiber bundle-related port. This field can consist of several sub-TLVs to indicate the failed elements.

Failed Switch Element ID list; variable

This field describes the failed optical switch fabric such as, wavelength converters, cross connect elements, and so on. It depends on the optical switching systems.

The encoding of Failed Switch Element is TBD

9. Optical Service Model Definition

TBD

10. Failure Response Codes

This chapter describes the failure and warning states which can occur in setup optical connections. The following lists are the codes that SHOULD be defined and added in the Failure Response messages. These codes MAY be added more when the services for optical switching are defined.

If the switch issues a failure response it MUST choose the most specific failure code according to the following precedence. The code numbers will be assigned in IANA.

Optical Connection Failure

- recovery failure
  Due the limitation of available resource for backup connection, for example, multiple links failure, the switch can not be succeeded the recovery procedure for shared protected connection.

- waveband connection setup failure
  There are not available wavelengths which belong to the range of min and max limits of the waveband

- reservation failure for optical burst
  In case of delayed reservation in time is not exactly matched, the reservation of optical burst can be failed.

The following list gives a summary of the failure codes defined for failure response messages:

- no available label for shortage of available wavelengths
- no available resource for recovery
- no available resource for waveband connection setup
- no match for the delayed reservation for optical burst connection

11. Security Considerations

This document does not have any security concerns. The security requirements using this document are describes in the referenced documents.

Appendix I. Protection and Restoration Capability in GSMPv3

The GSMP controller MUST support the protection and restoration capabilities because the optical switch delivers several Gbps data traffic in a single wavelength. To achieve fast protection and restoration, the optical switch is capable of taking an action independent of the GSMP controller, then it informs the controller after completing the restoration [2]. This differs from the master-slave relationship in GSMP.

Recovery mechanisms do not distinguish path (end-to-end) and link recovery in GSMPv3. The difference of them is considered in signaling protocol. In case of dynamically calculating the backup link after a fault occurs, GSMPv3 establishes a new backup link by using the existing Add Branch message. Therefore, this draft considers pre-planned recovery mechanisms, such as 1+1 dedicated recovery, 1:1 dedicated recovery with/without extra traffic, and 1:N/M:N shared recovery.

The label switch SHOULD provide the protection and restoration capabilities in order to provide the recovery mechanisms. For example, an ingress/egress node reserves backup resources according the each recovery mechanism, and setup the switch fabric. Then, GSMPv3 is used to control the switch.

In this section, the recovery mechanisms which can be provided by GSMPv3 is specified with including a fault notification, and restoration, and related required messages. For example, the port configuration command MUST be extended to allow autonomous protection mechanism. The current GSMP connection management also MUST be extended to support this function. In the following subsections, the supported recovery mechanisms in GSMPv3 are introduced.

1.1 1+1 dedicated recovery mechanism

In this recovery mechanism, GSMPv3 utilizes the existing Connection Management messages. It is not necessary to notify a fault to the controller and restore the failed working link at physical layer. Then, the switch notifies the recovery completion to the controller by using Event message. The recovery procedure of the mechanism follows.

- Backup link configuration
Use Add Branch message as for working link.

- Fault notification
Let physical layer process before GSMPv3 recognizes.

- Recovery procedure
Let physical layer process before GSMPv3 recognizes.

- After recovery completion;
Firstly, the switch notifies recovery completion to the controller by using Restoration Completion message, then

* Revertible mode; GSMPv3 uses Move Input message to switch the currently used backup link to the restored working link at an egress node.

* Non-revertible mode; GSMPv3 deletes the restored working link by using Delete Branch message, and then configures a new backup link by using Add Branch message.

1.2 1:1 dedicated recovery mechanism

- Backup link configuration
An ingress/egress node configure a backup link by using Reservation Request message, and core nodes use Add Branch message to reserve backup link. In this recovery mechanism, extra traffic can be delivered through the backup link. If it could be possible, core nodes use Reservation request message, not Add Branch message. However this draft only considers the former case as this mechanism.

- Fault notification

* Fault detected from signaling protocol; GSMPv3 have already known the fault, it directly go into the recovery procedure.

* Fault detected from the switch; Event message (esp. Fault Notification message) is used to notify the fault to the controller.

- Recovery procedure
An ingress node uses Move Output message and an egress node used Move Input message in order to configure a backup link. Since the backup path is configured through the network, core nodes do not take any action for recovery.

- After recovery completion
Firstly, the switch notifies recovery completion to the controller by using Restoration Completion message, then

* Revertible mode; GSMPv3 uses Move Input message (at an ingress

node) and Move Output message (at an egress node) to switch the currently used backup link to the restored working link at

destination node. The backup link is still used for backup by using Reservation Request message.

* Non-revertible mode; Delete Branch message can be used to delete the restored working link. GSMPv3 uses Reservation Request message to reserve new backup link for the working link.

1.3 1:N/M:N shared recovery mechanism

- Backup link configuration

Reservation Request message is used to configure a backup link. Since several working links (= N) share one backup link (1:N) or several backup links (M:N) GSMPv3 SHUOLD know the sharing working link IDs for the backup links. Resource management of GSMPv3 is out of scope of this draft.

- Fault notification

* Fault detected from signaling protocol; GSMPv3 have already known the fault, it directly go into the recovery procedure.

* Fault detected from the switch; Event message (esp. Fault Notification message) is used to notify the fault to the controller.

- Recovery procedure

When GSMPv3 is notified a fault, it uses Add Branch message to configure a new working link by using reserved backup link.

- After recovery completion

Firstly, the switch notifies recovery completion to the controller by using Restoration Completion message, then

* Revertible mode; GSMPv3 uses Move Input message (at an ingress node) and Move Output message (at an egress node) to switch the currently used backup link to the restored working link at destination node. The backup link is still used for shared backup by using Reservation Request message.

* Non-revertible mode; Delete Branch message can be used to delete the restored working link. GSMPv3 uses Reservation Request message to reserve new backup link for the working link.

Appendix II. GSMPv3 support for optical cross-connect system

The GSMPv3 controls and manages the optical cross-connect systems as label switches. The optical cross-connect (OXC) is a space division switch that can switch an optical data stream on an input port to an output port. The OXCs are all optical cross-connects (optical-

optical-optical), transparent optical cross connects (optical-electrical-optical, frame independent), and opaque optical cross

connects (optical-electrical-optical, SONET/SDH frames).These OXC (optical cross connect) systems can be IP-based optical routers which are dynamic wavelength routers, optical label switches, or burst/packet-based optical cross connects, and so on[2].

The OXC system consists of switching fabric, multiplexer/ demultiplexer, wavelength converter, and optical-electrical/ electrical-optical converter. Multiple wavelengths are multiplexed or demultiplexed into a fiber. Multiple fibers belong to a fiber bundle. A wavelength, a waveband, and a fiber can be used to establish a connection in an optical switch. They SHOULD be recognized at a port in the OXC since they are connection entities. When the OXC has optical-electrical conversion at the input port and electrical-optical conversion at the output port it is called as opaque OXC. Or, when it processes optical data stream all optically it is called as transparent OXC. Wavelength converter SHOULD be used to resolve output port contention when two different connections try to be established in a same output port. Since the wavelength converter can work only within a limited operating range, the limited numbers of wavelengths are used at the output port. It limits the available wavelengths at the output port.

If OXCs perform protection and restoration functions they SHOULD have suitable switch structure to support them. In case of 1+1 dedicated recovery, input ports and output ports MUST be duplicated in a switch. The switch transmits optical signal through two ports (one for working connection and another for backup connection) simultaneously. When a fault happens the switch switches over from failed working connection to dedicated backup connection without noticing a controller.

In order to control and manage the OXC systems, GSMP SHOULD be located as a subset of functions for it and MUST know the current switch, port and service configuration information. GSMP controller SHOULD identify the connection entities at the OXC and match them with the optical labels.

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