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General Switch Management Protocol (GSMP) v3 for Optical Support

Status of this Memo

Abstract

This document describes the General Switch Management Protocol version 3 (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 the General Switch Management Protocol version 3 (GSMPv3) for the support of optical switching. 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 optical cross connect (OXC) systems can be IP-based optical routers which are dynamic wavelength routers, optical label switches, or burst/packet-based optical cross connects [2]. In this draft, we do not limit specific OXC systems, but aim 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. The optical resources used in connection setup are different from those used in 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. This specification defines the services, traffic control, and QoS guarantee necessary at to support optical switches. This draft defines several sub-TLVs, parameters, and new messages to support optical services and optical connection management. 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 function. 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 survivable capability of switches and connections. By extending the management messages of GSMPv3, this function will be implemented.

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

2. GSMP Packet Encapsulation

GSMP Packets may be transported via any suitable medium. GSMP packet encapsulation for optical support will be defined in separate documents.

3. Common Definitions and Procedures for Optical Support.

3.1 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. Generalized Multi-Protocol Label Switching (GMPLS) defines packet switching capable (PSC), Time-Division Multiplex Capable (TDM), lambda switching capable (LSC), fiber switching capable (FSC) interfaces, and it introduces needs of generalized labels to support them [3][4]. The following list is the labels to be supported in GSMPv3 for optical support [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

All labels are encoded in a common structure composed of three fields, a Type, a Length, and a Value [1]. A label TLV is encoded as a 2-octet field that uses 12 bits to specify a Type and four bits to specify certain behavior specified below, followed by 2-octec Length field, and followed by a variable length Value field.

A summary of TLV labels supported by the GSMPv3 extensions for optical support defined in this document is listed below:

TLV Label	Label Type
Fiber Label	0x300
Waveband Label	0x301
Wavelength Label	0x302
Optical burst Label	0x303

All labels will be designated as follow:

X: Reserved Flags
These are generally used by specific messages and will be defined in those messages.

S
Stacked Label Indicator

Label Type
A 12-bit field indicating the type of label.

Label Length

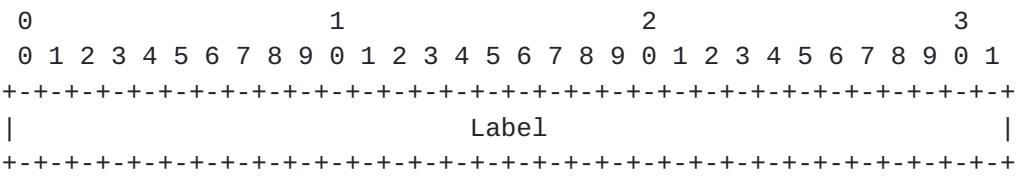
A 16-bit field indicating the length of the Label Value field in bytes.

Label value: Variable
A variable length field that is an integer number of 32 bit words long. The interpretation of this field depends on the Label Type as described in the following sections.

3.1.1 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 it has the following format:

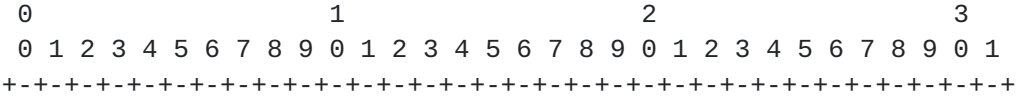


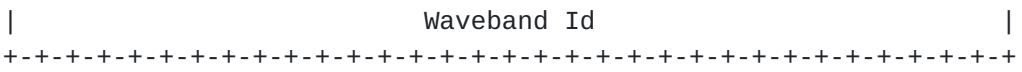
Label: 32 bits
Indicates a label for fiber to be used.

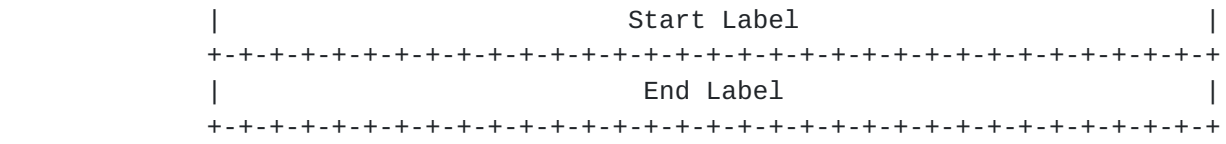
3.1.2 Labels for Waveband

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 wavelength.

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




Waveband Id



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.

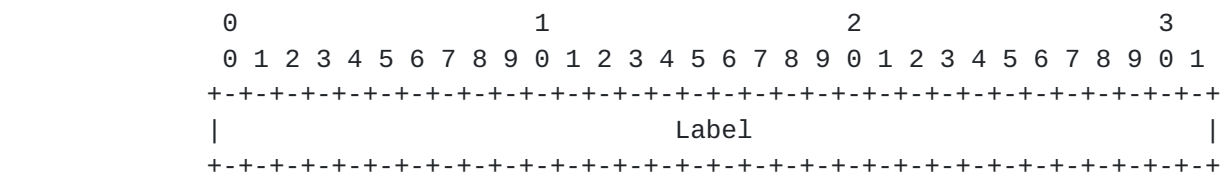
End Label: 32 bits
Indicates the highest value wavelength in the waveband.

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].

3.1.3 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.

3.1.4 Labels for optical burst

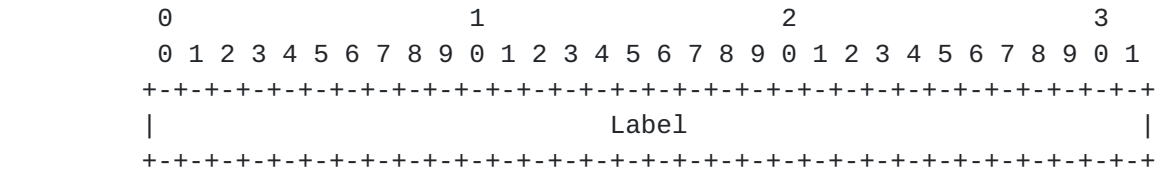
The label for optical burst represents a label for switching data burst in optical domain.

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 a connection setup for data burst, 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 switching operation autonomously, using synchronization methods prescribed for the burst network it is operating in.

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



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

4. Connection Management Messages

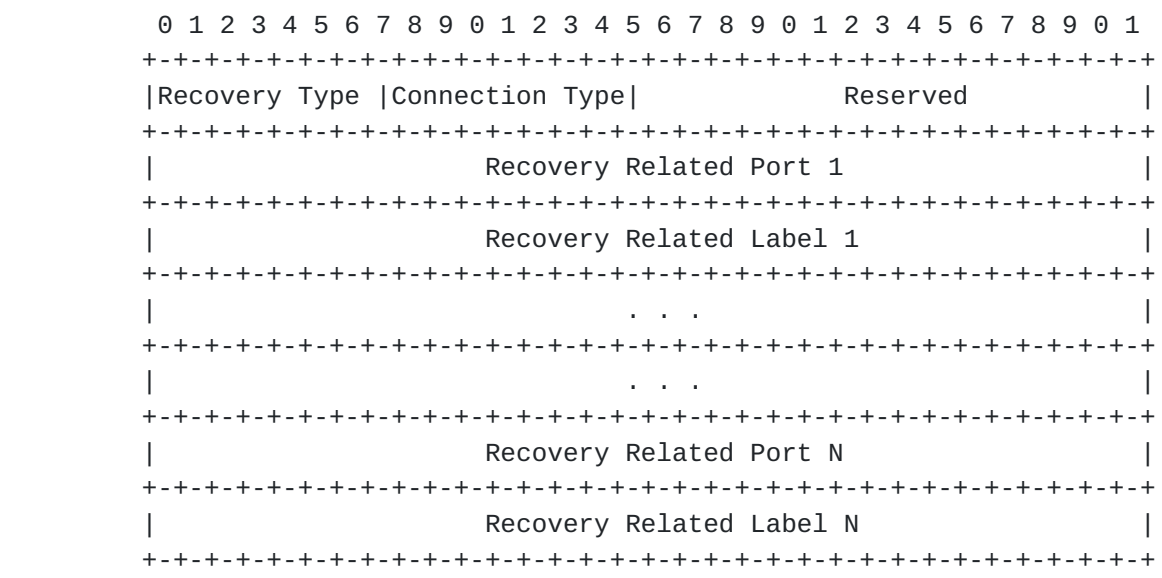
Connection management messages, which are used for establishing, releasing, modifying, and verifying connections across the switch by the controller, SHOULD operate for optical switching. Connection management messages also SHOULD support recovery capabilities of optical switch and these are mainly dealt 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.

4.1 Add Branch Message: Recovery Specific Block

Recovery capability of optical switch is supported by Add Branch message by establishing recovery connection in order to protect working connection. By using this message a recovery connection is established for various types of recovery mechanism. The recovery block defines a recovery type, connection type, and related connection information for the purpose of recovery.

The Add Branch message adds the following block for recovery capability.



Recovery Type; 8 bits
This field provides the required information for various types of recovery mechanism when a recovery connection is established by using Add Branch message. The Recovery Type has the following value for various types of recovery mechanism.

- 0: 0:1 unprotected
- 1: 1+1 dedicated protection
- 2: 1:1 protection
- 3: 1:1 restoration
- 4: 1:N shared recovery
- 5: M:N shared recovery

Connection Type: 8 bits
This field indicates which the message is for a working connection or a recovery connection.

- 0: working connection
- 1: recovery connection

Recovery Related Connection
This field indicates the corresponding connection for recovery purpose. If the Add Branch message is used to setup a working connection the field implies the related recovery connection, and vice versa. This information consists of the following two fields.

- Recovery Related Port
- Recovery Related Label

5. Reservation Management Messages

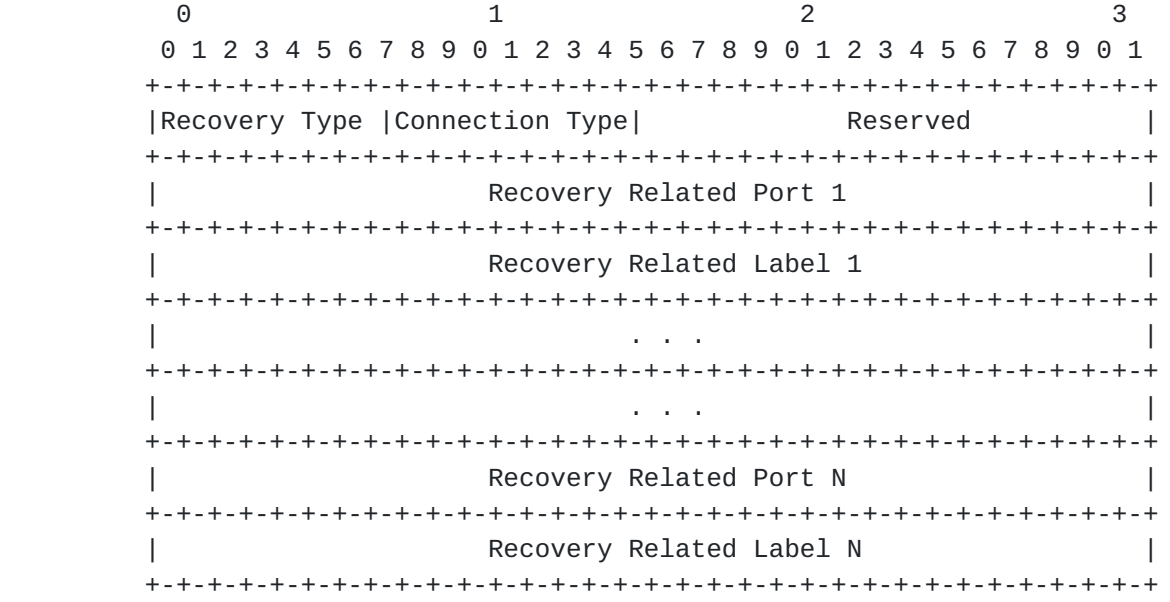
The GSMPv3 allows a switch to reserve resources for connections before establishing them through Reservation Management messages.

Reservable resources are bandwidth, buffers, queues, labels and etc. In this draft the resources imply optical resources, such as data burst, wavelengths, fibers, and so on. In this section, recovery capability and data burst level switching are supported by using the Reservation Management messages.

5.1 Reservation Request Message: Recovery Specific Block

Reservation Request message is used to reserve a recovery connection for various types of recovery mechanisms. Especially, in 1:N (M:N) shared recovery scheme, a spare connection is reserved for N working connections. In order to support recovery capability, a recovery connection is configured by reserving backup resource for working connections. 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.

Reservation Request message adds the following block for recovery capability.



NOTE: Fields and parameters in the block refer to section 4.1.

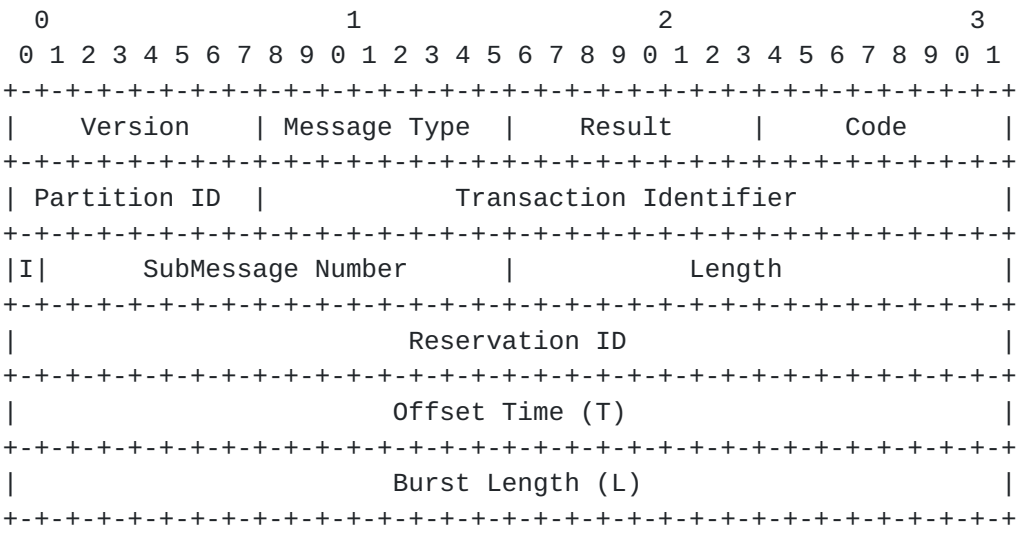
5.2 Reservation Request Message: Optical Burst Specific Block

Reservation Request message also supports a new connection per data burst in optical domain. Data burst is very short in huge bandwidth of a wavelength and needs to process just in time. However, it takes much time to reserve resource and setup a connection per data burst

by using the Reservation Request message. Therefore, a short form of Reservation Request message is used to support data burst. The

original Reservation Request message tries to reserve resource for data burst and the short form of the message is used to trigger the resource to switch and transmit the data burst. This message only contains information to identify the reservation as well as the original message. In order to configure a connection per burst, two parameters, offset time and burst length, are added on the message. When a controller receives a request for a connection setup for data burst it sends the message. According to the different switching mechanisms for optical burst [7][8], the value of two fields in the message are assigned. That is, by applying them, connection setup and release are performed explicitly or implicitly. This draft does not limit the usage of the block in a specific switching technology. The following message is the short form of Reservation Request message to support data burst.

Message type = TBA



NOTE: Fields and parameters that have not been explained 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

6. Management Message

6.1 Label Range Message

The label range, which is specified for each port by the Port

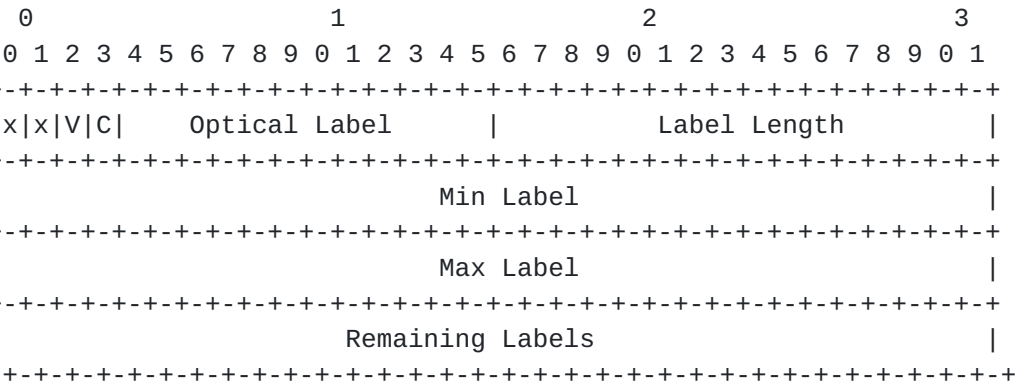
Configuration or the All Ports Configuration message, can be specified to the range of label supported by a specified port and to

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 the format of this message follows [1].

6.1.1 Optical Label

If the Label Type is equal to optical label, the label range message MUST be interpreted as shown:



V: Label
The Label flag is not used.

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

Optical Label
The optical label indicates the type of label for optical support and is referred to the section 3.1 of this document.

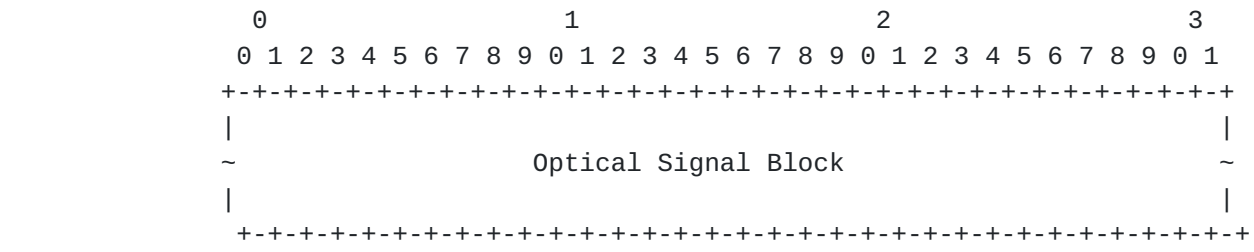
Min Label:
The minimum label value in the range.

Max Label:
The maximum label value in the range.

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

7. Statistics Messages: Optical Signal Specific Block

The statistics messages are used to query the performance statistics related to ports and connections for optical transmission. The statistics contain optical transmission characteristics which specify transmission quality 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 Block which specifies the transmission property of connections as shown in the below.



Optical Signal Block; 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 blocks 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.

8. Configuration Messages

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

8.1 Switch Configuration Message: Optical Switch Specific Block

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, the following optical switch configuration blocks SHOULD be added in the Switch Configuration message.


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

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  SW capable   |                  Reserved                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Switching Capable Layer : 8 bits
This field indicates the supported switching capable layers in an optical switch. It has three flags which indicate the layers. The flags can be set at the same time when the optical switch contains multiple transport layers.

```
X X X X X X F B L
------------------
```

X: reserved field
F: indicates the switching capable layer per a fiber
B: indicates the switching capable layer per a waveband
L: indicates the switching capable layer per a wavelength

8.2 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.

The basic format and usage of Port Configuration message follow [1]. The following new port types are defined to support optical switch.

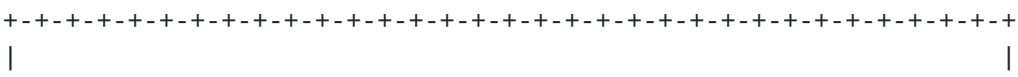
Value	PortType
10	a fiber (wavelength)

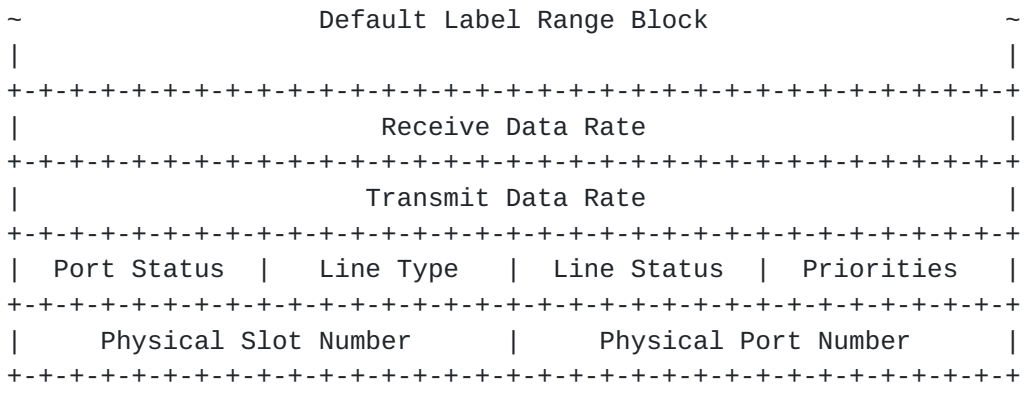
When the value of PortType is in the above range, we call "PortType = Optical Switching" in the following section.

8.2.1 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].

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|P|M|L|R|Q|  Label Range Count  |      Label Range Length       |
```





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

Port Status
Give the administrative state of the port. The new values of the Port Status are defined to indicate recovery capability in port.

Recovery:
Port Status = 6. The port is reserved for recovery support. For 1+1 dedicated protection, this port is configured to transmit traffic as a backup. On the other hand, for 1:1 protection, this port is just configured to reserve the connection without transmitting traffic.

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 range of wavelength, fiber type, and so on. For example,

Line Type for PortType = a fiber

Single Mode Fiber
Multi Mode Fiber

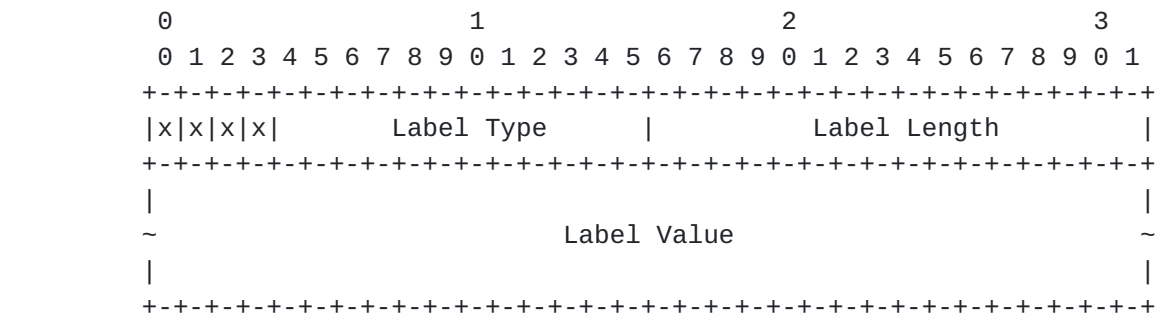
Dispersion Shifted Fiber
Nonzero Dispersion Fiber
à

Line Type	for PortType = a wavelength
1300nm	
1550nm	

à

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.



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

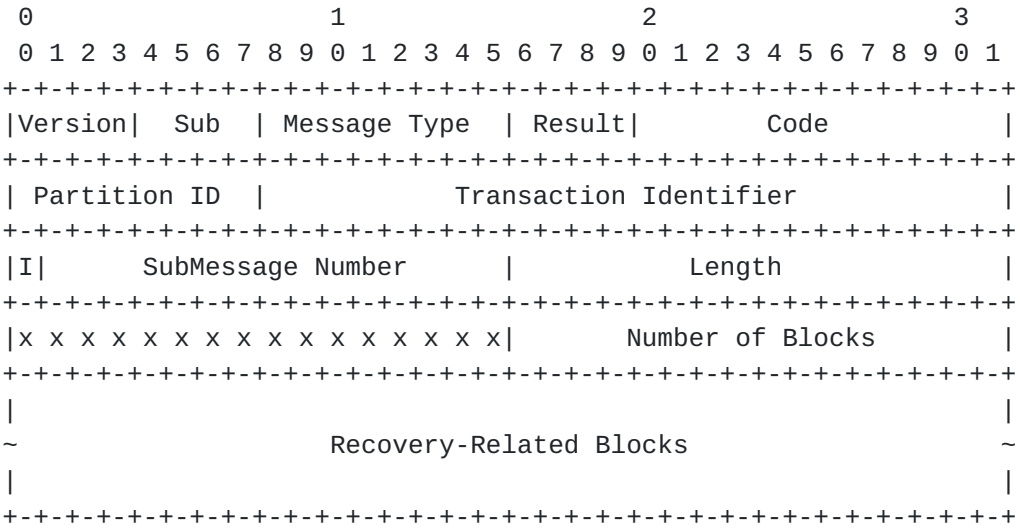
Label value: Variable
Carries label information. The interpretation of this field depends on the type of the link (or the type of connection) over which the label is used. Min Label and Max label value imply the range of available optical labels. Each encoding type of the labels is TBD.

9. Event Messages

The Event messages allow a switch to inform a controller of certain asynchronous events. This draft deals with recovery-related events. The indication of these asynchronous events related to ports and labels can inform failure of them to the controller and it can initiate a fault recovery mechanism. In the following sub-sections, two messages, Recovery Completion message and Fault Notification

message, are used to notify a controller fault-related events of a switch.

Event messages for recovery-related events have the following format:



[Note] Fields and Parameters that have not been explained SHOULD be referred to [1].

Number of Blocks
This field implies the total number of the recovery-related blocks. By notifying the contents of the recovery-related blocks in a single event message to the controller the recovery-related events can be processed in very short time. The number of Blocks in a single Event message for recovery-related events MUST NOT cause the packet length to exceed toe maximum transmission unit defined by the encapsulation.

Recovery-Related Blocks
This field contains several recovery-related blocks for the suitable purpose of the messages. In this draft, these fields are used to notify recovery completion or fault notification. More message specific contents are dealt with in the following sub-sections.

9.1 Recovery Completion Message

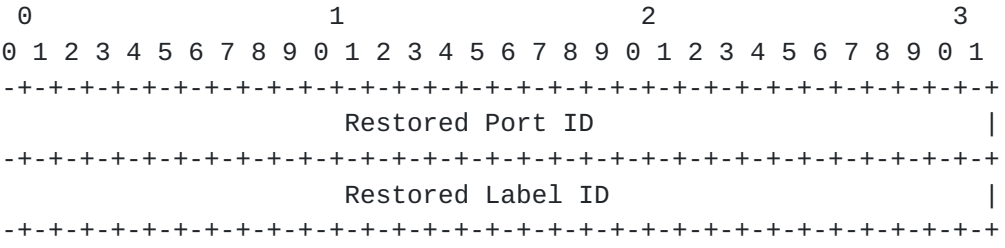
This message is used to notify the recovery completion to the controller by the switch after the failed elements are restored. This message contains restored connection information. Restored Connection information implies restored Port IDs and Label IDs. By using this message, the recovery completion of several failed connections, which consist of port and label, are notified to the controller at one time.

Message Type = TBA

If a message type is equal to Recovery Completion message the

following Recovery Completion Blocks SHOULD be added on the message

in order to notify the recovery completion of all failed ports and all fault-affected labels to the controller.



Restored Port ID list; variable
This field describes the restored port IDs which contain different types of port which indicate wavelength-related port, fiber-related port, or fiber bundle-related port.

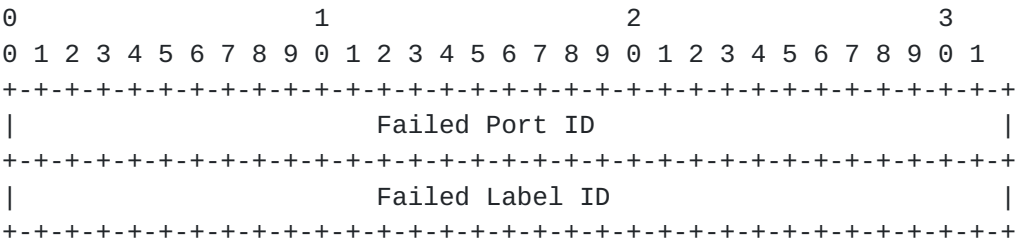
Restored Label ID list; variable
This field describes the restored label ID which comes to be used again from a fault.

9.2 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 Fault Notification blocks SHOULD be added in Event message.

Message type = TBA

If a message type is equal to Fault Notification message the following Fault Notification blocks SHOULD be added on the message in order to notify all fault-affected ports and labels 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.

Failed Label ID list; variable

This field describes the failed label ID which comes to not be used from a connection failed.

10. Service Model Definition

In the GSMP Service Model a controller may request the switch to establish a connection with a given Service. The requested Service is identified by including a Service ID in the Add Branch message or the Reservation message. The Service ID refers to a Service Definition (defined in chapter 10 of [1]). This chapter defines the various Service ID for optical capable switches.

The following Service Identifiers are defined for optical support.

ID Range	Service Type
128 - 191	Optical Switch Services

Service Identifier
The reference number used to identify the Service in GSMP.

Service Characteristics
A definition of the Service

Traffic Parameters
A definition of the Traffic Parameters used in connection management messages.

QoS parameters
A definition of the QoS Parameters that are included in the Capability Set for instances of the Service.

Traffic Controls
A definition of the Traffic Controls that may be supported by an instance of the Service.

11. 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.

- recovery failure
  Due the limitation of available resource for recovery 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

12. Security Considerations

This document does not have any security concerns. The security requirements using this document are described 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 MAY be 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 recovery connection after a fault occurs, GSMPv3 establishes a new recovery connection 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 are specified with an included 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

- Recovery connection configuration
All nodes on a working connection use Add Branch message(P) to configure a recovery connection. The ingress node transmits traffic through the working connection as well as the recovery connection. An egress only chooses traffic from the working connection with ignoring them from the recovery connection. In order to support this type of recovery mechanism, the optical switch SHOULD support it physically.

- Recovery procedure
When a failure occurs, a fault-affected working connection is switched over a 1+1 dedicated recovery connection without notifying the controller. The recovery process is performed at the physical layer automatically. After the recovery is completed, the switch notifies the recovery completion to the controller by using Event message.

1.2 1:1 dedicated recovery mechanism

1) 1:1 protection

- Recovery connection configuration
All nodes on a working connection configure a recovery connection by using Add Branch message. However, the ingress node does not transmit any traffic through the reserved recovery connection since the switch does not cross connect for the recovery connection.

- Recovery procedure
When an ingress node detects a fault it switches over the fault-affected working connection to the reserved recovery connection. This type of recovery does not require configuring additional connection configuration because the recovery connection has been already established by using Add Branch message(P). Then, an egress node switches over the recovery connection to receive traffic.

2) 1:1 restoration

- Recovery connection configuration
An ingress node and an egress node both configure a recovery connection by using the Reservation Request message(P), and core nodes also use it to reserve recovery connection. Extra traffic can be delivered through the recovery connection.

- Recovery procedure
The ingress node and the egress node use Add Branch message in order to configure a recovery connection. Other core nodes also configure the recovery connection with Add Branch message(P) with the reserved resource.

1.3 1:N/M:N shared recovery mechanism (M, N > 1, M <= N)

- Recovery connection configuration
Reservation Request message(P) is used to configure a recovery connection. Since several working connections (= N) share one recovery connection (1:N) or several recovery connections (M:N) GSMPv3 SHUOLD know the sharing working connection IDs for the recovery connections.

- Recovery procedure
When the GSMPv3 controller is notified a fault, it uses Add Branch message(P) to configure a new working connection by using reserved recovery connection. The Add Branch message(P) SHOULD contain the information about the reserved recovery connection.

Appendix II. GSMPv3 support for optical cross-connect systems

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 recovery connection) simultaneously. When a fault happens the switch switches over from failed working connection to dedicated recovery connection without noticing a controller.

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