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Signaling Extensions for Wavelength Switched Optical Networks
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Abstract

This document provides extensions to Generalized Multi-Protocol Label Switching (GMPLS) signaling for control of Wavelength Switched Optical Networks (WSON). Such extensions are applicable in WSONs under a number of conditions including: (a) when optional processing, such as regeneration, must be configured to occur at specific nodes along a path, (b) where equipment must be configured to accept an optical signal with specific attributes, or (c) where equipment must be configured to output an optical signal with specific attributes. This document provides mechanisms to support distributed wavelength assignment with choice in distributed wavelength assignment algorithms.

Status of this Memo

Conventions used in this document

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 [RFC2119].

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1. Introduction

This document provides extensions to Generalized Multi-Protocol Label Switching (GMPLS) signaling for control of Wavelength Switched Optical Networks (WSON). Fundamental extensions are given to permit simultaneous bidirectional wavelength assignment while more advanced extensions are given to support the networks described in [RFC6163] which feature connections requiring configuration of input, output, and general signal processing capabilities at a node along a Label Switched Path (LSP).

These extensions build on previous work for the control of lambda and G.709 based networks.

Related references with this document are [RFC7446] that provides a high-level information model and [WSON-Encode] that provides common encodings that can be applicable to other protocol extensions such as routing.

2. Terminology

CWDM: Coarse Wavelength Division Multiplexing.

DWDM: Dense Wavelength Division Multiplexing.

ROADM: Reconfigurable Optical Add/Drop Multiplexer. A reduced port count wavelength selective switching element featuring ingress and egress line side ports as well as add/drop side ports.

RWA: Routing and Wavelength Assignment.

Wavelength Conversion/Converters: The process of converting information bearing optical signal centered at a given frequency (wavelength) to one with "equivalent" content centered at a different wavelength. Wavelength conversion can be implemented via an optical-electronic-optical (OEO) process or via a strictly optical process.

WDM: Wavelength Division Multiplexing.

Wavelength Switched Optical Networks (WSON): WDM based optical networks in which switching is performed selectively based on the frequency of an optical signal.

AWG: Arrayed Waveguide Grating.

OXC: Optical Cross-Connect.

Optical Transmitter: A device that has both a laser tuned on certain wavelength and electronic components, which converts electronic signals into optical signals.

Optical Receiver: A device that has both optical and electronic components. It detects optical signals and converts optical signals into electronic signals.

Optical Transponder: A device that has both an optical transmitter and an optical receiver.

Optical End Node: The end of a wavelength (optical lambdas) lightpath in the data plane. It may be equipped with some optical/electronic devices such as wavelength multiplexers/demultiplexer (e.g. AWG), optical transponder, etc., which are employed to transmit/terminate the optical signals for data transmission.

FEC: Forward Error Correction. Forward error correction (FEC) is a digital signal processing technique used to enhance data reliability. It does this by introducing redundant data, called error correcting code, prior to data transmission or storage. FEC provides the receiver with the ability to correct errors without a reverse channel to request the retransmission of data.

3R Regeneration: The process of amplifying (correcting loss), reshaping (correcting noise and dispersion), retiming (synchronizing with the network clock), and retransmitting an optical signal.

3. Requirements for WSON Signaling

The following requirements for GMPLS based WSON signaling are in addition to the functionality already provided by existing GMPLS signaling mechanisms.

3.1. WSON Signal Characterization

WSON signaling needs to convey sufficient information characterizing the signal to allow systems along the path to determine compatibility and perform any required local configuration. Examples

of such systems include intermediate nodes (ROADMs, OXCs, Wavelength converters, Regenerators, OEO Switches, etc...), links (WDM systems) and end systems (detectors, demodulators, etc...). The details of any local configuration processes are out of the scope of this document.

From [RFC6163] we have the following list of WSON signal characteristic information

1. Optical tributary signal class (modulation format).
2. FEC: whether forward error correction is used in the digital stream and what type of error correcting code is used
3. Center frequency (wavelength)
4. Bit rate
5. G-PID: General Protocol Identifier for the information format

The first three items on this list can change as a WSON signal traverses a network with regenerators, OEO switches, or wavelength converters. These parameters are summarized in the Optical Interface Class as defined in the [RFC7446] and the assumption is that a class always includes signal compatibility information.
An ability to control wavelength conversion already exists in GMPLS signaling along with the ability to share client signal type information (G-PID). In addition, bit rate is a standard GMPLS signaling traffic parameter. It is referred to as Bandwidth Encoding in [RFC3471].

3.2. Per Node Processing Configuration

In addition to configuring a node along an LSP to input or output a signal with specific attributes, we may need to signal the node to perform specific processing, such as 3R regeneration, on the signal at a particular node. [RFC6163] discussed three types of processing:

(A) Regeneration (possibly different types)

(B) Fault and Performance Monitoring

(C) Attribute Conversion

The extensions here provide for the configuration of these types of processing at nodes along an LSP.

3.3. Bidirectional WSON LSPs

WSON signaling can support LSP setup consistent with the wavelength continuity constraint for bidirectional connections. The following

cases need to be separately supported:

(a) Where the same wavelength is used for both upstream and downstream directions

(b) Where different wavelengths can be used for both upstream and downstream directions.

This document will review existing GMPLS bidirectional solutions according to WSON case.

3.4. Distributed Wavelength Assignment Selection Method

WSON signaling can support the selection of a specific distributed wavelength assignment method.

This method is beneficial in cases of equipment failure, etc., where fast provisioning used in quick recovery is critical to protect carriers/users against system loss. This requires efficient signaling which supports distributed wavelength assignment, in particular when the wavelength assignment capability is not available.

As discussed in the [RFC6163] different computational approaches for wavelength assignment are available. One method is the use of distributed wavelength assignment. This feature would allow the specification of a particular approach when more than one is implemented in the systems along the path.

3.5. Optical Impairments

This draft does not address signaling information related to optical impairments.

4. WSON Signal Traffic Parameters, Attributes and Processing

As discussed in [RFC6163] single channel optical signals used in WSONs are called "optical tributary signals" and come in a number of classes characterized by modulation format and bit rate. Although WSONs are fairly transparent to the signals they carry, to ensure compatibility amongst various networks devices and end systems, it can be important to include key lightpath characteristics as traffic parameters in signaling [RFC6163].

LSPs signaled through extensions provided in this document MUST apply the following signaling parameters:

. Switching Capability = WSON-LSC ([WSON-OSPF]).
. Encoding Type = Lambda ([RFC3471])
. Label Format = as defined in [RFC6205]

[RFC6205] defines the label format as applicable to LSC capable device.

4.1. Traffic Parameters for Optical Tributary Signals

In [RFC3471] we see that the G-PID (client signal type) and bit rate (byte rate) of the signals are defined as parameters and in [RFC3473] they are conveyed in the Generalized Label Request object and the RSVP SENDER_TSPEC/FLOWSPEC objects respectively.

4.2. WSON Processing Hop Attribute TLV

Section 3.1. provided the requirements for signaling to indicate to a particular node along an LSP what type of processing to perform on an optical signal or how to configure that node to accept or transmit an optical signal with particular attributes.

To target a specific node, this section defines a WSON Processing Hop Attribute TLV. This TLV is encoded as an attributes TLV, see [RFC5420]. The TLV is carried in the ERO and RRO LSP Attribute Subobjects, and processed according to the procedures, defined in [RSVP-RO]. The type value of the WSON Processing Hop Attribute TLV is TBD by IANA.

The WSON Processing Hop Attribute TLV carries one or more sub-TLVs with 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |   Length      |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               |
//                            Value                            //
|                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           ...                 |        Padding                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type

The identifier of the sub-TLV.

Length

Indicates the total length of the sub-TLV in octets. That is, the combined length of the Type, Length, and Value fields, i.e., two plus the length of the Value field in octets.

The entire sub-TLV MUST be padded with zeros to ensure four-octet alignment of the sub-TLV.

Value

Zero or more octets of data carried in the sub-TLV.

Padding: Variable

Padding is used to ensure that the length of the WSON Processing Hop Attribute TLV meets the multiple of 4 byte size requirement.

Sub-TLV ordering is significant and MUST be preserved. Error processing follows [RSVP-RO].

The following sub-TLV types are defined in this document:

Sub-TLV Name	Type	Length
ResourceBlockInfo	1	variable
WavelengthSelection	2	8 octets (2 octet padding)

The TLV can be represented in Reduced Backus-Naur Form (RBNF) [RFC5511] syntax as:

<WSON Processing Hop Attribute> ::= <ResourceBlockInfo>
[<ResourceBlockInfo>] [<WavelengthSelection>]

4.2.1. ResourceBlockInfo Sub-TLV

The format of the ResourceBlockInfo sub-TLV value field is defined in Section 4 of [WSON-Encode]. It is a list of available Optical Interface Classes and processing capabilities.

At least one ResourceBlockInfo sub-TLV MUST be present in the WSON_ Processing Hop Attribute TLV. No more than two ResourceBlockInfo sub-TLVs SHOULD be present. Any present ResourceBlockInfo sub-TLVs MUST be processed in the order received, and extra (unprocessed) SHOULD be ignored.

The ResourceBlockInfo field contains several information elements as defined by [WSON-Encode]. The following rules apply to the sub-TLV:

o RB Set Field can carry one or more RB Identifier. Only the first of RB Identifier listed in the RB Set Field SHALL be processed, any others SHOULD be ignored.

o In the case of unidirectional LSPs, only one ResourceBlockInfo sub-TLV SHALL be processed and the I and O bits can be safely ignored.

o In the case of a bidirectional LSP, there MUST be either:

(a) only one ResourceBlockInfo sub-TLV present in a WSON_Processing Hop Attribute TLV, and the bits I and O both set to 1, or

(b) two ResourceBlockInfo sub-TLVs present, one of which has only the I bit set and the other of which has only the O bit set.

o The rest of information carried within the ResourceBlockInfo sub-TLV includes Optical Interface Class List, Input Bit Rate List and Processing Capability List. These lists MAY contain one or more elements. These elements apply equally to both bidirectional and unidirectional LSPs.

Any violation of these rules detected by a transit or egress node SHALL be treated as an error and be processed per [RSVP-RO].

A ResourceBlockInfo sub-TLV can be constructed by a node and added to a ERO_Hop_ATTRIBUTE subobject in order to be processed by downstream nodes (transit and egress). As defined in [RSVP-RO], the R bit reflects the LSP_REQUIRED_ATTRIBUTE and LSP_ATTRIBUTE semantic defined in [RFC5420] and SHOULD be set accordingly.

Once a node properly parses a ResourceBlockInfo Sub-TLV received in an ERO_Hop_ATTRIBUTE subobject (according to the rules stated above and in [RSVP-RO]), the node allocates the indicated resources, e.g., the selected regeneration pool, for the LSP. In addition, the node SHOULD report compliance by adding a RRO_Hop_ATTRIBUTE subobject with the WSON Processing Hop Attribute TLV (and its sub-TLVs) indicating the utilized resources. ResourceBlockInfo Sub-TLVs carried in a RRO_Hop_ATTRIBUTE subobject are subject to [RSVP-RO] and standard RRO processing, see [RFC3209].

4.2.2. WavelengthSelection Sub-TLV

Routing + Distributed Wavelength Assignment (R+DWA) is one of the options defined by the [RFC6163]. The output from the routing

function will be a path but the wavelength will be selected on a hop-by-hop basis.

As discussed in [RFC6163], the wavelength assignment can be either for a unidirectional lightpath or for a bidirectional lightpath constrained to use the same lambda in both directions.

In order to indicate wavelength assignment directionality and wavelength assignment method, the Wavelength Selection, or WavelengthSelection, sub-TLV is defined to be carried in the WSON Processing Hop Attribute TLV defined above.

The WavelengthSelection sub-TLV value field is defined as:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|W|  WA Method  |                    Reserved                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Where:

W (1 bit): 0 denotes requiring the same wavelength in both directions, 1 denotes that different wavelengths on both directions are allowed.

Wavelength Assignment (WA) Method (7 bits):

0 - unspecified (any); This does not constrain the WA method used by a specific node. This value is implied when the WavelengthSelection Sub-TLV is absent.

1 - First-Fit. All the wavelengths are numbered and this WA method chooses the available wavelength with the lowest index.

2 - Random. This WA method chooses an available wavelength randomly.

3 - Least-Loaded (multi-fiber). This WA method selects the wavelength that has the largest residual capacity on the most loaded link along the route. This method is used in multi-fiber networks. If used in single-fiber networks, it is equivalent to the FF WA method.

4- 127: Unassigned.

The processing rules of this TLV are as follows:

If a receiving node does not support the attribute(s), its behaviors are specified below:

- W bit not supported: a PathErr MUST be generated with the Error Code "Routing Problem" (24) with error sub-code "Unsupported WavelengthSelection Symmetry value" (value to be assigned by IANA, suggested value: 107).

- WA method not supported: a PathErr MUST be generated with the Error Code "Routing Problem" (24) with error sub-code "Unsupported Wavelength Assignment value" (value to be assigned by IANA, suggested value: 108).

A WavelengthSelection sub-TLV can be constructed by a node and added to a ERO_Hop_ATTRIBUTE subobject in order to be processed by downstream nodes (transit and egress). As defined in [RSVP-RO], the R bit reflects the LSP_REQUIRED_ATTRIBUTE and LSP_ATTRIBUTE semantic defined in [RFC5420] and SHOULD be set accordingly.

Once a node properly parses the WavelengthSelection Sub-TLV received in an ERO_Hop_ATTRIBUTE subobject, the node use the indicated wavelength assignment method (at that hop) for the LSP. In addition, the node SHOULD report compliance by adding a RRO_Hop_ATTRIBUTE subobject with the WSON Processing Hop Attribute TLV (and its sub-TLVs) indicated the utilized method. WavelengthSelection Sub-TLVs carried in a RRO_Hop_ATTRIBUTE subobject are subject to [RSVP-RO] and standard RRO processing, see [RFC3209].

5. Security Considerations

This document is built on the mechanisms defined in [RFC3473], and only differs in specific information communicated. As such, this document introduces no new security considerations to the existing GMPLS signaling protocols. See [RFC3473], for details of the supported security measures. Additionally, [RFC5920] provides an overview of security vulnerabilities and protection mechanisms for the GMPLS control plane.

6. IANA Considerations

Upon approval of this document, IANA is requested to make the assignment of a new value for the existing "Attributes TLV Space" registry located at http://www.iana.org/assignments/rsvp-te-parameters/, as updated by [RSVP-RO]:

Type	Name	Allowed on LSP ATTRIBUTES	Allowed on LSP REQUIRED ATTRIBUTES	Allowed on RO LSP Attribute Subobject	Reference
TBA	WSON Processing Hop Attribute TLV	No	No	Yes	[This.I-D]

Upon approval of this document, IANA is requested to create a new registry named "Sub-TLV Types for WSON Processing Hop Attribute TLV" located at http://www.iana.org/assignments/rsvp-te-parameters/.

The following entries are to be added:

Value	Sub-TLV Type	Reference
1	ResourceBlockInfo	[This.I-D]
2	WavelengthSelection	[This.I-D]

All assignments are to be performed via Standards Action or Specification Required policies as defined in [RFC5226 <http://tools.ietf.org/html/rfc5226>].

Upon approval of this document, IANA is requested to create a new registry named "Values for Wavelength Assignment Method field in WavelengthSelection Sub-TLV" located at http://www.iana.org/assignments/rsvp-te-parameters/.

The following entries are to be added:

Value	Meaning	Reference
0	unspecified	[This.I-D]
1	First-Fit	[This.I-D]

2	Random	[This.I-D]
3	Least-Loaded (multi-fiber)	[This.I-D]
4-127	unassigned	

All assignments are to be performed via Standards Action or Specification Required policies as defined in [RFC5226]. The assignment policy chosen for any specific code point must be clearly stated in the document that describes the code point so that IANA can apply the correct policy.

Upon approval of this document, IANA is requested to make the assignment of a new value for the existing "Sub-Codes . 24 Routing Problem" registry located at http://www.iana.org/assignments/rsvp-parameters/:

Value	Description	Reference
107	Unsupported WavelengthSelection symmetry value	[This.I-D]
108	Unsupported Wavelength Assignment value	[This.I-D]

7. Acknowledgments

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8. References

8.1. Normative References

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