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Signaling Extensions for Wavelength Switched Optical Networks

Abstract

This document provides extensions to Generalized Multiprotocol Label Switching (GMPLS) signaling for control of Wavelength Switched Optical Networks (WSONs). 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 a choice of distributed wavelength assignment algorithms.

Status of This Memo

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1. Introduction

This document provides extensions to Generalized Multiprotocol Label Switching (GMPLS) signaling for control of Wavelength Switched Optical Networks (WSONs). 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 documents are [RFC7446] that provides a high-level information model and [RFC7581] 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 (WSONs): 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 a certain wavelength, and electronic components that convert 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. 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.

2.1. 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].

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 outside the scope of this document.

From [RFC6163], we have the following list of WSON signal characteristics:

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 [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 supported separately:

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

(b) Where different wavelengths are 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 that supports distributed wavelength assignment, in particular, when the wavelength assignment capability is not available.

As discussed in [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 document 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:

- o Switching Capability = WSON-LSC [RFC7688]
- o Encoding Type = Lambda [RFC3471]
- o Label Format = as defined in [RFC6205]

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

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 provides requirements to signal to a node along an LSP what type of processing to perform on an optical signal and how to configure itself 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 Hop Attributes subobjects and processed according to the procedures defined in [RFC7570]. The type value of the WSON Processing Hop Attribute TLV is 4 as assigned 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.

Value

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

Padding

Variable

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

Sub-TLV ordering is significant and MUST be preserved. Error processing follows [RFC7570].

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 [RFC7581]. 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) sub-TLVs SHOULD be ignored.

The ResourceBlockInfo field contains several information elements as defined by [RFC7581]. The following rules apply to the sub-TLV:

- RB Set field can carry one or more RB Identifier. Only the first RB Identifier listed in the RB Set field SHALL be processed; any others SHOULD be ignored.

- 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 with only the I bit set and the other with only the O bit set.

o The rest of the information carried within the ResourceBlockInfo sub-TLV includes the 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 [RFC7570].

A ResourceBlockInfo sub-TLV can be constructed by a node and added to an ERO Hop Attributes subobject in order to be processed by downstream nodes (transit and egress). As defined in [RFC7570], the R bit reflects the LSP_REQUIRED_ATTRIBUTE and LSP_ATTRIBUTE semantic defined in [RFC5420], and it SHOULD be set accordingly.

Once a node properly parses a ResourceBlockInfo sub-TLV received in an ERO Hop Attributes subobject (according to the rules stated above and in [RFC7570]), the node allocates the indicated resources, e.g., the selected regeneration pool, for the LSP. In addition, the node SHOULD report compliance by adding an RRO Hop Attributes subobject with the WSON Processing Hop Attribute TLV (and its sub-TLVs) indicating the utilized resources. ResourceBlockInfo sub-TLVs carried in an RRO Hop Attributes subobject are subject to [RFC7570] 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 [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 WavelengthSelection sub-TLV is 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 First-Fit WA method.

4-127: Unassigned.

The processing rules for 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" (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" (108).

A WavelengthSelection sub-TLV can be constructed by a node and added to an ERO Hop Attributes subobject in order to be processed by downstream nodes (transit and egress). As defined in [RFC7570], the R bit reflects the LSP_REQUIRED_ATTRIBUTE and LSP_ATTRIBUTE semantic defined in [RFC5420], and it SHOULD be set accordingly.

Once a node properly parses the WavelengthSelection sub-TLV received in an ERO Hop Attributes subobject, the node use the indicated wavelength assignment method (at that hop) for the LSP. In addition, the node SHOULD report compliance by adding an RRO Hop Attributes subobject with the WSON Processing Hop Attribute TLV (and its sub-TLVs) that indicate the utilized method. WavelengthSelection sub-TLVs carried in an RRO Hop Attributes subobject are subject to [RFC7570] and standard RRO processing; see [RFC3209].

5. Security Considerations

This document is built on the mechanisms defined in [RFC3473], and only differs in the specific information communicated. The specific additional information (optical resource and wavelength selection properties) is not viewed as substantively changing or adding to the security considerations of the existing GMPLS signaling protocol mechanisms. 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

IANA has assigned a new value in the existing "Attributes TLV Space" registry located at <http://www.iana.org/assignments/rsvp-te-parameters>, as updated by [RFC7570]:

Type	Name	Allowed on LSP ATTRIBUTES	Allowed on LSP REQUIRED ATTRIBUTES	Allowed on RO LSP Attribute Subobject	Reference
4	WSON Processing Hop Attribute TLV	No	No	Yes	RFC 7689

IANA has created 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 have been added:

Value	Sub-TLV Type	Reference
0	Reserved	RFC 7689
1	ResourceBlockInfo	RFC 7689
2	WavelengthSelection	RFC 7689

All assignments are to be performed via Standards Action or Specification Required policies as defined in [RFC5226].

IANA has created 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 have been added:

Value	Meaning	Reference
0	unspecified	RFC 7689
1	First-Fit	RFC 7689
2	Random	RFC 7689
3	Least-Loaded (multi-fiber)	RFC 7689
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.

IANA has assigned new values in 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	RFC 7689
108	Unsupported Wavelength Assignment value	RFC 7689

7. References

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