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 Signaling Extensions for Wavelength Switched Optical Networks

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Abstract

 This memo 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. In addition this memo provides mechanisms to

 support distributed wavelength assignment with choice in distributed

 wavelength assignment algorithms. These extensions build on previous

 work for the control of lambda and G.709 based networks, i.e. update

 RFC6205, to make it applicable to WSON-LSC capable equipment.

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 "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 memo 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. This document updates [RFC6205] as make it

 applicable to WSON-LSC capable equipment.

 Related references with this document are [WSON-Info] that provides

 a high-level information model and 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.

 FOADM: Fixed Optical Add/Drop Multiplexer.

 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 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.

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 WDM: Wavelength Division Multiplexing.

 Wavelength Switched Optical Networks (WSON): WDM based optical

 networks in which switching is performed selectively based on the

 center wavelength 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 Responder: 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 responder.

 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.

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.

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

 characteristic information:

 List 1. 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 the [WSON-Info] 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.

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 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 centralized 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].

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 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. This document extends [RFC6205] as make its label format

 applicable also to WSON-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 Generalized Label Request object and the

 RSVP SENDER\_TSPEC/FLOWSPEC objects respectively.

 4.2. WSON Processing HOP Attribute TLV

 Section 3.2. 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 //

 | |

 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

 Type

 The identifier of the sub-TLV.

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 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., four 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. The Length field does not include any padding.

 Value

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

 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 1 (3 octets 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.

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 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 [HZang00], a number of different wavelength

 assignment algorithms may be employed. In addition 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.

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 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 WavlengthSelection 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:

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 - 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.

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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/rsvp-te-parameters.xhtml, as updated by [RSVP-RO]:

 Type Name Allowed on Allowed on Allowed on Reference

 LSP LSP REQUIRED RO LSP

 ATTRIBUTES ATTRIBUTES Attribute

 Subobject

 TBA WSON No No Yes [This.I-D]

 Processing

 HOP

 Attribute

 TLV

 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/rsvp-

 te-parameters.xhtml.

 The following entries are to be added:

 Value Sub-TLV Type Reference

 1 (suggested) ResourceBlockInfo [This.I-D]

 2 (Suggested) WavelengthSelection [This.I-D]

 All assignments are to be performed via Standards Action and

 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/rsvp-te-

 parameters.xhtml.

 The following entries are to be added:

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 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 and

 Specification Required policies as defined in [RFC5226

 <http://tools.ietf.org/html/rfc5226>].

 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/rsvp-parameters.xml:

 Value Description Reference

 107 (suggested) Unsupported WavelengthSelection

 symmetry value [This.I-D]

 108 (suggested) Unsupported Wavelength Assignment

 value [This.I-D]

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