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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 (WSO<sub>N</sub>). Such extensions are applicable in WSO<sub>N</sub>s 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 WSO<sub>N</sub>-LSC capable equipment.

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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.



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.





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 NE. [[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 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](#)].



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 Encoding

[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, which is carried in the subobjects defined in [[RSVP-RO](#)]. The Type value of the WSON Processing HOP Attribute TLV is TBD by IANA.

The contents of this TLV is defined in the subsequent sections. [Section 4.3](#) for ResourceBlockInfo sub-TLV and [Section 4.4](#) for WavelengthSelection sub-TLV, respectively. The TLV can be represented in Reduced Backus-Naur Form (RBNF) [[RFC5511](#)] syntax as:

```
<WSON Processing HOP Attribute> ::= < ResourceBlockInfo>
[<ResourceBlockInfo>] <WavelengthSelection>
```

The WSON Processing HOP Attribute TLV is a type of a HOP Attributes TLV, as defined in [[RSVP-RO](#)]. If a receiving node does not recognize a sub-TLV, it will follow the procedure defined in [[RFC5420](#)], i.e., it MUST generate a PathErr with a new error value of the existing Error Code "Unknown Attributes TLV (Sub-codes - 29)".



#### 4.3. Resource Block Information Sub-TLV

The Resource block information , or ResourceBlockInfo, sub-TLV contains a list of available Optical Interface Classes and processing capabilities.

The format of the ResourceBlockInfo sub-TLV value field is defined in Section 4 of [[WSON-Encode](#)].

Type	Sub-TLV Name
1 (TBA)	ResourceBlockInfo

At least one ResourceBlockInfo sub-TLV MUST be present in the WSON\_Processing HOP Attribute TLV. At most two ResourceBlockInfo sub-TLVs MAY be present in the WSON\_Processing HOP Attribute TLV. If more than two sub-TLVs are encountered, the first two MUST be processed and the rest SHOULD be ignored.

The <ResourceBlockInfo> contains several information as defined by [[WSON-Encode](#)]. The following processing rules apply to the sub-TLV:

RB Set Field MAY contain more than one RB Identifier. Only the first of which MUST be processed, the others SHOULD be ignored.

In case of signaling a unidirectional LSP, only one ResourceBlockInfo sub-TLV MUST be processed and I/O bits can be safely ignored.

In case of signaling a bidirectional LSP: if only one ResourceBlockInfo is included, bits I and O MUST be both set to 1, if two ResourceBlockInfo sub-TLVs are included, bits I and O MUST have different values, i.e., only one bit can be set in each ResourceBlockInfo sub-TLV. Any violation of these detected by a transit or egress node will incur a processing error and SHOULD NOT trigger any RSVP message but can be logged locally, and perhaps reported through network management mechanisms.

The rest of information available within ResourceBlockInfo sub-TLV is Optical Interface Class List, Input Bit Rate List and Processing Capability List. These lists MAY contain one or more elements. The usage of WSON Processing HOP Attribute TLV for the bidirectional case is the same as per unidirectional. When an intermediate node uses information from this TLV to instruct a node about wavelength



regeneration, the same information applies to both downstream and upstream directions.

This sub-TLV is constructed by an ingress node and the processing is applied to all nodes (transit and egress) whose R bit is set in the ERO HOP ATTRIBUTE subobject according to [\[RSVP-RO\]](#). When the R bit is set, a node MUST examine the ResourceBlockInfo sub-TLV present in the subobject following the rule described in [\[RFC5420\]](#).

If a node processing an ERO HOP ATTRIBUTE subobject with WSON Processing HOP Attributes TLV (which may include the ResourceBlockInfo sub-TLVs) longer than the ERO subobject SHOULD return a PathErr with an error code "Routing Error" and error value "Bad EXPLICIT\_ROUTE object" with the EXPLICIT\_ROUTE object included as defined in [\[RSVP-RO\]](#) [Section 3.3](#).

Once a node properly parsed the Sub-TLV, the node applies the selected regeneration pool (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) which describes the attributes to be reported.

#### 4.4. Wavelength Selection 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.

Under this hypothesis, the node initiating the signaling process needs to declare its own wavelength availability (through a label\_set object). Each intermediate node may delete some labels due to connectivity constraints or its own assignment policy. At the end, the destination node has to make the final decision on the wavelength assignment among the ones received through the signaling process.

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.

In order to indicate wavelength assignment directionality and wavelength assignment method, a new Wavelength Selection, or WavelengthSelection, sub-TLV is defined to be carried in the WSON







- 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).

This sub-TLV is constructed by an ingress node and the processing is applied to all nodes (transit and egress) whose R bit is set in the ERO HOP ATTRIBUTE subobject according to [\[RSVP-RO\]](#). When the R bit is set, a node MUST examine the WavelengthSelection sub-TLV present in the subobject following the rule described in [\[RFC5420\]](#).

If a node processing an ERO HOP ATTRIBUTE subobject with WSON Processing HOP Attributes TLV (which may include the WavelengthSelection sub-TLVs) longer than the ERO subobject SHOULD return a PathErr with an error code "Routing Error" and error value "Bad EXPLICIT\_ROUTE object" with the EXPLICIT\_ROUTE object included as defined in [\[RSVP-RO\]](#) [Section 3.3](#).

Once a node properly parsed the Sub-TLV, the node applies 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) which describes the attributes to be reported.

## 5. Security Considerations

This document is builds 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/rsvp-te-parameters.xhtml>:

Type	Name	Allowed on LSP ATTRIBUTES	Allowed on LSP REQUIRED_ ATTRIBUTES	Reference
4 (Suggested)	WSON Processing HOP Attribute TLV	No	No	[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/rsvp-te-parameters.xhtml>.

The following entries are to be added:

Value	Length	Sub-TLV Type	Reference
1 (suggested)	variable	ResourceBlockInfo	[This.I-D]
2 (Suggested)	4	WavelengthSelection	[This.I-D]

All assignments are to be performed via Standards Action 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:

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 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 "Error Codes and Globally-Defined Error Value Sub-Codes - 29 Unknown Attribute TLV" registry located at <http://www.iana.org/assignments/rsvp-parameters/rsvp-parameters.xml>:

Value	Meaning	Reference
41 (suggested)	Unknown WSOON Processing HOP Attribute sub-TLV type	[This.I-D]

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	Unsupported WavelengthSelection symmetry value	[This.I-D]
108	Unsupported Wavelength Assignment value	[This.I-D]

## 7. Acknowledgments

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