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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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Bernstein et al. Expires March 2015 [Page 1]

Internet-Draft WSON Signaling Extensions September 2014

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this document are to be interpreted as described in [RFC2119].

Table of Contents

1. Introduction...................................................3

2. Terminology....................................................3

3. Requirements for WSON Signaling................................4

3.1. WSON Signal Characterization..............................4

3.2. Per Node Processing Configuration.........................5

3.3. Bidirectional WSON LSPs...................................6

3.4. Distributed Wavelength Assignment Selection Method........6

3.5. Optical Impairments.......................................6

4. WSON Signal Traffic Parameters, Attributes and Processing......6

4.1. Traffic Parameters for Optical Tributary Signals..........7

4.2. WSON Processing HOP Attribute TLV.........................7

4.2.1. Resource Block Information Sub-TLV......................8

4.2.2. Wavelength Selection Sub-TLV............................9

5. Security Considerations.......................................11

6. IANA Considerations...........................................12

7. Acknowledgments...............................................13

Bernstein et al. Expires March 2015 [Page 2]

Internet-Draft WSON Signaling Extensions September 2014

8. References....................................................14

8.1. Normative References.....................................14

8.2. Informative References...................................15

Author's Addresses...............................................15

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.

Bernstein et al. Expires March 2015 [Page 3]

Internet-Draft WSON Signaling Extensions September 2014

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.

Bernstein et al. Expires March 2015 [Page 4]

Internet-Draft WSON Signaling Extensions September 2014

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.

Bernstein et al. Expires March 2015 [Page 5]

Internet-Draft WSON Signaling Extensions September 2014

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].

Bernstein et al. Expires March 2015 [Page 6]

Internet-Draft WSON Signaling Extensions September 2014

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.

Bernstein et al. Expires March 2015 [Page 7]

Internet-Draft WSON Signaling Extensions September 2014

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.

Bernstein et al. Expires March 2015 [Page 8]

Internet-Draft WSON Signaling Extensions September 2014

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.

Bernstein et al. Expires March 2015 [Page 9]

Internet-Draft WSON Signaling Extensions September 2014

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:

Bernstein et al. Expires March 2015 [Page 10]

Internet-Draft WSON Signaling Extensions September 2014

- 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.

Bernstein et al. Expires March 2015 [Page 11]

Internet-Draft WSON Signaling Extensions September 2014

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:

Bernstein et al. Expires March 2015 [Page 12]

Internet-Draft WSON Signaling Extensions September 2014

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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Bernstein et al. Expires March 2015 [Page 13]

Internet-Draft WSON Signaling Extensions September 2014

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Bernstein et al. Expires March 2015 [Page 15]

Internet-Draft WSON Signaling Extensions September 2014

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Bernstein et al. Expires March 2015 [Page 16]