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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 necessary 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 bidirectional LSPs, and choice in distributed wavelength assignment algorithms. These extensions build on previous work for the control of lambda and G.709 based networks.

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].

Table of Contents

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 bi-directional 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 LSP.

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

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 an 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 MUST 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 LSP Network Element Processing Configuration

In addition to configuring a network element (NE) along an LSP to input or output a signal with specific attributes, we may need to signal the NE to perform specific processing, such as 3R regeneration, on the signal at a particular NE. In [RFC6163] we discussed three types of processing not currently covered by GMPLS:

(A) Regeneration (possibly different types)

(B) Fault and Performance Monitoring

(C) Attribute Conversion

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

3.3. Bi-Directional WSON LSPs

WSON signaling MAY support LSP setup consistent with the wavelength continuity constraint for bi-directional connections. The following cases MAY 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 current GMPLS bidirectional solutions according to WSON case.

3.4. Distributed Wavelength Assignment Support

WSON signaling MAY 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. Out of Scope

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].

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. Signal Attributes and Processing

Section 3.2. gave the requirements for signaling to indicate to a particular NE along an LSP what type of processing to perform on an optical signal or how to configure that NE to accept or transmit an optical signal with particular attributes.

One way of accomplishing this is via a new EXPLICIT_ROUTE subobject. Reference [RFC3209] defines the EXPLICIT_ROUTE object (ERO) and a number of subobjects, while reference [RFC5420] defines general mechanisms for dealing with additional LSP attributes. Although reference [RFC5420] defines a RECORD_ROUTE object (RRO) attributes subobject, it does not define an ERO subobject for LSP attributes.

Regardless of the exact coding for the ERO subobject conveying the input, output, or processing instructions. This new "processing" subobject would follow a subobject containing the IP address, or the interface identifier [RFC3477], associated with the link on which it is to be used along with any label subobjects [RFC3473].

In regards to specific information required, the [WSON-Encode] already provides all necessary definitions and encoding. In particular the Resource block information sub-TLV which contains, among others, a list of available Optical Interface Classes and processing capabilities.

The WSON Signal Processing object is defined as an LSP_ATTRIBUTES and extends the PATH message. It is defined as the following:

<WSON Processing> ::= <RBInformation>

Where:

<RBInformation> is the object defined in Section 5.1 of [WSON-Encode].

This is the only sub-TLV available within the <WSON Processing>. Only one <RBInformation> object MUST be present.

4.2.1. WSON Processing Object Encoding

```
    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: to be defined by IANA

Value: sub-TLVS according to section 4.1.

5. Bidirectional Lightpath Setup

With the wavelength continuity constraint in CI-incapable [RFC3471] WSONs, where the nodes in the networks cannot support wavelength conversion, the same wavelength on each link along a unidirectional lightpath should be reserved. In addition to the wavelength continuity constraint, requirement 3.3 gives us another constraint on wavelength usage in data plane, in particular, it requires the same wavelength to be used in both directions. [RFC6163] in section 6.1 reports on the implication to GMPLS signaling related to both bi-directionality and Distributed Wavelengths Assignment.

Current GMPLS solution defines a bidirectional LSP (as defined by [RFC3471]). The label distribution is based on Label_Set and Upstream_Label objects. In case of specific constraints such as the same wavelengths in both directions, it may require several signaling attempts using information from the Acceptable_Label_Set received from path error messages. Since this mechanism is currently available and proven to work, no additional extensions are needed for WSON. Potential optimizations are left for further studies.

The usage of <WSON Processing> object for the bidirectional case is the same as per unidirectional. When an intermediate node uses information from this object to instruct a node about wavelength regeneration, the same information applies to both downstream and upstream directions.

Some implementations may prefer using two unidirectional LSPs. This solution has been always available as per [RFC3209] however recent work introduces the association concept [RFC4872] and [ASSOC-Info]. Recent transport evolutions [ASSOC-ext] provide a way to associate two unidirectional LSPs as a bidirectional LSP. In line with this, a small extension can make this approach work for the WSON case.

6. RWA Related

6.1. Wavelength Assignment Method Selection

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 maybe 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.

A simple TLV could be used to indication wavelength assignment directionality and wavelength assignment method. This would be placed in an LSP_REQUIRED_ATTRIBUTES object per [RFC5420]. The use of a TLV in the LSP required attributes object was pointed out in [Xu].

[TO DO: The directionality stuff needs to be reconciled with the earlier material]

Unique Wavelength: 0 same wavelength in both directions, 1 may use different wavelengths [TBD: shall we use only 1 bit]

Wavelength Assignment Method: 0 unspecified (any), 1 First-Fit, 2 Random, 3 Least-Loaded (multi-fiber). Others TBD.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Unique WL  |    WA Method  |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

7. Security Considerations

This document has no requirement for a change to the security models within GMPLS and associated protocols. That is the OSPF-TE, RSVP-TE, and PCEP security models could be operated unchanged.

However satisfying the requirements for RWA using the existing protocols may significantly affect the loading of those protocols. This makes the operation of the network more vulnerable to denial of service attacks. Therefore additional care maybe required to ensure that the protocols are secure in the WSON environment.

Furthermore the additional information distributed in order to address the RWA problem represents a disclosure of network capabilities that an operator may wish to keep private. Consideration should be given to securing this information.

8. IANA Considerations

TBD. Once finalized in our approach we will need identifiers for such things and modulation types, modulation parameters, wavelength assignment methods, etc...

9. Acknowledgments

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