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MSWS Method to Support Shared-Mesh Restoration for Wavelength Switched Optical Networks
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Abstract

This document proposes a method called Most Sharable Wavelength per Segment (MSWS) to support shared-mesh restoration for wavelength switched optical networks (WSON). The proposed method can perform efficient wavelength sharing in a distributed fashion. It uses the signaling extensions for WSON which is previously proposed in the document "Signaling Extensions for Wavelength Switched Optical Networks" (draft-bernstein-ccamp-wson-signaling-01) and no other protocol extensions of Generalized Multi-Protocol Label Switching (GMPLS) routing and signaling are needed.

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1. Introduction

GMPLS extends MPLS to support Time-Division Multiplex Capable (TDM), Lambda Switch Capable (LSC) and Fiber-Switch Capable (FSC) interfaces and switching. However optical switching technologies are significantly different from other circuit switch technologies such as TDM. [WSON-frame] provided a framework for applying GMPLS and Path Computation Element (PCE) architecture to the control of WSON. In [WSON-Info], an informational model and efficient encodings of information needed by routing and wavelength assignment (RWA) in WSON are provided. [WSON-Signaling] provides extensions to GMPLS signaling

for control of WSON. [WSON-PCEP] provides requirements and protocol enhancements for the Path Computation Element communication Protocol (PCEP) for the support of WSON.

Through an automated common control plane, GMPLS can provide various and flexible recovery mechanisms. Functional description, protocol extensions, terminology and analysis of GMPLS-based recovery mechanisms are given in [RFC4426], [RFC4427], [RFC4428], [RFC4872] and [RFC4873]. Shared-mesh restoration defined in [RFC4427], is an efficient approach to reduce the restoration resource requirements by allowing multiple restoration (Label Switched Paths) LSPs to share common resources. Until now, requirements and extensions of GMPLS to support shared-mesh restoration for WSON are not specified.

This memo proposes MSWS method to support shared mesh restoration for WSON. The proposed method can perform efficient wavelength sharing in a distributed fashion. It uses the signaling extensions for WSON which is proposed by [WSON-Signaling] and no other protocol extensions of GMPLS routing and signaling is needed.

2. 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 RFC-2119.

3. Problem Statement and Analysis

3.1. Current GMPLS-based Shared-Mesh Restoration

According to current GMPLS-based shared-mesh restoration mechanism, the routing approach does not require the flooding of any per LSP information or any detailed distribution of the bandwidth allocation per component link or individual ports. This routing approach is referred to as a Partial (or Aggregated) Information Routing [RFC4428]. To be specific, the Maximum Reservable Bandwidth, the Unreserved Bandwidth, and the Maximum LSP Bandwidth (see [RFC4202]) are the useful information during protecting path computation in shared-mesh restoration. By using the aggregated information, source node can perform path computation for the protecting path considering resource sharing. Then signaling process is generated. First, the recovery resources for the protecting LSPs are pre-reserved during the provisioning phase. Then when a failure on the working LSP occurs, an explicit signaling action is required to activate the protecting LSPs[RFC 4872]. An ASSOCIATION object is defined to associate working LSPs with their corresponding protecting LSPs. A PRIMARY_PATH_ROUTE object is defined to inform nodes along the path of the protecting

LSP about which resources are being used by the associated working LSP.

3.2. Wavelength Resource Sharing in WSON

In a WSON with no wavelength converters, it is normally required that the same wavelength be allocated on all the links along the path. This limitation is known as the "wavelength continuity constraint", which makes the path selection of WSON different from that of other circuit switched networks (such as TDM). With wavelength converters, a lightpath does not have to be on the same wavelength and can consist of several consecutive wavelength continuous segments, with wavelength conversion carried out at the junction nodes. Network performance can be greatly improved by adding wavelength conversion ability. However, since wavelength converters are still expensive, only some of the network nodes will have capability of wavelength conversion. In the case of limited or no wavelength converters are implemented, route computation is known as Routing and Wavelength Assignment (RWA) problem. Three possible RWA computation architectures are discussed in [WSON-Frame]. They are combined RWA, separate routing and WA and routing with distributed WA. In the first two methods, exact network link wavelength information is required at any entity that responsible for RWA or WA. In the third method, routing is performed at a computational entity (PCE or NE), while wavelength assignment is performed in a distributed fashion across nodes along the path. In this memo, we focus on shared-mesh restoration under routing with distributed WA architecture.

Here we discuss the shortcomings of existing GMPLS protocols in supporting shared-mesh restoration for WSON. The current link resource measures in GMPLS do not provide enough information needed for RWA [WSON-frame]. If current routing methods for shared-mesh restoration are used, the pre-reserved wavelength resource for a protecting path may not satisfy the "Wavelength Continuity Constraints". [WSON-Signaling] proposed a more compact Wavelength Sets object instead of the LABEL_SET object (see [RFC3471] and [RFC3473]) to describe the current set of available wavelengths during the distributed WA process. On reception of Path message, destination node gets the available wavelengths along the path, thus it can perform certain wavelength selection algorithm such as First-Fit, Random, Least-Loaded. (Notice that Least-Loaded algorithm needs some supplemental information.) This method works well for the distributed WA of working path, but not for the protecting path. Even if Wavelength Set object is used to collect the wavelength availability information along the protecting path, it is still hard to perform efficient distributed WA at the destination node. An example is given as follows.

```
+---------------------------------------------------+
|   +-----+                                         |
|   | PCE1|                                         |
|   +--+--+                                         |
|      || routing results                           |
|      ||                                           |
|      ||                                           |
|     +---+     +---+     +---+     +---+           |
|     | A +-----+ B +-----+ C +-----+ D |           |
|     +---+     +---+     +---+     +---+           |
|       |         ------>             |             |
|       |      Path message           |             |
|       *                             |             |
|   working path    protecting path-->|             |
|       *                             |             |
|       |                             |             |
|       |       +---+     +---+     +-+-+           |
|       +-------+ G +-----+ F +-----| E |           |
|               +---+     +---+     +---+           |
|           wavelength selection                    |
|               at node G                           |
|                                                   |
+---------------------------------------------------+
```

Figure 1 Example network topology

Example:

Figure 1 depicts part of a mesh topology WSON network which consists of Wavelength Cross-Connects (WXCs) and (Dense WDM) DWDM links. A lightpath (wavelength-based LSP) from node A to node G is to be setup. Routing with distributed WA is used and routing for working path and protecting path is performed at a computational entity PCE1 [WSON-PCEP]. Node A generates Path message and starts the distributed WA process.

Here, we use the network link configuration given in [WSON-Signaling]. A 40 channel C-Band DWDM system with 100GHz spacing with lowest frequency 192.0THz (1561.4nm) and highest frequency 195.9THz (1530.3nm) is used in the example network. These frequencies correspond to n = -11, and n = 28 respectively. Now suppose the following channels are available and five wavelengths (1, 2, 3, 4, 6) are sharable on some link. n value and bit map position are defined for Wavelength Set object [WSON-Signaling]. The wavelength available and sharable information is showed as follows:

Symbol	Frequency (THz)	n Value	bit map position	sharable link
1	192.0	-11	0	(A-B),(D-E)
2	192.3	-8	3	(F-G)
3	193.1	0	11	(B-C)
4	194.5	14	25	(D-E)
5	194.8	17	28	--
6	195.5	24	35	(B-C),(C-D),(E-F)

By checking the information in PRIMARY_PATH_ROUTE object, each node along the protecting path can decide which wavelength on the local links can be shared with the current protecting path. On reception of a Path message with the available wavelengths in Wavelength Set object, the destination selects a wavelength for the lightpath. Since no per wavelength information on each link is known to node G. It will be confused to choose a wavelength according to the wavelength available information in Wavelength Set object and can not realize efficient resource sharing. According to local information at G, the wavelength sharing can be only performed at last hop (link F-G) by selecting 2 (2 is the only wavelength G knows for sure that can be shared). In fact, wavelength sharing can be performed at link (B-C), (C-D) and (E-F) if 6 is selected.

4. MSWS Method

This section presents our MSWS method to support shared-mesh restoration under routing with distributed WA architecture in WSON.

A lightpath can have one or more consecutive wavelength continuous segments, with wavelength conversion carried out at the junction nodes. In a segment, the first node (at upstream) is its head-end node and the last node (at downstream) is its tail-end node. The basic idea of MSWS method is to collect the wavelength sharable information in Path message along the protecting path. And on reception of the Resv message, the tail-end node of each segment selects the most sharable wavelength of this segment based on the collected information.

4.1. Conveying Wavelength Sharable information

Wavelength Set Metric TLV is defined in [WSON-Signaling] to provide supplemental information for distributed wavelength assignment. Here we inherit that TLV to convey information about sharable capability of each wavelength. Info Type is set to 1 (means list). There is a one-to-one correspondence between the value in the list of Wavelength Set Metric and the available wavelength in Wavelength Set. Along the

protecting path, RSVP-TE Path message will collect the wavelength sharable information and modify Wavelength Set Metric TLV. This process will be explained in the following sections.

4.2. Procedures

4.2.1. With No Wavelength Converters

First, a simple scenario where no wavelength converters are implemented to the network (or no wavelength converters will be used along the protecting path) is considered. In this case, the whole path is a single wavelength continuous segment. As RSVP-TE Path message travels along the path, following operations should be performed:

1. A Wavelength Set object is used to indicate the wavelength availability along the path. The operation for processing this object is the same to that is described in [RFC3473] and [WSON-signaling].

2. At the beginning, the value corresponding to each wavelength in Wavelength Set Metric is set to 0. Source node generates Path message with Wavelength Set object and Wavelength Set Metric. On reception of the Path message, each node is responsible to decide the sharable wavelengths for this hop (from itself to its downstream node). If certain wavelength is sharable, its corresponding value in Wavelength Set Metric is increased by 1.

3. Wavelength Set Metric is modified and passed along the protecting path in Path message until it gets to the destination node. The destination node is responsible to perform wavelength selection according to Wavelength Set object and Wavelength Set Metric. The wavelength with largest value (the most sharable wavelength) in the list of Wavelength Set Metric value is selected.

Example: In Figure 1, the Wavelength Set object and Wavelength Set Metric TLV received at destination node G is showed as follows:

Wavelength Set object:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Action = 4    | Reserved      |    Num Wavelengths = 40       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Grid |  C.S. |S|    Reserved   | n  for lowest frequency = 11  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |1 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0 0 0 1 0 0 0 0|   Not used in 40 Channel system (all zeros)   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Here, Grid=1, C.S.=4, S=1. (see [WSON-Signaling] and [Otani])

Wavelength Set Metric TLV:

```
    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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Info Type=1   | M.Size = 0    |   Num Metrics = 6             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |       2       |       1       |      1        |       1       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |       0       |       3       |          Padded to 0          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Since the value corresponding to 6 is 3, 6 will be selected by destination node G and wavelength sharing will be performed on three links on the protecting path.

4.2.2. With Limited Wavelength Converters

In case Wavelength Converters are used each lightpath may include several consecutive wavelength continuous segments. On reception of the Path message, intermediate node with wavelength conversion ability can decide whether wavelength conversion is required by checking whether the egress available wavelengths for the available wavelengths in Wavelength Set object is null or deemed too small.

1. Source node generates Path message with Wavelength Set object and Wavelength Set Metric. The operations to process Wavelength Set object and Wavelength Set Metric inside a wavelength continuous segment are similar to that in section 4.2.1. On reception of the Path message, the tail-end node of a segment stores the Wavelength Set and Wavelength Set Metric of this segment. And it generates a new Wavelength Set Metric according to the Wavelength Set and resets the value in the list in Wavelength Set Metric TLV to 0. If this tail-end node is not the destination, it must be the head-end of the next wavelength continuous segment. It will decide the sharable wavelength of the next hop and starts a new round of collecting Wavelength Set Metric operation.

2. The destination node is always the tail-end of the last wavelength continuous segment and it is responsible to perform wavelength selection for the last segment according to the Wavelength Set and Wavelength Set Metric of its segment. On reception of the Resv message, the tail-end of each segment is responsible to perform wavelength selection for its own segment.

5. Discussion

Wavelength converter sharing is allowed but not deliberately considered in our proposed method. The tail-end of a wavelength continuous segment can optionally carry out wavelength converter sharing during the Resv process if it is possible.

A probable way to explore wavelength converter sharing ability is to enlarge the wavelength set at every node where wavelength sharing is possible. However, this will potentially lead to break wavelength continuity even though it is not necessary. Maybe the "Reserve field" in Wavelength Set object can be used to provide more precisely control to deal with this contradiction.

6. Security Considerations

This document introduces no new security considerations to [RFC3473].

7. IANA Considerations

This document includes no request to IANA.

8. Acknowledgments

This document was prepared using 2-Word-v2.0.template.dot.

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