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Generalized Labels for G.694 Lambda-Switching Capable Label Switching Routers

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Abstract

Technology in the optical domain is constantly evolving and as a consequence new equipment providing lambda switching capability has been developed and is currently being deployed. However, [RFC 3471](#) has defined that a wavelength label ([section 3.2.1.1](#)) "only has significance between two neighbors" and global wavelength continuity is not considered. In order to achieve interoperability in a network composed of next generation lambda switch-capable equipment, this document defines a standard lambda label format, being compliant with ITU-T G.694. Moreover some consideration on how to ensure lambda continuity with RSVP-TE is provided. This document is a companion to

the Generalized Multi-Protocol Label Switching (GMPLS) signaling. It defines the label format when Lambda Switching is requested in an all optical network.

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[1](#). Introduction

As described in [[RFC3945](#)], Generalized MPLS (GMPLS) extends MPLS from supporting only packet (Packet Switching Capable - PSC) interfaces and switching to also include support for four new classes of interfaces and switching:

- o Layer-2 Switch Capable (L2SC)
- o Time-Division Multiplex (TDM)
- o Lambda Switch Capable (LSC)
- o Fiber-Switch Capable (FSC).

A functional description of the extensions to MPLS signaling needed to support new classes of interfaces and switching is provided in [[RFC3471](#)].

This document presents details that are specific to the use of GMPLS with a new generation of Lambda Switch Capable (LSC) equipment. Technologies such as Reconfigurable Optical Add/Drop Multiplex (ROADM) and Wavelength Cross-Connect (WXC) operate at the wavelength switching level. As such, the wavelength is important information that is necessary to set up a wavelength-based LSP appropriately and the wavelength defined in [G.694] is widely utilized.

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](#) [[RFC2119](#)].

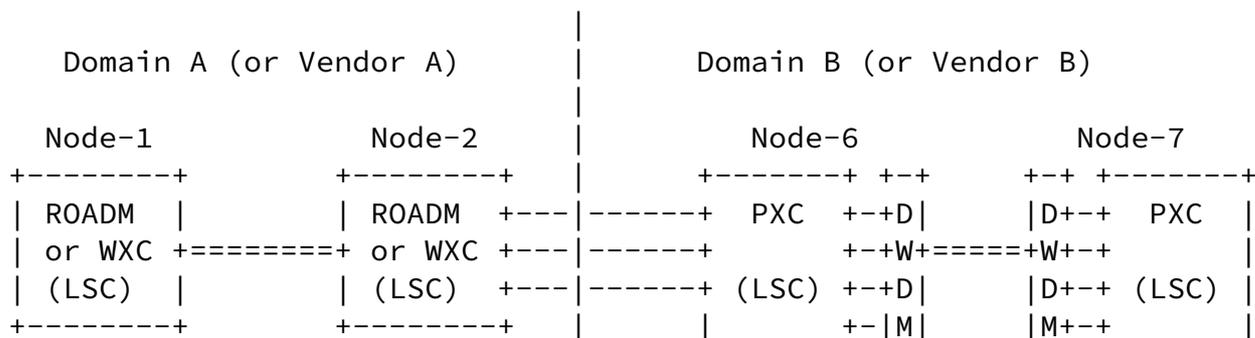
3. Assumed network model and related problem statement

Figure 1 depicts an all-optically switched network consisting of different vendor's optical network domains. Vendor A's network consists of ROADMs or WXC, and vendor B's network consists of PXC and DWDMs, otherwise both vendors' networks might be based on the same technology.

In this case, the use of standardized wavelength label information is quite significant to establish a wavelength-based LSP. It is also an important constraint when conducting CSPF calculation for RSVP-TE signaling. The way the CSPF is performed is outside the scope of this document, but defined in [[GMPLS-CSPF](#)].

It is needless to say, a LSP must be appropriately provisioned between a selected pair of ports not only within Domain A but also over multiple domains satisfying wavelength constraints.

Figure 2 illustrates in detail the interconnection between Domain A and Domain B.



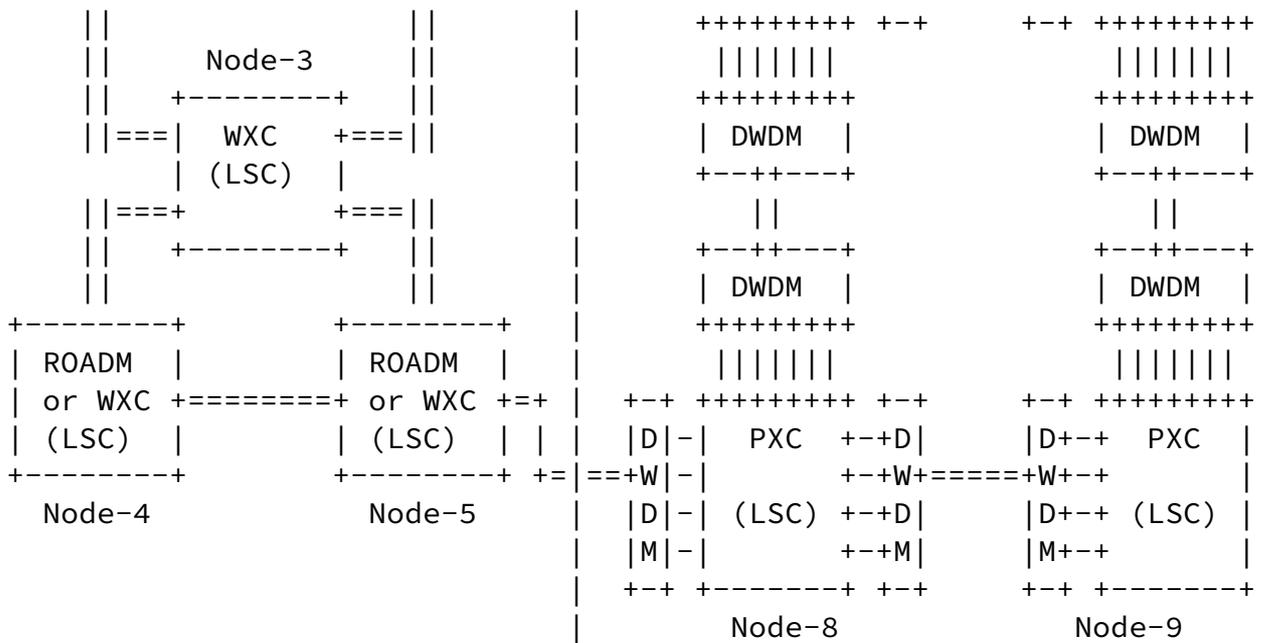


Figure 1 Wavelength-based network model.

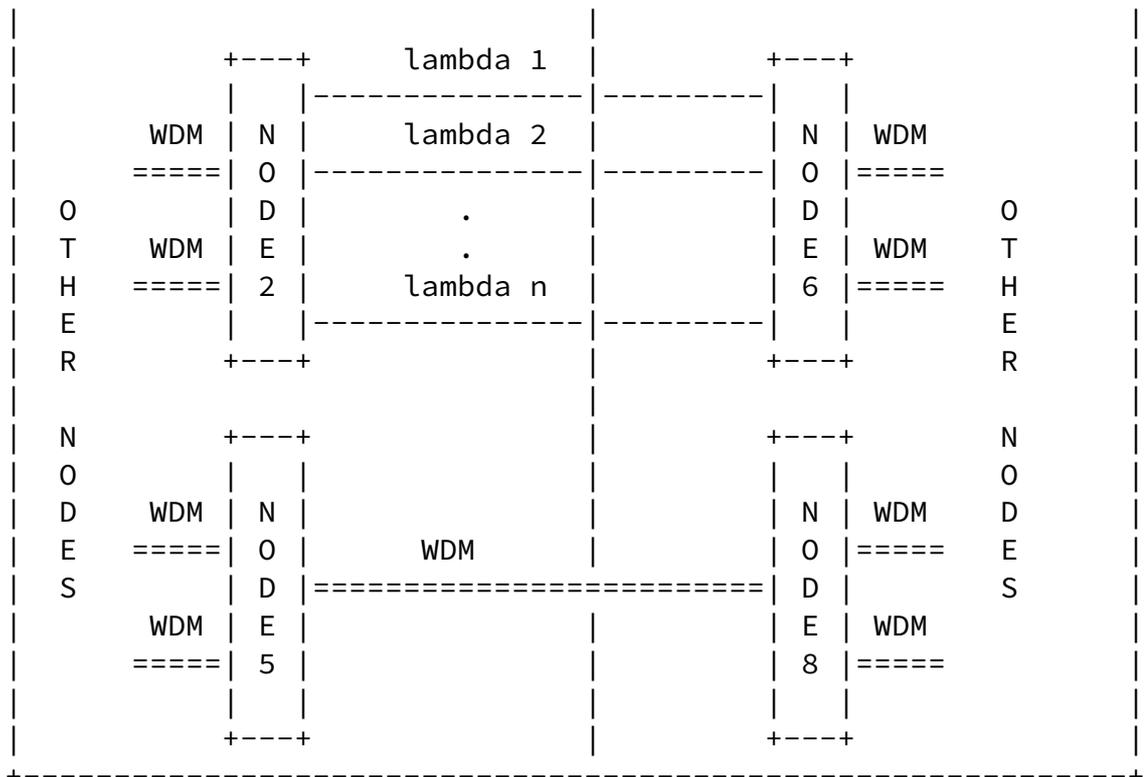
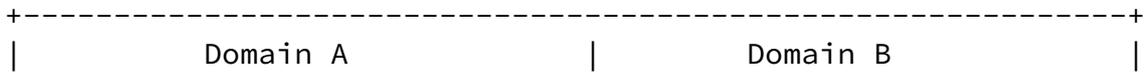


Figure 2 Interconnecting details between two domains.

In the scenario of Figure 1, consider the setting up of a bidirectional LSP from ingress switch 1 to egress switch 9. In order to satisfy wavelength continuity constraint, a fixed wavelength (λ_1) needs to be used in domain A and domain B. A Path message will be used for the signaling, the PATH message must contain the upstream label and a label set object; both containing the same λ_1 . The label set object is made by only one sub channel that must be same as the upstream label. The path setup will continue downstream to switch 9 by configuring each λ_1 switch based on the wavelength label. This label allows the correct switching of λ_1 switches and the label contents needs to be used over the inter-domain. As same above, the path setup will continue downstream to switch 9 by configuring λ_1 switch based on multiple wavelength labels. If the node has a tunable wavelength transponder, the tuning wavelength is considered as a part of wavelength switching operation.

Not using a standardized label would add undue burden on the operator to enforce policy as each manufacturer may decide on a different representation and therefore each domain may have its own label formats. Moreover, manual provisioning may lead to misconfiguration if domain-specific labels are used.

Therefore, a wavelength label should be standardized in order to allow interoperability between multiple domains; otherwise appropriate existing labels are identified in support of wavelength availability. As identical wavelength information, the ITU-T frequency grid specified in [G.694.1] for Dense WDM (DWDM) and wavelength information in [G.694.2] for Coarse WDM (CWDM) are used by LSRs and should be followed as a wavelength label.

[4. Label Related Formats](#)

To deal with the widening scope of MPLS into the optical and time domains, several new forms of "label" have been defined in [RFC3471]. This section contains clarifications for the Wavelength label based on [G.694] and Label Set definition specific for LSC LSRs.

4.1 Wavelength Labels

In [section 3.2.1.1 of \[RFC3471\]](#), a Wavelength label is defined to have significance between two neighbors, and the receiver may need to

convert the received value into a value that has local significance.

LSC equipment uses multiple wavelengths controlled by a single control channel. In such case, the label indicates the wavelength to be used for the LSP. This document proposes to standardize the wavelength label. As an example of wavelength values, the reader is referred to [G.694.1] which lists the frequencies from the ITU-T DWDM frequency grid. The same can be done for CWDM technology by using the wavelength defined in [G.694.2]. In that sense, we can call G.694 wavelength labels.

Since the ITU-T DWDM grid is based on nominal central frequencies, we need to indicate the appropriate table, the channel spacing in the grid and a value n that allows the calculation of the frequency. That value can be positive or negative.

The frequency is calculated as such in [G.694.1]:

$$\text{Frequency (THz)} = 193.1 \text{ THz} + n * \text{channel spacing (THz)}$$

, where n is an integer (positive, negative or 0) and channel spacing is defined to be 0.0125, 0.025, 0.05 or 0.1 THz. When wider channel spacing such as 0.2 THz is utilized, the combination of narrower channel spacing and the value n can provide proper frequency with that channel spacing. Channel spacing is not utilized to indicate the LSR capability but only to specify a frequency in signaling.

For the other example of the case of the ITU-T CWDM grid, the spacing between different channels was defined to be 20nm, so we need to pass the wavelength value in nm in this case. Examples of CWDM wavelengths are 1471, 1491, etc. nm.

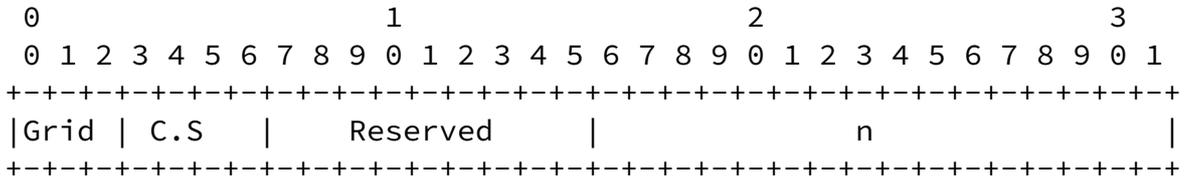
The wavelength is calculated as follows

$$\text{Wavelength (nm)} = 1471 \text{ nm} + n * 20 \text{ nm}$$

The tables listed in [G.694.1] and [G.694.2] are not numbered and change with the changing frequency spacing as technology advances, so an index is not appropriate in this case.

4.2 DWDM Wavelength Label

For the case of DWDM, the information carried in a Wavelength label is:



(1) Grid: 3 bits

The value for grid is set to 1 for ITU-T DWDM Grid as defined in [\[G.694.1\]](#).

+-----+-----+
Grid Value
+-----+-----+
ITU-T DWDM 1
+-----+-----+
ITU-T CWDM 2
+-----+-----+
Future use 3 - 7
+-----+-----+

(2) C.S.(channel spacing): 4 bits

DWDM channel spacing is defined as follows.

+-----+-----+
C.S(GHz) Value
+-----+-----+
100 1
+-----+-----+
50 2
+-----+-----+
25 3
+-----+-----+
12.5 4
+-----+-----+
Future use 5 - 15
+-----+-----+

(3) n: 16 bits

n is an integer to take either a negative, zero or a positive value. The value used to compute the frequency as shown above.

4.3 CWDM Wavelength Label

For the case of CWDM, the information carried in a Wavelength label is:

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```

  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
  +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
  |Grid | C.S  |      Reserved      |              n              |
  +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

```

The structure of the label in the case of CWDM is the same as that of DWDM case.

(1) Grid: 3 bits

The value for grid is set to 2 for ITU-T CWDM Grid as defined in [\[G.694.2\]](#).

```

+-----+-----+
|  Grid  | Value |
+-----+-----+
|ITU-T DWDM|  1  |
+-----+-----+
|ITU-T CWDM|  2  |
+-----+-----+
|Future use| 3 - 7 |
+-----+-----+

```

(2) C.S.(channel spacing): 4 bits

CWDM channel spacing is defined as follows.

```

+-----+-----+
| C.S(nm) | Value |
+-----+-----+
|   20    |  1  |
+-----+-----+
|Future use| 2 - 15 |
+-----+-----+

```

(3) n: 16 bits

n is an integer. The value used to compute the wavelength as shown above.

We do not need to define a new type as the information stored is either a port label or a wavelength label. Only the wavelength label as above needs to be defined.

5. Security Considerations

This document introduces no new security considerations to [\[RFC3473\]](#). GMPLS security is described in [section 11 of \[RFC3471\]](#) and refers to [\[RFC3209\]](#) for RSVP-TE.

[6.](#) IANA Considerations

This document has no actions for IANA.

[7](#). Acknowledgement

The authors would like to thank Adrian Farrel, Lawrence Mao, Zafar Ali, Dan Li and Daniele Ceccarelli for the discussion and their comments.

8.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), March 1997.
- [RFC3209] Awduche, D., Berger, L., Gan, D., Li, T., Srinivasan, V., and G. Swallow, "RSVP-TE: Extensions to RSVP for LSP Tunnels", [RFC 3209](#), December 2001.
- [RFC3471] Berger, L., "Generalized Multi-Protocol Label Switching (MPLS) Signaling Functional Description", [RFC 3471](#), January 2003.
- [RFC3473] Berger, L., "Generalized Multi-Protocol Label Switching (MPLS) Signaling - Resource ReserVation Protocol Traffic Engineering (RSVP-TE) Extensions", [RFC 3473](#), January 2003.
- [RFC3945] Mannie, E., Ed., "Generalized Multiprotocol Label Switching (GMPLS) Architecture", [RFC 3945](#), October 2004.

8.2. Informative References

- [GMPLS-CSPF] Otani, T., et al, "Considering Generalized Multiprotocol Label Switching Traffic Engineering Attributes During Path Computation", [draft-otani-ccamp-gmpls-cspf-constraints-08.txt](#), Feb. 2008.
- [G.694.1] ITU-T Recommendation G.694.1, "Spectral grids for WDM applications: DWDM frequency grid", June 2002.
- [G.694.2] ITU-T Recommendation G.694.2, "Spectral grids for WDM applications: CWDM wavelength grid", December 2003.

[Appendix A](#). DWDM Example

Considering the network displayed in figure 1 it is possible to show an example of LSP set up using the lambda labels.

Node 1 receives the request for establishing an LSP from itself to Node 9. The ITU-T grid to be used is the DWDM one, the channel spacing is 50Ghz and the wavelength to be used is 193,35 THz.

Node 1 signals the LSP via a Path message including a Wavelength Label structured as defined in [section 4.2](#):

```

      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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|Grid | C.S  |   Reserved   |                               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

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Where:

Grid = 1 : ITU-T DWDM grid
 C.S. = 2 : 50 GHz channel spacing
 n = 5 :

$$\text{Frequency (THz)} = 193.1 \text{ THz} + n * \text{channel spacing (THz)}$$

$$193.35 \text{ (THz)} = 193.1 \text{ (THz)} + n * 0.05 \text{ (THz)}$$

$$n = (193.35 - 193.1) / 0.05 = 5$$

[Appendix B](#). CWDM Example

The network displayed in figure 1 can be used also to display an example of signaling using the Wavelength Label in a CWDM environment.

This time the signaling of an LSP from Node 4 to Node 7 is considered. Such LSP exploits the CWDM ITU-T grid with a 20nm channel spacing and is established using wavelength equal to 1331 nm.

Node 4 signals the LSP via a Path message including a Wavelength Label structured as defined in [section 4.3](#):

```

    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
    +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
    |Grid | C.S  |   Reserved   |                               n                               |
    +---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
    
```

Where:

Grid = 2 : ITU-T CWDM grid
 C.S. = 1 : 20 nm channel spacing
 n = -7 :

$$\text{Wavelength (nm)} = 1471 \text{ nm} + n * 20 \text{ nm}$$

$$1331 \text{ (nm)} = 1471 \text{ (nm)} + n * 20 \text{ nm}$$

$$n = (1331 - 1471) / 20 = -7$$

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