OSPF extensions for support spectrum sub-band allocation
draft-wang-ccamp-flexigrid-wavelength-range-ospf-02.txt

Abstract

This document addresses the requirements and routing protocol extension of spectrum sub-band allocation in order to help reduce non-linear effect and raise spectrum utilization rate in the scenario of indiscriminately positioning of various channels with different bit rates.

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1. Introduction

In current DWDM systems, completely freedom and indiscriminate positioning of various channels with different bit rates is likely to lead to dramatically impaired system performance due to XPM (Cross-phased Modulation) effect and low spectrum utilization rate.

Cross phase modulation (XPM) is known as the phenomenon that variations of intensity of one optical signal can change the refractive index of the fiber, and modulate the phase of the other optical signals co-propagating in the same fiber.

When DWDM was first introduced, the typical wavelength date rate was 2.5Gb/s. 10Gb/s wavelength was enabled because of the development of higher performance optical modulators. However, the same simple modulation format was used at both 2.5Gb/s and 10Gb/s. The modulation technique is Intensity Modulation with Direct Detection (IM-DD). Barrier appeared if we want a wavelength to transport data with 40 Gb/s bitrate or more. After years of development, coherent technology is introduced to broken the limit for 40Gb/s and soon for 100Gb/s transmission.

Intensity modulation direct detection (IM-DD) systems are less sensitive to the variation of phase of the signal and is going to bring the variation of the intensity, then the changes of refractive index of the fiber. Just the reverse, optical coherent systems is a phase sensitive system. The modulated phase due to XPM has significant influence on the system performance. This is due to the fact that the phase modulation due to XPM can be transformed into intensity modulation through the chromatic dispersion of the fiber and will result in the distortion of signal. For example, if we mix 10Gbit/s NRZ modulated channels with 100Gbit/s xPSK modulated channels indiscriminately, XPM would have a detrimental effect on the 100Gbit/s signal if this are caused by 10Gbit/s signal; Complex modulation formats (e.g., 16QAM) would be used to modulate signal beyond 100Gbit/s (e.g., 400Gbit/s, 1Tbit/s), while QAM modulation format experiences both intensity and phase modulation, a QAM signal may affect another QAM signal due to XPM effect.

In current DWDM system with different bit rates, general advice is to group the channels with the same bit rates into the same spectrum sub-band to avoid the detrimental XPM effect.

Except the advantage described above, grouping of channels with the same bitrates will help reduce fragment in flexible grid network. Two kinds of DWDM application is described in the newest version of [G.694.1], one is fixed grid, and the other is flexible grid. Fixed grid is the traditional DWDM application with fixed channel slot.
width (e.g., 50GHz) which has been deployed in large scale in the network and flexible grid is a new kind of DWDM application with different channel slot widths which can be used to transport large bandwidth data. The flexible grid technology is also a DWDM application which is different from fixed grid application. Flexible grid is a kind of new DWDM application with different channel slot width (e.g., 50GHz, 87.5GHz etc). Signals with different bit rates may occupy different slot widths and use different modulation format. Grouping of signals with the same bit rates into the same spectrum may also be a better choice than completely freedom positioning.

Frequently setup and release of flexible grid optical channels which occupy different slot widths would result in the spectrum fragments that can’t be used anymore, and this will cause the decline of spectrum utilization rate. Global Concurrent Optimization (GCO), which combines with the implementation of the stateful PCE, can be used for defragmentation and raise spectrum utilization rate. But it’s complicated to apply the GCO in current network, because this will involve a large scale of resources and computation. Another method that can be used is to group the channels with the same bit rates into the same spectrum sub-band and this is also a feasible solution to help raise spectrum utilization rate.

According to the previous description, grouping of channels with the same bit rates maybe a good choice to reduce the XPM effect and raise spectrum utilization rate, especially in network with different slot widths. So in order to take the grouping into consideration during the path computation, a sub-band spectrum of the available spectrum SHOULD be allocated in advance and this spectrum allocation information SHOULD be known by path computation element when compute the path. This document mainly addresses the routing protocol extension to support the advertisement of the spectrum allocation information. Policy may be used by operator when split spectrum supported on a link into several sub-bands. One spectrum sub-band can only be used for path (optical channel) setup with specific attributes, for example, with specific bitrates and/or modulation format.

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 [RFC2119].
3. Overview of the Solution

In current DWDM system with different bit rates, general advice is to group the channels with the same bit rates and modulation format into the same spectrum sub-band to avoid the detrimental XPM effect. As signals of the same bitrates usually use the same modulation format on a specific link, this document mainly pays attention to grouping of channels with the same bitrates. Figure 1 shows an example, in which part of the spectrum frequency slots (i.e., the left sub-band) are allocated to 10 Gbit/s channels while another part of the frequency slots (i.e., the right sub-band) are allocated to 100 Gbit/s channels. Currently an NRZ modulation format is employed for 10 Gbit/s channels, while 40 Gbit/s and/or 100 Gbit/s channels are mostly phase-modulated (e.g. xPSK) signals. As noted above it is common practice to keep an appropriate guard band between channels with different bit rates and/or modulation format to minimize nonlinear effects induced signal degradations and to group channels with the same bit rate and modulation format.

![Figure 1: Group of Channels](image)

[Notes: According to the simulation results about grouped spectrum allocation and ungrouped spectrum allocation for 100Gbit/s and 400Gbit/s transmissions are carried. A grouped spectrum allocation only resulted in a small improvement (about 0.2 and 0.5 dB) compared to ungrouped spectrum allocation for 100G and 400G data transmissions respectively. The penalty induced by mixed QPSK and 16QAM signals seems to be much smaller than in a QPSK and NRZ hybrid system. This may be explained by the similar spectrum of the QPSK and 16QAM formats for the same baud rate. These results seem to indicate that systems operated with only phase modulated signals may show significantly lower impairments compared to systems operated with a mix of NRZ and phase modulated signals.]

[Note: we are not sure if grouping of channels with the same bit rate is needed in future. According to the discussion in ITU-T, a part of]
the experts express that: we should use grouping of channels with the same bit rate in the short term, however, in the long term, it may be forced to use indiscriminate positioning of the spectrum.

Some other advantages are also brought if operator split available spectrum into several sub-bands and one spectrum sub-band can only be used for optical channel setup with the same bit rate. A spectrum sub-band which can only be used for optical channel setup with the same bit rate will help reduce fragments. Channels in the same spectrum group sub-band with the same bitrates looks almost like fixed grid technology with the same slot width, and they won't generate fragments in the process of path setup and release. It may also be convenient for operator to manage the network if the operator groups the optical channel with the same bit rate.

When control plane uses path computation element to setup an end-to-end path through the DWDM network, spectrum available information and restriction information (e.g., spectrum partition information) should be taken into consideration in order to compute a suitable end-to-end path. The spectrum sub-band information needs to be advertised by routing protocol in order to help the path computation. Section 4 describes the extension of OSPF routing protocol to advertise these spectrum sub-band information in order to help path computation.

4. Extension of routing protocol

4.1. Relationship with WSON

WSON related work can be re-used in this document to advertise the spectrum group information. This Section addresses the routing extension work of the features which is describe in the previous section base on the current WSON work in IETF CCAMP Group. In the document [draft-ietf-ccamp-general-constraint-encode], a new link sub-TLV called Port Label Restrictions sub-TLV is defined. Descriptions about Port Label Restrictions sub-TLV in the draft [draft-ietf-ccamp-gmpls-general-constraints-ospf-te] are introduced here: "Port label restrictions describe the label restrictions that the network element (node) and link may impose on a port. These restrictions represent what labels may or may not be used on a link and are intended to be relatively static. More dynamic information is contained in the information on available labels. Port label restrictions are specified relative to the port in general or to a specific connectivity matrix for increased modeling flexibility" and "For example, Port Label Restrictions describes the wavelength restrictions that the link and various optical devices such as OXCs, ROADMs, and waveband multiplexers may impose on a port in WSON".
According to the previous description, the restrictions information carried in the port label restriction sub-TLV are used to represent what wavelength/spectrum may or may not be used on a link and are relatively static. The spectrum group allocation information described in this document can be regarded as label restrictions which are imposed by network element (node) on a port, and the network element include various optical devices such as OXCs, ROADMs and waveband multiplexers and so on. These spectrum sub-bands restrictions represent the spectrum allocation information and a spectrum sub-band can only be used for channels setup with specific bitrates and/or modulation format. This restriction is relatively static and can be carried in Port Label Restrictions sub-TLV.

4.2. Extensions of OSPF Protocol to Support Spectrum Group Allocation

Spectrum sub-band allocation information should be known by path computation element if operators want to compute an end-to-end optical channel path. As described in the previous section, Port Label Restrictions sub-TLV can be used to carry this spectrum sub-band allocation restriction information. Figure 1 is the format of Port Label Restrictions sub-TLV which is described in [draft-ietf-ccamp-general-constraint-encode] and definition of the parameters included in this sub-TLV can be found in this document.

<table>
<thead>
<tr>
<th>MatrixID</th>
<th>RestrictionType</th>
<th>Reserved/Parameter</th>
<th>Additional Restriction Parameters per RestrictionType</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</td>
<td>+-----------------------------------------------+</td>
<td>:</td>
<td>+-----------------------------------------------</td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</td>
<td>+-----------------------------------------------+</td>
<td>:</td>
<td>+-----------------------------------------------</td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</td>
<td>+-----------------------------------------------+</td>
<td>:</td>
<td>+-----------------------------------------------</td>
</tr>
</tbody>
</table>

Figure 2: Port Label Restrictions sub-TLV

4.2.1. Spectrum sub-band Allocation by Bitrates

As described in section 3, channels on a single fiber with the same bitrates usually use the same modulation format, especially when the equipments come from one vendor. So here operator can split spectrum into several spectrum sub-bands by bitrates. In this section, OSPF protocol is extended to cover the spectrum sub-bands allocation information by bitrates.
The spectrum sub-bands allocation information by bitrates is needed in the process of path computation if an end-to-end path needs to be computed by path computation element and this information SHOULD be advertised by routing protocols. Figure 3 gives a new kinds of Port Label Restrictions sub-TLV which mainly extent the Additional Restriction Parameters field to cover the spectrum sub-bands allocation information. The parameters in the Additional Restriction Parameters field include Bit Rate which indicates the bitrates of the specific spectrum sub-bands and spectrum boundaries information of the sub-band.

```
\begin{verbatim}
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   MatrixID    |RestrictionType|          Reserved             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Bit Rate                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                 Spectrum Sub-band Range                       :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\end{verbatim}
```

**Figure 3**

Definition of MatrixID and RestrictionType field can be found in the document [draft-ietf-ccamp-general-constraint-encode]. Value of RestrictionType needs to be assigned by IANA.

[Note: As several routing documents exist in the CCAMP and the label_set object encoding is not determined, this document use "spectrum sub-band range" to represent spectrum allocation information temporarily.]

"Bit Rate" field indicates the bitrates of the specific spectrum sub-band.

In some situation, modulation format information may also be needed to help allocation wavelength range, as signals with the same bitrates on a single fiber can use different modulation format. In this case, modulation formats information is needed to be carried in Port Label Restrictions sub-TLV. Wavelength that is supported by subsystems can be partitioned to service traditional fixed grid technology.
5. Security Considerations

TBD

6. IANA considerations

TBD.

7. References

7.1. Normative References


7.2. Informative References


[G.694.1 v1] International Telecommunications Union, "Draft revised G.694.1 version 1.3".

[WD6-12] International Telecommunications Union, "Discussion on progressing Q.6/15’s work on DWDM applications using flexible grid".


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