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Y. Li
F. Zhang
ZTE
R. Casellas
CTTC
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Flexible Grid Label Format in Wavelength Switched Optical Network
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Abstract

Flexible grid is regarded as an efficient way to improve the network capacity utilization. Mixed bit rate transmission systems can allocate their channel with different spectral bandwidths so that they can be optimized for the bandwidth requirements of the particular bit rate and modulation scheme of the individual channels. To support the flexible grid technique, this document extends the wavelength label to accommodate this new specification. It is demonstrated that the extended label format is compatible to the rigid one and can be used in the routing and signaling procedure in the Wavelength Switched Optical Network (WSON).

Table of Contents

1. Introduction

Dense Wavelength Division Multiplexing (DWDM) optical network is widely deployed by telecom operators to carry their data service. With the continuing exponential growth of internet traffic, more efficient utilization of optical network bandwidth for extremely high data rates is required. Although multi-level modulation formats and advanced photonics techniques have enabled 100 G/s transmission within a 50 GHz DWDM fixed gird (or channel spacing), much higher speed traffic, such as 400 Gbit/s and 1 Tbit/s signals are not expected to adapt such a narrow channel. So a wider fixed grid like 100 GHz spacing is required to enable these new transmission formats without inter-channel crosstalk. However, the total available spectrum resource of the specific band is limited (about 4.4 THz in C band). If a wider grid is chosen, the fewer wavelengths can be allocated to carry the data. Not to mention that some low bitrate signals will occupy too much spectral bandwidth so that the total utilization efficiency of the spectrum resource is relatively low.

The recent revision of ITU-T Recommendation [G.694.1] has decided to introduce the flexible grid DWDM technique which provide a new tool that operators can implement to provide a higher degree of network optimization than fixed grid systems. Flexible grid network is composed of arbitrarily assigned spectral slices. That means in such networks the adjacent channel spacing and assigned spectral bandwidth per wavelength are variable. Mixed bitrate transmission systems can allocate their channel with different spectral bandwidths so that they can be optimized for the bandwidth requirements of the particular bit rate and modulation scheme of the individual channels. This technique is regarded to be a promising way to improve the network utilization efficiency and fundamentally reduce the cost of the IP core network.

Based on the DWDM technique, Wavelength Switched Optical Network (WSON) uses the control plane to dynamically provide Label Switched Paths (LSPs) for the requested end to end connections. The label switching is performed selectively on wavelength label representing the center wavelength/frequency of the optical signal. To support the flexible grid technique, this document extends the wavelength label defined in [RFC6205] to accommodate the new specification. It is proved that the extended label format is compatible to the rigid one and can be used in the routing and signaling procedure in WSON and generic GMPLS network.

2. Terminology

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. Label format

3.1. Label values

The wavelength label format is defined in [RFC6205] and the corresponding wavelength or frequency value is referred to ITU-T Recommendations [G.694.1] and [G.694.2] for DWDM and CWDM grid respectively. The ITU-T fixed grid is based on nominal center frequency/wavelength.

For DWDM system, the nominal center frequency is calculated as:

Frequency (THz)=193.1 THz+n* channel spacing

In the context of rigid grid, the channel spacing of DWDM can support 12.5 GHz, 25 GHz, 50 GHz, or 100 GHz. However, once chosen, the adjacent channel spacing of the wavelengths is fixed. As mentioned in the section 1, 50 GHz channel spacing is most commonly used.

The recent revision of [G.694.1] has defined suggested values for the flexible DWDM grid. The concept of "frequency slot" is introduced to describe the frequency range allocated to a channel. A frequency slot is defined by its nominal central frequency and its required slot width values.

For the flexible DWDM grid, the allowed frequency slots have a nominal central frequency (in THz) defined by:

Frequency (THz)=193.1 THz + n * 0.00625

and a slot width (the same meaning as the spectral bandwidth) defined by:

12.5 GHz * m

where m is a positive integer.

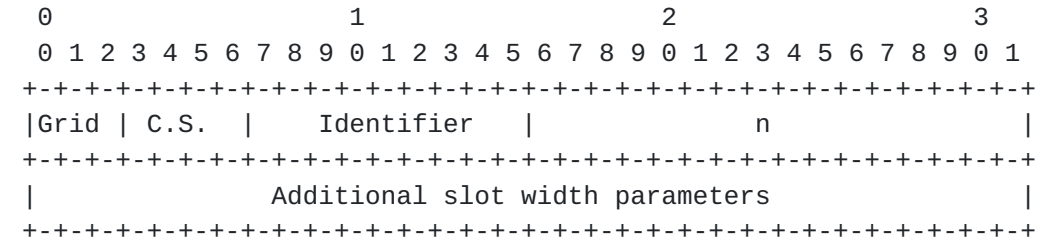
The nominal center frequency representations of the fixed grid and flexible grid types are similar except that the latter has a more precise channel spacing granularity (6.25 GHz). Meanwhile the adjacent channel spacing (the spacing of the adjacent nominal center frequency) is implied to be (n1-n2) * 6.25 GHz, where n1 and n2 represent the n number defined above for the nominal center frequency of the adjacent frequency slots respectively (n is an integer

including positive, negative integer and 0). The slot width assigned to a frequency slot is arbitrary times of the slot width granularity. It was agreed on flexible grids with a granularity of 6.25 GHz for the central frequency and slot width of a multiple of 12.5 GHz. The slot width granularity is twice the channel spacing granularity, so that by carefully choosing n and m, the spectral resources can be allocated without leaving any gaps between slots. Therefore, in contrast to the rigid label, the new flexible label should have a capability to indicating the slot width allocation.

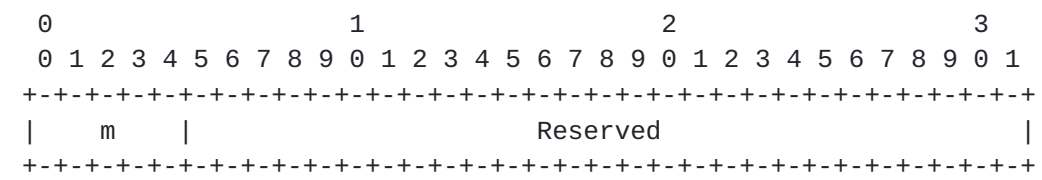
Note that in this document, the concepts "slot width" and "frequency slot" are similar to "spectral bandwidth" and "wavelength channel" respectively.

3.2. Flexible Label

To accommodate the new feature mentioned above, the wavelength label supporting flexible grid is illustrated as follows :



Additional slot width parameters:



Grid:

One new Grid type called "Flexible DWDM" is defined.

Grid	Value
Reserved	0
ITU-T DWDM	1
ITU-T CWDM	2

Flexible DWDM	3
Future use	4-7

C.S.:

For Grid=1 and 2, C.S. is referred to DWDM and CWDM channel spacing [RFC6205], which indicates that the adjacent channel spacing is constant. In this situation, the spectral bandwidth value allocated to every single channel is equal to value of the channel spacing.

For Grid=3, C.S. is referred to channel spacing granularity, accordingly the slot width granularity is twice of the C.S.. Minimum channel spacing granularity of 6.25 GHz with a slot width granularity of 12.5 GHz is supported.

C.S. (GHz)	Value
Reserved	0
100	1
50	2
25	3
12.5	4
6.25	5
Future use	6-15

Identifier:

The identifier field in the flexible label format is left unmodified compared with [RFC6205]. It is defined to distinguish which transmitter is used to carry the lambda. This identifier only has a local significance that should be indicated in the signaling message for LSP establishment. For routing information flooding, this filed is meaningless and should be ignored on receipt.

n:

This field is used to compute the nominal center frequency/wavelength

of the channel mentioned above. Together with the channel spacing granularity (C.S.), the spacing of the adjacent channel is (n1-n2) * 6.25 GHz in flexible grid network (see definition of n1 and n2 in section 3.1).

Additional slot width parameters.

The slot width parameters field is mandatory only when Grid is set to 3 for flexible grid condition. These 5 bits field are used to represent how many slot width granularity the label has occupied. As the granularity is defined to be twice of the channel spacing granularity, so the slot width is calculated to be m * 2 * C.S..

4. Flexible label applications

This section illustrated the routing, signaling, PCE application of the extended flexible grid label.

4.1. Application for Routing

Flexible grid is regarded as an enabler for another kind of networks, requiring network elements, or nodes, that go past beyond the functional requirements of OXCs or ROADMs, in the sense that they do switching based on a frequency range. This means that a new swithing type called e.g. "Spectrum Selective Switching" in Interface Switching Capability Descriptor (ISCD) SHOULD be defined. However this is beyond the scope of this document and will be studied in the routing draft.

In addition to the topology information, wavelength constraints information like Port Label Restrictions, Shared Backup Labels, Resource Pool Wavelength Constrains, Resource Block Available Wavelengths detailed in [I-D.ietf-ccamp-rwa-info] should be flooded in the network through routing protocol like OSPF-TE. All the information is described by the label set object. The general label set is described in [RFC3471] and specific wavelength label set in [I-D.ietf-ccamp-general-constraint-encode] . There are 5 ways to represent the wavelength label set

1. Inclusive list
2. Exclusive list
3. Inclusive range
4. Exclusive range
5. Bitmap set

For flexible grid optical network, the label set should be more actually to represent the spectral resources constraints. For type 1

and 2, flexible label with different slot width is acceptable to put into the list. For type 3 and 4, start label and end label with minimal slot width (while it is not mandatory) is RECOMMENDED. For type 5, the base label/frequency slot is REQUIRED to have a minimum slot width (m=1). As there MAY exist some situations that the unused bandwidth between two occupied bandwidth is odd times of the channel spacing granularity (not integral times of the slot with granularity), two bits are needed to represent a single slot. It can be seen that these 5 types of representations can be easily inherited by incorporating the new flexible label into the object. Note that in the procedure of wavelength constraints flooding, any combination of the 5 types of label sets is feasible.

4.2. Applications for Signaling

In flexibel grid network, flexible label representing frequency "slots" or "ranges" rather than individual wavelengths is requested to establish the LSP. The extensions to the Genralized Label Request object and TSPEC object are needed, this will be studied in the future.

To establish a label switched path, an available wavelength label satisfying the wavelength continuity constraints is reserved with signaling protocol like RSVP-TE. For the flexible grid DWDM network, this procedure should be modified to assign available spectral resources. In other words, the label is not only assigning the nominal center frequency of wavelength but also the slot width for the LSP. The slot width is definitely clarified through the field m in the label. Nevertheless in the procedure, wavelength continuity constraint is unchanged.

4.3. Applications for PCE

[RFC6163] describes a Path Computation Element (PCE) can be used to performing routing and wavelength assignment in WSON. [RFC5440] details the path computation element communication protocol messages for this purpose. According to the modulation format, FEC type, client
bitrates[I-D.ietf-ccamp-rwa-info][I-D.ietf-ccamp-rwa-wson-encode], and physical impairment, the required frequency slot indicated by flexible label should be calculated out by the PCE to carry the client signal.

5. Acknowledgements

6. IANA Considerations

A future revision of this document will present requests to IANA for codepoint allocation.

7. Security Considerations

8. References

8.1. Normative references

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Authors' Addresses

Yao Li
ZTE
P.R.China

Phone: +86 025 52871109
Email: li.yao3@zte.com.cn

Zhang Fei
ZTE
P.R.China

Phone: +86 025 52871109
Email: zhang.fei3@zte.com.cn

Ramon Casellas
CTTC
Spain

Phone: +34 936452916
Email: ramon.casellas@cttc.es