

Network Working Group  
Internet-Draft  
Intended status: Standards Track  
Expires: March 26, 2017

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September 22, 2016

Link Management Protocol Extensions for Grid Property Negotiation  
draft-ietf-ccamp-grid-property-lmp-04

Abstract

ITU-T [G.694.1] introduces the flexible-grid DWDM technique, which provides a new tool that operators can implement to provide a higher degree of network optimization than is possible with fixed-grid systems. This document describes the extensions to the Link Management Protocol (LMP) to negotiate link grid property between the adjacent DWDM nodes before the link is brought up.

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## 1. Introduction

ITU-T [G.694.1] introduces the flexible-grid DWDM technique, which provides a new tool that operators can implement to provide a higher degree of network optimization than is possible with fixed-grid systems. A flexible-grid network supports allocating a variable-sized spectral slot to a channel. Flexible-grid DWDM transmission systems can allocate their channels with different spectral bandwidths/slot widths 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 spectrum utilization efficiency and can be used in the beyond 100Gbit/s transport systems.

Fixed-grid DWDM system is regarded as a special case of Flexi-grid DWDM. It is expected that fixed-grid optical nodes will be gradually replaced by flexible nodes and interworking between fixed-grid DWDM and flexible-grid DWDM nodes will be needed as the network evolves. Additionally, even two flexible-grid optical nodes may have different grid properties based on the filtering component characteristics, thus need to negotiate on the specific parameters to be used during neighbor discovery process [RFC7698]. This document describes the extensions to the Link Management Protocol (LMP) to negotiate a link grid property between two adjacent nodes before the link is brought up.

### 1.1. 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].

## 2. Terminology

For the flexible-grid DWDM, the spectral resource is called frequency slot which is represented by the central frequency and the slot width. The definition of nominal central frequency, nominal central frequency granularity, slot width and slot width granularity can be referred to [RFC7698].

In this contribution, some definitions are listed below except those defined in [RFC7698]:

Tuning range: It describes the supported spectrum slot range of the switching nodes or interfaces. It is represented by the supported minimal slot width and the maximum slot width.

Channel spacing: It is used in traditional fixed-grid network to identify spectrum spacing between two adjacent channels.

## 3. Requirements for Grid Property Negotiation

### 3.1. Flexi-fixed Grid Nodes Interworking

Figure 1 shows an example of interworking between flexible and fixed-grid nodes. Node A, B, D and E support flexible-grid. All these nodes can support frequency slots with a central frequency granularity of 6.25 GHz and slot width granularity of 12.5 GHz. Given the flexibility in flexible-grid nodes, it is possible to configure the nodes in such a way that the central frequencies and slot width parameters are backwards compatible with the fixed DWDM grids (adjacent flexible frequency slots with channel spacing of

8\*6.25 and slot width of 4\*12.5 GHz is equivalent to fixed DWDM grids with channel spacing of 50 GHz).

As node C can only support the fixed-grid DWDM property with channel spacing of 50 GHz, to establish a LSP through node B, C, D, the links between B to C and C to D must set to align with the fixed-grid values. This link grid property must be negotiated before establishing the LSP.

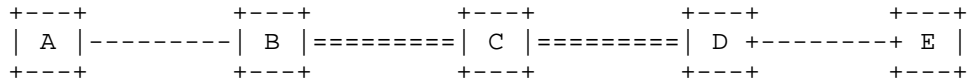


Figure 1: Interworking between flexible and fixed-grid nodes

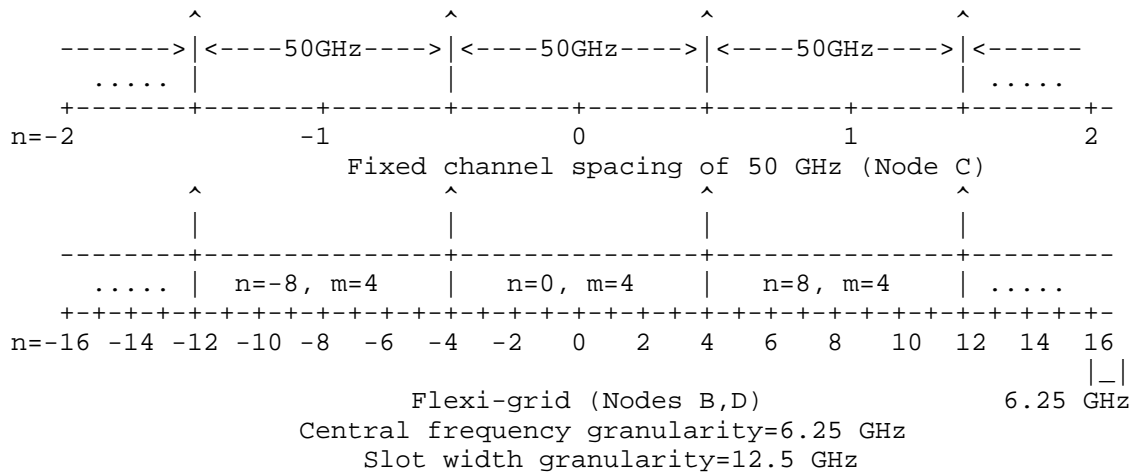


Figure 2: Fixed grid channel spacing and flexi-grid spectrum slot

### 3.2. Flexible-Grid Capability Negotiation

The updated version of ITU-T [G.694.1] has defined the flexible-grid with a central frequency granularity of 6.25 GHz and a slot width granularity of 12.5 GHz. However, devices or applications that make use of the flexible-grid may not be able to support every possible slot width or position. In other words, applications may be defined where only a subset of the possible slot widths and positions are required to be supported. Taking node G in figure 3 as an example, an application could be defined where the nominal central frequency granularity is 12.5 GHz (by only requiring values of  $n$  that are even) requiring slot widths being multiple of 25 GHz (the values of  $m$  SHOULD be even). Therefore the link between two optical node F and G with different grid granularity must be configured to align with the

larger of both granularities. Besides, different nodes may have different slot width tuning ranges. For example, in figure 3, node F can only support slot width with tuning change from 12.5 to 100 GHz, while node G supports tuning range from 25 GHz to 200 GHz. The link property of slot width tuning range for the link between F and G should be chosen as the range intersection, resulting in a range from 25 GHz to 100 GHz.

+---+		+---+				
F +-----		G				
+---+		+---+				
+-----+-----+-----+-----+						
	Unit (GHz)		Node F		Node G	
+-----+-----+-----+-----+						
	Grid granularity		6.25 (12.5)		12.5 (25)	
+-----+-----+-----+-----+						
	Tuning range		[12.5, 100]		[25, 200]	
+-----+-----+-----+-----+						

Figure 3: Flexible-grid capability negotiation

Note: we should avoid the use of LMP in the case that a DWDM or Flex port is connected to a CWDM port, for this it is likely to cause the upgrade of hardware and LMP can not work in a "plug-and-play" way.

### 3.3. Summary

In summary, in a DWDM Link between two nodes, the following properties should be negotiated:

- o Grid capability: flexible grid or fixed grid DWDM.
- o Nominal central frequency granularity: a multiplier of 6.25 GHz.
- o Slot width granularity: a multiplier of 12.5 GHz.
- o Slot width tuning range: two multipliers of 12.5GHz, each indicate the minimal and maximal slot width supported by a port respectively.

And for ports on a link that do not have any grid properties in common, the link and its properties SHOULD not be advertised.

## 4. Application of Grid Property Negotiation

As described in [RFC7698], the control plane MAY include support for neighbor discovery such that a flexi-grid network can be constructed in a "plug-and-play" manner. The control plane SHOULD allow the nodes at opposite ends of a link to correlate the properties that

they will apply to the link. Such a correlation SHOULD include at least the identities of the nodes and the identities that they apply to the link. As described in this draft, for ports on a link that do not have any grid properties in common, the link and its properties SHOULD not be advertised to the PCE or other nodes in the same domain. Especially in the scenario of inter-domain, LMP can not be replaced by some other protocol. For example, if Path Computation Element (PCE) or a serial of PCEs coordinate to compute an end-to-end path which crosses more than one domain, it should take the inter-domain grid properties into consideration. Given the OSPF can not advertise the attributes of the border device on the other side, the inter-domain attributes must be negotiated in advance, otherwise the end-to-end path may not be set up successfully.

## 5. LMP extensions

### 5.1. Grid Property Subobject

According to [RFC4204], the LinkSummary message is used to verify the consistency of the link property on both sides of the link before it is brought up. The LinkSummary message contains negotiable and non-negotiable DATA\_LINK objects, carrying a series of variable-length data items called subobjects, which illustrate the detailed link properties. The subobjects are defined in Section 13.12.1 in [RFC4204].

To meet the requirements stated in section 3, this draft extends the LMP protocol by introducing a new DATA\_LINK subobject called "Grid property", allowing the grid property correlation between adjacent nodes. The encoding format of this new subobject is as follows:

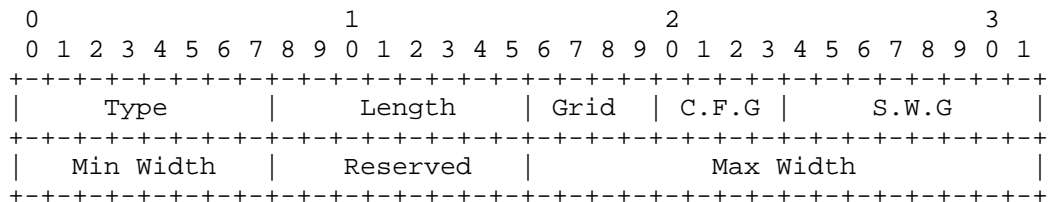


Figure 4

Type=TBD, Grid property type.

Grid: 4 bits

The value is used to represent which grid the node/interface supports. Values defined in RFC 6205 [RFC6205] identify DWDM

[G.694.1] and CWDM [G.694.2]. The value defined in [RFC7699] identifies flexible DWDM.

Grid	Value
Reserved	0
ITU-T DWDM	1
ITU-T CWDM	2
ITU-T Flex	3
Future use	4-16

C.F.G (central frequency granularity):

It is a positive integer. Its value indicates the multiple of 6.25 GHz in terms of central frequency granularity.

S.W.G (Slot Width Granularity):

It is a positive integer value which indicates the slot width granularity which is the multiple of 12.5 GHz.

Min Width and Max Width:

Min Width and Max Width are positive integers. Their value indicate the multiple of 12.5 GHz in terms of the slot width tuning range the interface supports. For example, for slot width tuning range from 25 GHz to 100 GHz (with regard to a node with slot width granularity of 12.5 GHz), the values of Min Width and Max Width should be 2 and 8 respectively. For fixed-grid nodes, these two fields are meaningless and should be set to zero.

## 6. Messages Exchange Procedure

### 6.1. Flexi-fixed Grid Nodes Messages Exchange

To demonstrate the procedure of grid property correlation, the model shown in Figure 1 is reused. Node B starts sending messages.

o After inspecting its own node/interface property, node B sends node C a LinkSummary message including the MESSAGE ID, TE\_LINK ID and DATA\_LINK objects. The setting and negotiating of MESSAGE ID and TE\_link ID can be referenced to [RFC4204]. As node B supports

flexible-grid property, the Grid and C.F.G values in the grid property subobject are set to be 3 (i.e., ITU-T Flex) and 1 (i.e., 1\*6.25GHz) respectively. The slot width tuning range is from 12.5 GHz to 200 GHz (i.e., Min Width=1, Max Width=16). Meanwhile, the N bit of the DATA\_LINK object is set to 1, indicating that the property is negotiable.

- o When node C receives the LinkSummary message from B, it checks the Grid, C.F.G, Min and Max values in the grid property subobject. Node C can only support fixed-grid DWDM and realizes that the flexible-grid property is not acceptable for the link. Since the receiving N bit in the DATA\_LINK object is set, indicating that the Grid property of B is negotiable, node C responds to B with a LinkSummaryNack containing a new Error\_code object and state that the property of the interface connected to node B needs further negotiation. Meanwhile, an accepted grid property subobject (Grid=2, C.F.G=4, fixed DWDM with channel spacing of 50 GHz) is carried in LinkSummaryNack message. At this moment, the N bit in the DATA\_LINK object is set to 0, indicating that the grid property subobject is non-negotiable.

- o As the channel spacing and slot width of the corresponding interface of node B can be configured to be any integral multiples of 6.25 GHz and 12.5 GHz respectively, node B supports the fixed DWDM values announced by node C. Consequently, node B will resend the LinkSummary message carrying the grid property subobject with values of Grid=2 and C.F.G=4.

- o Once received the LinkSummary message from node B, node C replies with a LinkSummaryACK message. After the message exchange, the link between node B and C is brought up with a fixed channel spacing of 50 GHz.

In the above mentioned grid property correlation scenario, the node supporting a flexible-grid is the one that starts sending LMP messages. The procedure where the initiator is the fixed-grid node is as follows:

- o After inspecting its own interface property, Node C sends B a LinkSummary message containing a grid property subobject with Grid=2, C.F.G=4. The N bit in the DATA\_LINK object is set to 0, indicating that it is non-negotiable.

- o As the channel spacing and slot width of node B can be configured to be any integral multiples of 6.25 GHz and 12.5 GHz respectively, node B is able to support the fixed DWDM parameters. Then, node B will make appropriate configuration and reply node C the LinkSummaryACK message



- o After the message exchange, the link between node B and C is brought up with a fixed channel spacing of 50 GHz.

## 6.2. Flexible Nodes Messages Exchange

To demonstrate the procedure of grid property correlation between two flexi-grid capable nodes, the model shown in figure 3 is reused. The procedure of grid property correlation (negotiating the grid granularity and slot width tuning range) is similar to the scenarios mentioned above.

- o The Grid, C.F.G, Min and Max values in the grid property subobject sent from node F to G are set to be 3,1,1,8 respectively. Meanwhile, the N bit of the DATA\_LINK object is set to 1, indicating that the grid property is negotiable.

o When node G has received the LinkSummary message from F, it will analyze the Grid, C.F.G, Min and Max values in the Grid property subobject. But the corresponding interface of node G can only support grid granularity of 12.5 GHz and a slotwidth tuning range from 25 GHz to 200 GHz. Considering the interface property of node F, node G will first match these property with its corresponding interface, and then judge the mismatch of the property of the link between node F and G, then respond F a LinkSummaryNack containing a new Error\_code object and state that the property need further negotiation. Meanwhile, an accepted grid property subobject (Grid=3, C.F.G=2, Min=2, Max=8, the slot width tuning range is set to the intersection of Node F and G) is carried in LinkSummaryNack message. Meanwhile, the N bit in the DATA\_LINK object is set to 1, indicating that the grid property subobject is non-negotiable.

o As the channel spacing and slot width of the corresponding interface of node F can be configured to be any integral multiples of 6.25 GHz and 12.5 GHz respectively, node F can support the lager granularity. The suggested slot width tuning range is acceptable for node F. In consequence, node F will resend the LinkSummary message carrying the grid subobject with values of Grid=3, C.F.G=2, Min=2 and Max=8.

o Once received the LinkSummary message from node F, node G replies with a LinkSummaryACK message. After the message exchange, the link between node F and G is brought up supporting central frequency granularity of 12.5 GHz and slot width tuning range from 25 GHz to 100 GHz.

From the perspective of the control plane, once the links have been brought up, wavelength constraint information can be advertised and

the wavelength label can be assigned hop-by-hop when establishing a LSP based on the link grid property.

## 7. IANA Considerations

This draft introduces the following new assignments:

LMP Sub-Object Class names:

- o under DATA\_LINK Class name (as defined in [RFC4204])
- Grid property type (sub-object Type = TBD.)

## 8. Acknowledgments

This work was supported in part by the China NSFC Project 61201260.

## 9. Security Considerations

LMP message security uses IPsec, as described in [RFC4204]. This document only defines new LMP objects that are carried in existing LMP messages. As such, this document introduces no other new security considerations not covered in [RFC4204].

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