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Y.Li
ZTE
G.Zhang
CATR
X.Fu
ZTE
R. Casellas
CTTC
Y.Wang
CATR

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Link Management Protocol Extensions for Grid Property Negotiation
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Abstract

The recent updated version of ITU-T [G.694.1] has introduced 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

The recent updated version of ITU-T [G.694.1] has introduced 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 100Gb/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 [draft-ietf-ccamp-flexi-grid-fwk-00]. This document describes the extensions to the Link Management Protocol (LMP) to negotiate a link grid property between two adjacent Flexi-grid 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 RFC 2119 [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 defined nominal central frequency and the slot width can be referred to [FLEX-FWK].

In this contribution, some other definitions are listed below:

Central frequency granularity: It is the granularity of the allowed central frequencies and is set to the multiple of 6.25 GHz.
Slot width granularity: It is the granularity of the allowed slot width, and is set to the multiple of 12.5 GHz.

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.

```
    +---+         +---+         +---+         +---+        +---+
    | A |---------| B |=========| C |=========| D +--------+ E |
    +---+         +---+         +---+         +---+        +---+
             Figure 1 An example of interworking between
                    flexible and fixed-grid nodes

           ^               ^               ^              ^
  ------->|<----50GHz---->|<----50GHz---->|<----50GHz---->|<------
    ..... |               |               |               | .....
  +-------+-------+-------+-------+-------+--------+------+-------+-
 n=-2             -1               0                1               2
                      Fixed channel spacing of 50 GHz (Node C)
           ^               ^               ^              ^
           |               |               |              |
```

```
     --------+---------------+---------------+---------------+---------
       ..... | n=-8, m=4       |   n=0, m=4    |   n=8, m=4    | .....
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
   n=-16 -14 -12 -10 -8 -6 -4 -2        0   2  4   6    8   10 12 14 16
                                                                     |_|
                            Flexi-grid (Nodes B,D)            6.25 GHz
                    Central frequency granularity=6.25 GHz
                        Slot width granularity=12.5 GHz
              Figure 2 Representation of fixed 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. In other words, applications may be defined where different grid granularity can be supported. Taking node G as an example, an application could be defined where the central frequency granularity is 12.5 GHz requiring slot widths being multiple of 25 GHz. Therefore the link between two optical nodes 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 An example of flexible-grid capability negotiation

3.3. Summary

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

o Grid capability: flexible grid or fixed grid DWDM.

o 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.

4. LMP extensions

4.1. 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 12.12.1 in [RFC4204].

To solve the problems 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Grid | C.F.G |      S.W.G    |      Min      |      Max      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type=TBD, Grid property type.

Grid:
The value is used to represent which grid the node/interface supports. Values defined in [RFC6205] identify DWDM [G.694.1] and CWDM [G.694.2]. The value defined in [I-D.farrkingel-ccamp-flexigrid-lambda-label] identifies flexible DWDM.

```
    +---------------+-------+
```

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

C.F.G (central frequency granularity):

For a fixed-grid node/interface, the C.F.G value is used to represent the channel spacing, as the spacing between adjacent channels is constant. For a flexible-grid node/interface, this field should be used to represent the central frequency granularity which is the multiple of 6.25 GHz.

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

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 & Max:

Min & Max indicate the slot width tuning range the interface supports (as defined in section 2). 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 and Max should be 2 and 8 respectively. For fixed-grid nodes, these two fields are meaningless and should be set to zero.

5. Messages Exchange Procedure

5.1. 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.S. values in the grid property subobject are set to be 3 and 5 respectively. The slot width tuning range is from 12.5 GHz to 200 GHz. 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.S., 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 needs further negotiation. Meanwhile, an accepted grid property subobject (Grid=2, C.S.=2, 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 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.S.=2.

- 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.S.=2. 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.

5.2. Flexible Nodes Messages Exchange

To demonstrate the procedure of grid property correlation between to 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.S., Min and Max values in the grid property subobject sent from node F to G are set to be 3,5,1,8 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.S., Min and Max values in the Grid property subobject. But node G can only support grid granularity of 12.5 GHz and a slotwdith tuning range from 25 GHz to 200 GHz. Considering the property of node F, node G then will 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.S.=4, Min=1, Max=4, 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 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.S.=4, Min=1 and Max=4.

- 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.

6. Security Considerations

TBD.

7. IANA Considerations

TBD.

8. References

8.1. Normative references

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[G.694.2] International Telecommunications Union, "Spectral grids for WDM applications: CWDM wavelength grid", Recommendation G.694.2, December 2003.

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9. Authors' Address

Yao Li (editor)

ZTE
Email: li.yao3@zte.com.cn

Guoying Zhang (editor)
China Academy of Telecom Research, MIIT

Email: zhangguoying@catr.cn

Xihua Fu (editor)

ZTE

Email: fu.xihua@zte.com.cn

Ramon Casellas

CTTC

Email: ramon.casellas@cttc.es

Yu Wang

China Academy of Telecom Research, MIIT
Email: wangyu@catr.cn

10. Contributors' Address

Wenjuan He (editor)
ZTE

Email: he.wenjuan1@zte.com.cn