Network Working Group   Q. Wang, Ed.
Internet-Draft   ZTE
Intended status: Standards Track   G. Zhang, Ed.
Expires: March 26, 2017   CAICT
                                                                Y. Li
                                                    Nanjing University
                                                          R. Casellas
                                                                 CTTC
                                                              Y. Wang
                                                                CAICT
                                                   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.

Status of This Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

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   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on March 26, 2017.

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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
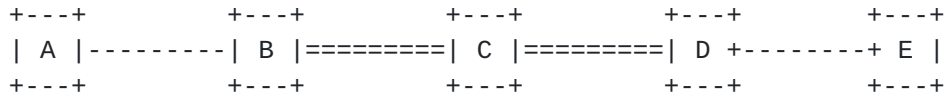establishing the LSP.

```
     +---+           +---+           +---+           +---+           +---+
     | A |---------| B |=========| C |=========| D +---------+ E |
     +---+           +---+           +---+           +---+           +---+
```

      Figure 1: 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
```
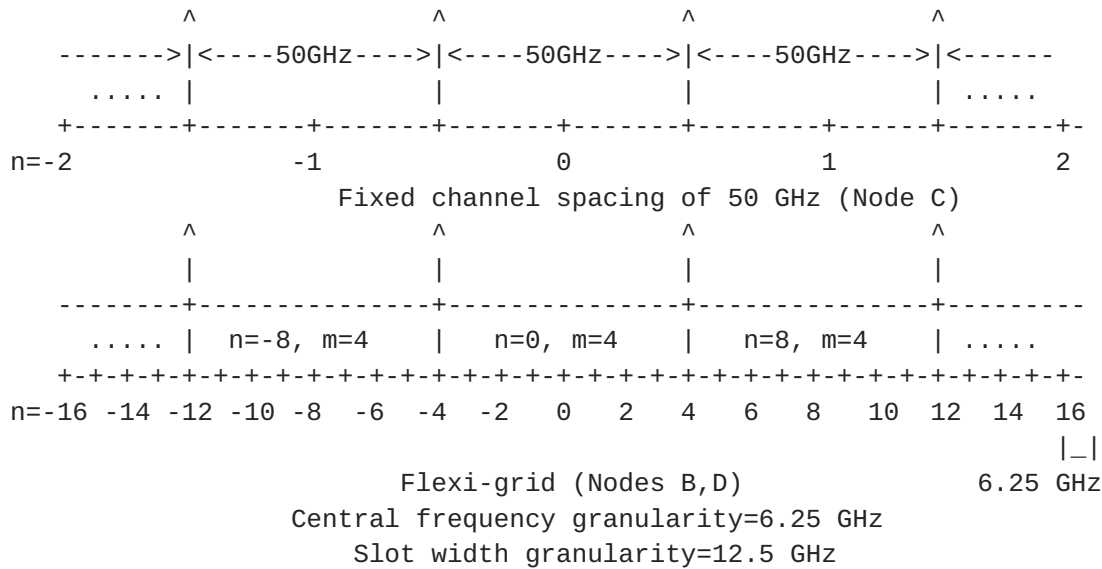
      Figure 2: Fixed grid channel spacing and flexi-grid spectrum slot

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
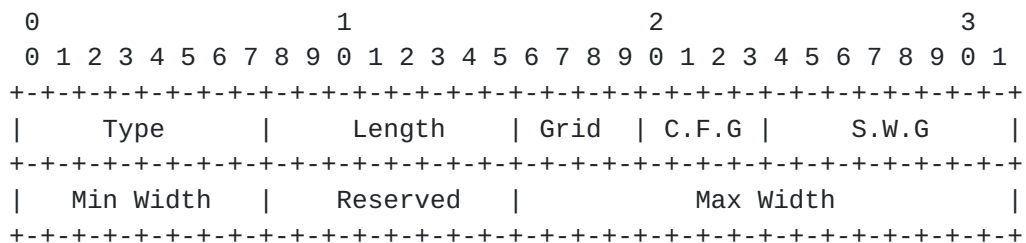nodes. The encoding format of this new subobject is as follows:

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

                         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 slotwdith 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].

10. Contributing Authors

   Wenjuan He
   ZTE
   he.wenjuan1@zte.com.cn

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Authors' Addresses

   Qilei Wang (editor)
   ZTE

   Email: wang.qilei@zte.com.cn

   Guoying Zhang (editor)
   CAICT

   Email: zhangguoying@catr.cn

   Yao Li
   Nanjing University

   Email: wsliguotou@hotmail.com

   Ramon Casellas
   CTTC

   Email: ramon.casellas@cttc.es

Yu Wang
CAICT

Email: wangyu@catr.cn