CCAMP Working Group   Xian Zhang
Internet-Draft   Haomian Zheng
Intended status: Standards Track   Huawei
                                                    Ramon Casellas
                                                              CTTC
                                              O. Gonzalez de Dios
                                                        Telefonica
                                                      D. Ceccarelli
                                                          Ericsson
Expires: December 17, 2015   June 17, 2015

GMPLS OSPF-TE Extensions in support of Flexible Grid

draft-ietf-ccamp-flexible-grid-ospf-ext-02.txt

Abstract

   This memo describes the OSPF-TE extensions in support of GMPLS
   control of networks that include devices that use the new flexible
   optical grid.

Status of this Memo

Copyright Notice

Table of Contents

 1. Introduction

[G.694.1] defines the Dense Wavelength Division Multiplexing (DWDM)
frequency grids for Wavelength Division Multiplexing (WDM)

applications. A frequency grid is a reference set of frequencies
used to denote allowed nominal central frequencies that may be used
for defining applications. The channel spacing is the frequency
spacing between two allowed nominal central frequencies. All of the
wavelengths on a fiber should use different central frequencies and
occupy a fixed bandwidth of frequency.

Fixed grid channel spacing is selected from 12.5 GHz, 25 GHz, 50 GHz,
100 GHz and integer multiples of 100 GHz. But [G.694.1] also
defines "flexible grids", also known as "flexi-grid". The terms
"frequency slot" (i.e., the frequency range allocated to a specific
channel and unavailable to other channels within a flexible grid)
and "slot width" (i.e., the full width of a frequency slot in a
flexible grid) are used to define a flexible grid.

[FLEX-FWK] defines a framework and the associated control plane
requirements for the GMPLS based control of flexi-grid DWDM networks.

[RFC6163] provides a framework for GMPLS and Path Computation
Element (PCE) control of Wavelength Switched Optical Networks
(WSONs), and [WSON-OSPF] defines the requirements and OSPF-TE
extensions in support of GMPLS control of a WSON.

[FLEX-SIG] describes requirements and protocol extensions for
signaling to set up LSPs in networks that support the flexi-grid,
and this document complements [FLEX-SIG] by describing the
requirement and extensions for OSPF-TE routing in a flexi-grid
network.

2. Terminology

For terminology related to flexi-grid, please consult [FLEX-FWK] and
[G.694.1].

2.1. 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].

3. Requirements for Flexi-grid Routing

The architecture for establishing LSPs in a Spectrum Switched
optical Network (SSON) is described in [FLEX-FWK].

A flexi-LSP occupies a specific frequency slot, i.e. a range of
frequencies. The process of computing a route and the allocation of

a frequency slot is referred to as RSA (Routing and Spectrum
Assignment). [FLEX-FWK] describes three types of architectural
approaches to RSA: combined RSA; separated RSA; and distributed SA.
The first two approaches among them could be called "centralized SA"
because both routing and spectrum (frequency slot) assignment are
performed by centralized entity before the signaling procedure.

In the case of centralized SA, the assigned frequency slot is
specified in the Path message during LSP setup. In the case of
distributed SA, the slot width of the flexi-grid LSP is specified in
the Path message, allowing the involved network elements to select
the frequency slot to be used.

If the capability of switching or converting the whole optical
spectrum allocated to an optical spectrum LSP is not available at
nodes along the path of the LSP, the LSP is subject to the Optical
"Spectrum Continuity Constraint", as described in [FLEX-FWK].

The remainder of this section states the additional extensions on
the routing protocols in a flexi-grid network. That is, the
additional information that must be collected and passed between
nodes in the network by the routing protocols in order to enable
correct path computation and signaling in support of LSPs within the
network.

3.1. Available Frequency Ranges

In the case of flexi-grids, the central frequency steps from 193.1
THz with 6.25 GHz granularity. The calculation method of central
frequency and the frequency slot width of flexi-LSP are defined in
[G.694.1].

On a DWDM link, the frequency slots must not overlap with each other.
However, the border frequencies of two frequency slots may be the
same frequency, i.e., the highest frequency of a frequency slot may
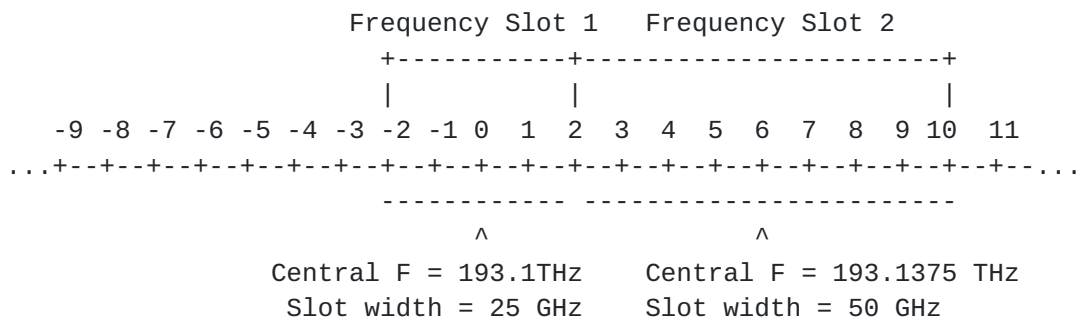be the lowest frequency of the next frequency slot.

```
                    Frequency Slot 1    Frequency Slot 2
                   +-----------+----------------------+
                   |           |                      |
   -9 -8 -7 -6 -5 -4 -3 -2 -1 0  1  2  3  4  5  6  7  8  9 10  11
...+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--...
                    ------------ ----------------------
                         ^                   ^
               Central F = 193.1THz    Central F = 193.1375 THz
               Slot width = 25 GHz     Slot width = 50 GHz
```

                 Figure 1 - Two Frequency Slots on a Link

   Figure 1 shows two adjacent frequency slots on a link. The highest
   frequency of frequency slot 1 denoted by n=2 is the lowest frequency
   of slot 2. In this example, it means that the frequency range from
   n=-2 to n=10 is occupied and is unavailable to other flexi-LSPs.

   Hence, in order to clearly show which LSPs can be supported and what
   frequency slots are unavailable, the available frequency ranges
   should be advertised by the routing protocol for the flexi-grid DWDM
   links. A set of non-overlapping available frequency ranges should
   be disseminated in order to allow efficient resource management of
   flexi-grid DWDM links and RSA procedures which are described in
   section 5.8 of [FLEX-FWK].

3.2. Application Compliance Considerations

   As described in [G.694.1], devices or applications that make use of
   the flexi-grid may not be capable of supporting every possible slot
   width or position (i.e., central frequency). In other words,
   applications or implementations may be defined where only a subset
   of the possible slot widths and positions are required to be
   supported.

   For 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) and that only requires slot widths as a multiple
   of 25 GHz (by only requiring values of m that are even).

   Hence, in order to support all possible applications and
   implementations the following information should be advertised for a
   flexi-grid DWDM link:

   o Central frequency granularity: a multiplier of 6.25 GHz.

   o Slot width granularity: a multiplier of 12.5 GHz.

   o Slot width range: two multipliers of 12.5GHz, each indicate the
     minimal and maximal slot width supported by a port respectively.

   The combination of slot width range and slot width granularity can
   be used to determine the slot widths set supported by a port.

3.3. Comparison with Fixed-grid DWDM Links

   In the case of fixed-grid DWDM links, each wavelength has a pre-
   defined central frequency and each wavelength has the same frequency
   range (i.e., there is a uniform channel spacing). Hence all the
   wavelengths on a DWDM link can be identified uniquely simply by
   giving it an identifier (such as the central wavelength [RFC6205]),
   and the status of the wavelengths (available or not) can be
   advertised through a routing protocol.

   Figure 2 shows a link that supports a fixed-grid with 50 GHz channel
   spacing. The central frequencies of the wavelengths are pre-defined
   by values of 'n' and each wavelength occupies a fixed 50 GHz
   frequency range as described in [G.694.1].

      W(-2) | W(-1) | W(0) | W(1) | W(2) |
   ...---------+-----------+-----------+-----------+-----------+----...
        | 50 GHz | 50 GHz | 50 GHz | 50 GHz |

      n=-2   n=-1   n=0   n=1   n=2
   ...---+-----------+-----------+-----------+-----------+----------...
                                  ^
                      Central F = 193.1THz
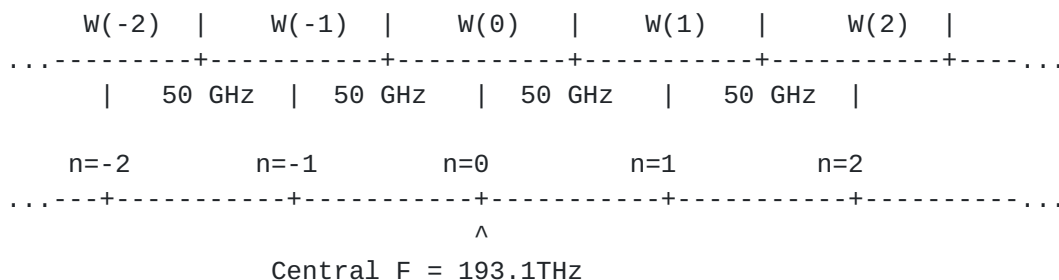
        Figure 2 - A Link Supports Fixed Wavelengths with 50 GHz Channel
                                 Spacing

   Unlike the fixed-grid DWDM links, on a flexi-grid DWDM link the slot
   width of the frequency slot are flexible as described in section 3.1.
   That is, the value of m in the formula is uncertain before a
   frequency slot is actually allocated. For this reason, the
   available frequency slot/ranges need to be advertised for a flexi-
   grid DWDM link instead of the specific "wavelengths" that are
   sufficient for a fixed-grid link. Moreover, thus advertisement is
   represented by the combination of Central Frequency Granularity and
   Slot Width Granularity.

4. Extensions

As described in [FLEX-FWK], the network connectivity topology
constructed by the links/nodes and node capabilities are the same as
for WSON, and can be advertised by the GMPLS routing protocols
(refer to section 6.2 of [RFC6163]). In the flexi-grid case, the
available frequency ranges instead of the specific "wavelengths" are
advertised for the link. This section defines the GMPLS OSPF-TE
extensions in support of advertising the available frequency ranges
for flexi-grid DWDM links.

4.1. ISCD for Flexi-grid

```
     Value                      Type

     -----                      ----

   152 (TBA by IANA)        Flexi-Grid-LSC capable (DWDM-LSC)
   Switching Capability and Encoding values MUST be used as follows:

          Switching Capability = Flexi-Grid-LSC

          Encoding Type = lambda [as defined in RFC3471]
```

When Switching Capability and Encoding fields are set to values
as stated above, the Interface Switching Capability Descriptor MUST
be interpreted as in RFC4203 with the optional inclusion of one or
more Switching Capability Specific Information sub-TLVs.

The Max LSP Bandwidth can be calculated based on the Max Slot
Width defined in Available Resource sub-TLV in Section 4.3, together
with corresponding modulation schemes.

4.2. Extensions to Port Label Restriction sub-TLV

As described in Section 3.2, a port that supports flexi-grid may
support only a restricted subset of the full flexible grid. The
Port Label Restriction sub-TLV is defined in [GEN-ENCODE]. It can
be used to describe the label restrictions on a port. A new
restriction type, the flexi-grid Restriction Type, is defined here
to specify the restrictions on a port to support flexi-grid.

```
      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      | RstType = TBA | Switching Cap |   Encoding    |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |    C.F.G      |    S.W.G      |         Min Slot Width         |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

MatrixID (8 bits): As defined in [GEN-ENCODE].

RstType (Restriction Type, 8 bits): Takes the value (TBA) to
indicate the restrictions on a port to support flexi-grid.

Switching Cap (Switching Capability, 8 bits): As defined in [GEN-
ENCODE], must be consistent with the one specified in ISCD as
described in Section 4.1.

Encoding (8 bits): As defined in [GEN-ENCODE], must be consistent
with the one specified in ISCD as described in Section 4.1.

C.F.G (Central Frequency Granularity, 8 bits): A positive integer.
Its value indicates the multiple of 6.25 GHz in terms of central
frequency granularity.

S.W.G (Slot Width Granularity, 8 bits): A positive integer. Its
value indicates the multiple of 12.5 GHz in terms of slot width
granularity.

Min Slot Width (16 bits): A positive integer. Its value indicates
the multiple of 12.5 GHz in terms of the supported minimal slot
width.

4.3. Available Resource sub-TLV

The Available Resource sub-TLV is defined to support indicating the
flexi-grid label availability as follow:

```
  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
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |     Pri       |       Max Slot Width      |    Reserved    |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                      Label Set Field                        |
  :                                                             :
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   Pri (priority flags): can be referred to Section 2.4 of [GEN-ENCODE].

   Max Slot Width (16 bits): A positive integer. Its value indicates
   the multiple of 12.5 GHz in terms of the supported maximal slot
   width.

   Label Set Field: the definition of Label Set Field can be referred
   to Section 2.6 of [GEN-ENCODE]. According to the possible action
   value, the usage of Label Set Field is described as the following
   sections, respectively.

4.3.1. Inclusive/Exclusive Label Ranges

   The inclusive/exclusive label ranges format of the Label Set Field
   defined in [GEN-ENCODE] can be used for specifying the frequency
   ranges of the flexi-grid DWDM links.

   Note that multiple Available Resource sub-TLVs may be needed if
   there are multiple discontinuous frequency ranges on a link.

4.3.2. Inclusive/Exclusive Label Lists

   The inclusive/exclusive label lists format of Available Labels Set
   sub-TLV defined in [GEN-ENCODE] can be used for specifying the
   available central frequencies of flexi-grid DWDM links.

4.3.3. Bitmap Label Set

   The bitmap format of Available Labels Set sub-TLV defined in [GEN-
   ENCODE] can be used for specifying the available central frequencies
   of the flexi-grid DWDM links

   Each bit in the bit map represents a particular central frequency
   with a value of 1/0 indicating whether the central frequency is in
   the set or not. Bit position zero represents the lowest central
   frequency and corresponds to the base label, while each succeeding

   bit position represents the next central frequency logically above
   the previous.

   Examples of the Available Resource sub-TLV can be found in Section
   4.4.

4.4. **Examples for Available Resource Sub-TLV**

   Figure 3 shows an example of available frequency range of a flexi-
   grid DWDM link.

```
   -9 -8 -7 -6 -5 -4 -3 -2 -1 0  1  2  3  4  5  6  7  8  9 10  11
...+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--...
                    |--Available Frequency Range--|
```

                   Figure 3 - Flexi-grid DWDM Link

   The symbol '+' represents the allowed nominal central frequency. The
   symbol "--" represents a 6.25 GHz frequency unit. The number on the
   top of the line represents the 'n' in the frequency calculation
   formula (193.1 + n * 0.00625). The nominal central frequency is
   193.1 THz when n equals zero.

   The usage of Action, Number of Labels and Length session of the
   Label set field can be referred to Section 2.6 in [GEN-ENCODE].

   Assume that the central frequency granularity is 6.25GHz, the label
   set can be encoded as follows:

   Inclusive Label Range:

   o Start Slot = -2;
   o End Slot = 8.

   The available central frequencies (-1, 0, 1, 2, 3, 4, 5, 6, 7) can
   be deduced by the Inclusive Label Range, because the Central
   Frequency Granularity is 6.25 GHz.

   Inclusive Label Lists:

o List Entry 1 = slot -1;
o List Entry 2 = slot 0;
o List Entry 3 = slot 1;
o List Entry 4 = slot 2;
o List Entry 5 = slot 3;
o List Entry 6 = slot 4;
o List Entry 7 = slot 5;
o List Entry 8 = slot 6;
o List Entry 9 = slot 7.

Bitmap:

o Base Slot = -1;
o Bitmap = 111111111(padded out to a full multiple of 32 bits)

5. IANA Considerations

[GEN-OSPF] defines the Port label Restriction sub-TLV of OSPF TE
Link TLV. It also creates a registry of values of the Restriction
Type field of that sub-TLV

IANA is requested to assign a new value from that registry as
follows:

Value   Meaning   Reference

TBD   Flexi-grid restriction   [This.I-D]

6. Implementation Status

[RFC Editor Note: Please remove this entire seciton prior to
publication as an RFC.]

This section records the status of known implementations of the
protocol defined by this specification at the time of posting of
this Internet-Draft, and is based on a proposal described in RFC
6982[RFC6982]. The description of implementations in this section
is intended to assist the IETF in its decision processes in
progressing drafts to RFCs. Please note that the listing of any
individual implementation here does not imply endorsement by the
IETF. Furthermore, no effort has been spent to verify the
information presented here that was supplied by IETF contributors.
This is not intended as, and must not be construed to be, a catalog
of available implementations or their features. Readers are advised
to note that other implementations may exist.

According to RFC 6982, "this will allow reviewers and working groups
to assign due consideration to documents that have the benefit of
running code, which may serve as evidence of valuable
experimentation and feedback that have made the implemented
protocols more mature. It is up to the individual working groups to
use this information as they see fit.

6.1. Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)

Organization Responsible for the Implementation: CTTC - Centre
Tecnologic de Telecomunicacions de Catalunya (CTTC), Optical
Networks and Systems Department, http://wikiona.cttc.es.

Implementation Name and Details: ADRENALINE testbed,
http://networks.cttc.es/experimental-testbeds/

Brief Description: Experimental testbed implementation of
GMPLS/PCE control plane.

Level of Maturity: Implemented as extensions to a mature
GMLPS/PCE control plane. It is limited to research / prototyping
stages but it has been used successfully for more than the last five
years.

Coverage: Support for the 64 bit label [FLEC-LBL] for flexi-grid
as described in this document, with available label set encoded as
bitmap.

It is expected that this implementation will evolve to follow the
evolution of this document.

Licensing: Proprietary

Implementation Experience: Implementation of this document
reports no issues. General implementation experience has been
reported in a number of journal papers. Contact Ramon Casellas for
more information or see http://networks.cttc.es/publications/?
search=GMPLS&research_area=optical-networks-systems

Contact Information: Ramon Casellas: ramon.casellas@cttc.es

Interoperability: No report.

7. Acknowledgments

This work was supported in part by the FP-7 IDEALIST project under
grant agreement number 317999.

8. Security Considerations

This document does not introduce any further security issues other
than those discussed in [RFC3630], [RFC4203].

9. References

9.1. Normative References

[RFC2119] S. Bradner, "Key words for use in RFCs to indicate
          requirements levels", RFC 2119, March 1997.

[G.694.1] ITU-T Recommendation G.694.1 (revision 2), "Spectral grids
          for WDM applications: DWDM frequency grid", February 2012.

[GEN-ENCODE] Bernstein, G., Lee, Y., Li, D., and W. Imajuku,
          "General Network Element Constraint Encoding for GMPLS
          Controlled Networks", draft-ietf-ccamp-general-constraint-
          encode, work in progress.

[GEN-OSPF] Fatai Zhang, Y. Lee, Jianrui Han, G. Bernstein and Yunbin
          Xu, " OSPF-TE Extensions for General Network Element
          Constraints ", draft-ietf-ccamp-gmpls-general-constraints-
          ospf-te, work in progress.

[RFC6205] T. Otani and D. Li, "Generalized Labels for Lambda-Switch-
          Capable (LSC) Label Switching Routers", RFC 6205, March
          2011.

[FLEX-LBL] King, D., Farrel, A. and Y. Li, "Generalized Labels for
          the Flexi-Grid in Lambda Switch Capable (LSC) Label
          Switching Routers", draft-farrkingel-ccamp-flexigrid-
          lambda-label, work in progress.

9.2. Informative References

[RFC6163] Y. Lee, G. Bernstein and W. Imajuku, "Framework for GMPLS
          and Path Computation Element (PCE) Control of Wavelength
          Switched Optical Networks (WSONs)", RFC 6163, April 2011.

   [FLEX-SIG] F.Zhang et al, "RSVP-TE Signaling Extensions in support
             of Flexible-grid", draft-ietf-ccamp-flexible-grid-rsvp-
             te-ext, work in progress.

   [FLEX-FWK] Gonzalez de Dios, O,, Casellas R., Zhang, F., Fu, X.,
             Ceccarelli, D., and I. Hussain, "Framework and
             Requirements for GMPLS based control of Flexi-grid DWDM
             networks', draft-ietf-ccamp-flexi-grid-fwk, work in
             progress.

   [WSON-OSPF] Y. Lee and G. Bernstein, "GMPLS OSPF Enhancement for
             Signal and Network Element Compatibility for Wavelength
             Switched Optical Networks ", draft-ietf-ccamp-wson-signal-
             compatibility-ospf, work in progress.

10. Authors' Addresses

Xian Zhang
Huawei Technologies
Email: zhang.xian@huawei.com

Haomian Zheng
Huawei Technologies
Email: zhenghaomian@huawei.com

Ramon Casellas, Ph.D.
CTTC
Spain
Phone: +34 936452916
Email: ramon.casellas@cttc.es

Oscar Gonzalez de Dios
Telefonica Investigacion y Desarrollo
Emilio Vargas 6
Madrid,   28045
Spain
Phone: +34 913374013
Email: ogondio@tid.es

Daniele Ceccarelli
Ericsson
Via A. Negrone 1/A
Genova - Sestri Ponente
Italy
Email: daniele.ceccarelli@ericsson.com

11. Contributors' Addresses

Adrian Farrel
Old Dog Consulting
Email: adrian@olddog.co.uk

Fatai Zhang
Huawei Technologies
Email: zhangfatai@huawei.com

Lei Wang,
ZTE
Email: wang.lei31@zte.com.cn