                  Generalized Labels for the Flexi-Grid in
             Lambda Switch Capable (LSC) Label Switching Routers

              draft-ietf-ccamp-flexigrid-lambda-label-00.txt

Abstract

   GMPLS supports the description of optical switching by identifying
   entries in fixed lists of switchable wavelengths (called grids)
   through the encoding of lambda labels. Work within the ITU-T Study
   Group 15 has defined a finer granularity grid, and the facility to
   flexibly select different widths of spectrum from the grid. This
   document defines a new GMPLS lambda label format to support this
   flexi-grid.

   This document updates RFC 3471 and RFC 6205 by introducing a new
   label format.

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Table of Contents

1. Introduction

   As described in [RFC3945], GMPLS extends MPLS from supporting only
   Packet Switching Capable (PSC) interfaces and switching, to also
   support four new classes of interfaces and switching that include
   Lambda Switch Capable (LSC).

   A functional description of the extensions to MPLS signaling needed
   to support this new class of interface and switching is provided in

[RFC3471].

Section 3.2.1.1 of [RFC3471] states that wavelength labels "only have
significance between two neighbors": global wavelength semantics are
not considered. [RFC6205] defines a standard lambda label format
that has a global semantic and which is compliant with both the Dense
Wavelength Division Multiplexing (DWDM) grid [G.694.1] and the Coarse
Wavelength Division Multiplexing (CWDM) grid [G.694.2]. The terms
DWDM and CWDM are defined in [G.671].

A flexible grid network selects its data channels as arbitrarily
assigned pieces of the spectrum. Mixed bitrate transmission systems
can allocate their channels with different spectral bandwidths so
that the channels can be optimized for the bandwidth requirements of
the particular bit rate and modulation scheme of the individual
channels. This technique is regarded as a promising way to improve
the network utilization efficiency and fundamentally reduce the cost
of the core network.

The "flexi-grid" has been developed within the ITU-T Study Group 15
to allow selection and switching of pieces of the optical spectrum
chosen flexibly from a fine granularity grid of wavelengths with
variable spectral bandwidth [G.694.1]. This document updates the
definition of GMPLS lambda labels provided in [RFC6205] to support
the flexi-grid.

This document relies on [G.694.1] for the definition of the optical
data plane and does not make any updates to the work of the ITU-T in
that regard.

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. Overview of Flexi-Grid

[G.694.1] defines DWDM fixed grids. The latest version of that
document extends the DWDM fixed grids to add support for flexible
grids. The basis of the work is to allow a data channel to be formed
from an abstract grid anchored at 193.1 THz and selected on a channel
spacing of 6.25 GHz with a variable slot width measured in units of
12.5 GHz. Individual allocations may be made on this basis from
anywhere in the spectrum, subject to allocations not overlapping.

[G.694.1] provides clear guidance on the support of flexible grid by
implementations in Section 2 of Appendix I:

The flexible DWDM grid defined in clause 7 has a nominal 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 have to be capable of supporting 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.

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).

Some additional background on the use of GMPLS for flexible grids
can be found in [FLEXFWRK].

3. Fixed Grid Lambda Label Encoding

[RFC6205] defines an encoding for a global semantic for a DWDM label
based on four fields:

- Grid: used to select which grid the lambda is selected from.
  Values defined in [RFC6205] identify DWDM [G.694.1] and CWDM
  [G.694.2].

- C.S. (Channel Spacing): used to indicate the channel spacing.
  [RFC6205] defines values to represent spacing of 100, 50, 25 and
  12.5 GHz.

- Identifier: a local-scoped integer used to distinguish different
  lasers (in one node) when they can transmit the same frequency
  lambda.

- n: a two's-complement integer to take a positive, negative, or zero
  value. This value is used to compute the frequency as defined in
  [RFC6205] and based on [G.694.1]. The use of n is repeated here
  for ease of reading the rest of this document: in case of
  discrepancy, the definition in [RFC6205] is normative.

    Frequency (THz) = 193.1 THz + n * frequency granularity (THz)

  where the nominal central frequency granularity for the flexible
  grid is 0.00625 THz

4. Flexi-Grid Label Format and Values

4.1 Flexi-Grid Label Encoding

   This document defines a generalized label encoding for use in flexi-
   grid systems. As with the other GMPLS lambda label formats defined
   in [RFC3471] and [RFC6205], the use of this label format is known a
   priori. That is, since the interpretation of all lambda labels is
   determined hop-by-hop, the use of this label format requires that all
   nodes on the path expect to use this label format.

   For convenience, however, the label format is modeled on the fixed
   grid label defined in [RFC6205] and briefly described in Section 3.

   Figure 1 shows the format of the Flexi-Grid Label. It is a 64 bit
   label.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Grid | C.S. |    Identifier   |              n                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             m               |            Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
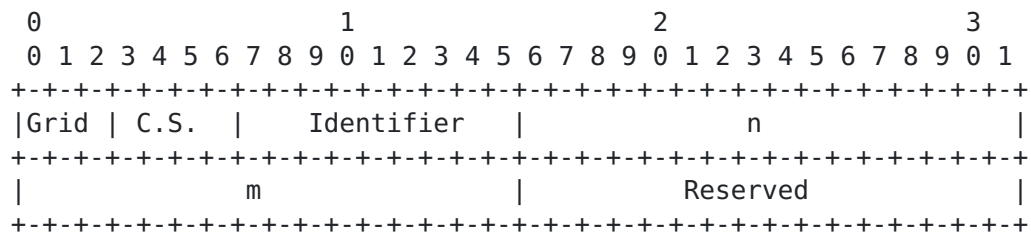
           Figure 1 : The Flexi-Grid Label Encoding

   This document defines a new Grid value to supplement those in
   [RFC6205]:

```
  +----------+---------+
  |   Grid   |  Value  |
  +----------+---------+
  |ITU-T Flex|    3    |
  +----------+---------+
```

   Within the fixed grid network, the C.S. value is used to represent
   the channel spacing, as the spacing between adjacent channels is
   constant. For the flexible grid situation, this field is used to
   represent the nominal central frequency granularity.

   This document defines a new C.S. value to supplement those in
   [RFC6205]:

```
+----------+---------+
| C.S(GHz) |  Value  |
+----------+---------+
|     6.25 |    5    |
+----------+---------+
```

The meaning of the Identifier field is maintained from [RFC6205] (see also Section 3).

The meaning of n is maintained from [RFC6205] (see also Section 3).

The m field is used to identify the slot width according to the formula given in [G.694.1] as follows. It is a 16 bit integer value encoded in lne format.

        Slot Width (GHz) = 12.5 GHz * m

The Reserved field MUST be set to zero on transmission and SHOULD be ignored on receipt.

An implementation that wishes to use the flexi-grid label encoding MUST follow the procedures of [RFC3473] and of [RFC3471] as updated by [RFC6205]. It MUST set Grid to 3 and C.S. to 5. It MUST set Identifier to indicate the local identifier of the laser in use as described in [RFC6205]. It MUST also set n according to the formula in Section 3 (inherited unchanged from [RFC6205]). Finally, the implementation MUST set m as described in the formula stated above.

4.2. Considerations of Bandwidth

There is some overlap between the concepts of bandwidth and label in many GMPLS-based systems where a label indicates a physical switching resource. This overlap is increased in a flexi-grid system where a label value indicates the slot width and so affects the bandwidth supported by an LSP. Thus the 'm' parameter is both a property of the label (i.e., it helps define exactly what is switched) and of the bandwidth.

In GMPLS signaling [RFC3473], bandwidth is requested in the TSpec object and confirmed in the Flowspec object. The 'm' parameter that is a parameter of the GMPLS flexi-grid label as described above, is also a parameter of the flexi-grid TSpec and Flowspec as described in [FLEXRSVP].

5. Manageability Considerations

This document introduces no new elements for management. That is, labels can continue to be used in the same way by the GMPLS protocols

and where those labels were treated as opaque quantities with local
or global significance, no change is needed to the management
systems.

However, this document introduces some changes to the nature of a
label that may require changes to management systems. Firstly,
systems that handle lambda labels as 32 bit quantities need to be
updated to process the 64 bit labels described in this document even
if the labels are treated as opaque quantities. Furthermore,
although management systems that can handle lambda labels as defined
in [RFC6205] can continue to process the fields defined in RFC 6205
as before, they have to handle new legal values of some of those
fields (Grid = 3 and C.S. = 5), and they have to be aware of the new
'm' field.

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:
   Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)
   Optical Networks and Systems Department

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 as described version 07 of this
      document.
      This affects mainly the implementation of RSVP-TE and PCEP
      protocols:
      - Generalized Label Support
      - Suggested Label Support
      - Upstream Label Support
      - ERO Label Subobjects and Explicit Label Control
      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. Security Considerations

   [RFC6205] notes that the definition of a new label encoding does not
   introduce any new security considerations to [RFC3471] and [RFC3473].
   That statement applies equally to this document.

   For a general discussion on MPLS and GMPLS-related security issues,
   see the MPLS/GMPLS security framework [RFC5920].

8. IANA Considerations

IANA maintains the "Generalized Multi-Protocol Label Switching
(GMPLS) Signaling Parameters" registry that contains several
subregistries.

8.1. Grid Subregistry

IANA is requested to allocate a new entry in this subregistry as
follows:

```
Value   Grid                       Reference
-----   -------------------------  ----------
  3     ITU-T Flex                 [This.I-D]
```

8.2. DWDM Channel Spacing Subregistry

IANA is requested to allocate a new entry in this subregistry as
follows:

```
Value   Channel Spacing (GHz)      Reference
-----   -------------------------  ----------
  5     6.25                       [This.I-D]
```

9. Acknowledgments

Very many thanks to Lou Berger for discussions of labels of more than
32 bits. Many thanks to Sergio Belotti and Pietro Vittorio Grandi
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and Fatai Zhang.

The authors would like to thank Ben Niven-Jenkins for inspiring the
choice of filename for this document.

10. References

10.1. Normative References

[RFC2119]   Bradner, S., "Key words for use in RFCs to Indicate
            Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC3471]   Berger, L., Ed., "Generalized Multi-Protocol Label
            Switching (GMPLS) Signaling Functional Description", RFC
            3471, January 2003.

[RFC3473]   Berger, L., Ed., "Generalized Multi-Protocol Label
            Switching (GMPLS) Signaling Resource ReserVation Protocol-
            Traffic Engineering (RSVP-TE) Extensions", RFC 3473,
            January 2003.

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

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

10.2. Informative References

[RFC3945]   Mannie, E., Ed., "Generalized Multi-Protocol Label
            Switching (GMPLS) Architecture", RFC 3945, October 2004.

[RFC5920]   Fang, L., Ed., "Security Framework for MPLS and GMPLS
            Networks", RFC 5920, July 2010.

[RFC6982]   Sheffer, Y. and A. Farrel, "Improving Awareness of Running
            Code: The Implementation Status Section", RFC 6982, July
            2013.
[RFC Editor Note: This reference can be removed when Section 6 is
removed]

[G.671]   ITU-T Recommendation G.671, "Transmission characteristics
            of optical components and subsystems", 2009.

[G.694.2]   ITU-T Recommendation G.694.2, "Spectral grids for WDM
            applications: CWDM wavelength grid", December 2003.

[FLEXFWRK] O. Gonzalez de Dios, et al., "Framework and Requirements
            for GMPLS based control of Flexi-grid DWDM networks",
            draft-ogrcetal-ccamp-flexi-grid-fwk, work in progress.

   [FLEXRSVP] Zhang, F., Gonzalez de Dios, O., and D. Ceccarelli,
             "RSVP-TE Signaling Extensions in support of Flexible
             Grid", draft-zhang-ccamp-flexible-grid-rsvp-te-ext, work
             in progress.

Appendix A. Flexi-Grid Example

   Consider a fragment of an optical LSP between node A and node B using
   the flexible grid. Suppose that the LSP on this hop is formed:
   - using the ITU-T Flexi-Grid
   - the nominal central frequency of the slot 193.05 THz
   - the nominal central frequency granularity is 6.25 GHz
   - the slot width is 50 GHz.

   In this case the label representing the switchable quantity that is
   the flexi-grid quantity is encoded as described in Section 4.1 with
   the following parameter settings. The label can be used in signaling
   or in management protocols to describe the LSP.

     Grid = 3 : ITU-T Flexi-Grid

     C.S. = 5 : 6.25 GHz nominal central frequency granularity

     Identifier = local value indicating the laser in use

     n = -8 :

          Frequency (THz) = 193.1 THz + n * frequency granularity (THz)

          193.05 (THz) = 193.1 (THz) + n * 0.00625 (THz)

          n = (193.05-193.1)/0.00625 = -8

      m = 4 :

          Slot Width (GHz) = 12.5 GHz * m

          50 (GHz) = 12.5 (GHz) * m

          m = 50 / 12.5 = 4

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