                 RSVP-TE Signaling Extensions in Support of Flexi-Grid
                 Dense Wavelength Division Multiplexing (DWDM) Networks

Abstract

   This memo describes the extensions to the Resource Reservation
   Protocol - Traffic Engineering (RSVP-TE) signaling protocol to
   support Label Switched Paths (LSPs) in a GMPLS-controlled network
   that includes devices using the flexible optical grid.

Status of This Memo

   This is an Internet Standards Track document.

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   received public review and has been approved for publication by the
   Internet Engineering Steering Group (IESG). Further information on
   Internet Standards is available in Section 2 of RFC 5741.

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   and how to provide feedback on it may be obtained at
   http://www.rfc-editor.org/info/rfc7792.

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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 that utilize WDM transmission. The channel
   spacing is the frequency spacing between two allowed nominal central
   frequencies. All of the wavelengths on a fiber use different central
   frequencies and occupy a designated range of frequencies.

   Fixed-grid channel spacing is selected from 12.5 GHz, 25 GHz, 50 GHz,
   100 GHz, and integer multiples of 100 GHz. Additionally, [G.694.1]
   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 introduced in [G.694.1] to define a flexible grid.

   [RFC7698] defines a framework and the associated control-plane
   requirements for the GMPLS-based [RFC3945] 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
   [RFC7689] describes the requirements and protocol extensions for
   signaling to set up Label Switched Paths (LSPs) in WSONs.

   This document describes the additional requirements and protocol
   extensions to Resource Reservation Protocol - Traffic Engineering
   (RSVP-TE) [RFC3473] to set up LSPs in networks that support the
   flexi-grid.

2. Terminology

   For terminology related to flexi-grid, please refer to [RFC7698] 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 Flexible-Grid Signaling

   The architecture for establishing LSPs in a flexi-grid network is
   described in [RFC7698].

   An optical-spectrum 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 "Routing and
   Spectrum Assignment" (RSA). [RFC7698] describes three architectural
   approaches to RSA: combined RSA, separated RSA, and distributed SA.
   The first two approaches are referred to as "centralized SA", because
   routing (i.e., path determination) and spectrum assignment (i.e.,
   selection of frequency slots) are both performed by a centralized
   entity prior to the signaling procedure.

   In the case of centralized SA, the assigned frequency slot is
   specified in the RSVP-TE 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 network elements to select the
   frequency slot to be used when they process the RSVP-TE messages.

   If the capability to switch or convert the whole optical spectrum
   allocated to an optical-spectrum LSP is not available at some nodes
   along the path of the LSP, the LSP is subject to the Optical
   "spectrum continuity constraint" as described in [RFC7698].

   The remainder of this section states the additional requirements for
   signaling in a flexi-grid network.

3.1. Slot Width

   The slot width is an end-to-end parameter representing how much
   frequency resource is requested for a flexi-grid LSP. It is the
   equivalent of optical bandwidth, although the amount of bandwidth
   associated with a slot width will depend on the signal encoding.

   Different LSPs may request different amounts of frequency resource in
   flexible-grid networks, so the slot width MUST be carried in the
   signaling message during LSP establishment. This enables the nodes
   along the LSP to know how much frequency resource has been requested
   (in a Path message) and how much has been allocated (by a
   Resv message) for the LSP.

3.2. Frequency Slot

   The frequency slot information identifies which part of the frequency
   spectrum is allocated on each link for an LSP in a flexi-grid
   network.

   This information MUST be present in a Resv message to indicate,
   hop by hop, the central frequency of the allocated resource. In
   combination with the slot width indicated in a Resv message (see
   Section 3.1), the central frequency carried in a Resv message
   identifies the resources reserved for the LSP (known as the
   frequency slot).

   The frequency slot can be represented by two parameters, as follows:

      Frequency slot = [(central frequency) - (slot width)/2] ~
                       [(central frequency) + (slot width)/2]

   As is common with other resource identifiers (i.e., labels) in GMPLS
   signaling, it must be possible for the head-end node, when sending a
   Path message, to suggest or require the central frequency to be used
   for the LSP. Furthermore, for bidirectional LSPs, the Path message
   MUST be able to specify the central frequency to be used for
   reverse-direction traffic.

   As described in [G.694.1], the allowed frequency slots for the
   flexible DWDM grid have a nominal central frequency (in THz),
   defined by:

      193.1 + n * 0.00625

      where n is zero or a positive or negative integer.

   The slot width (in GHz) is defined as:

      12.5 * m

      where m is a positive integer.

   It is possible that an implementation supports only a subset of the
   possible slot widths and central frequencies. For example, an
   implementation can be built that is

   1. limited to have a nominal central frequency granularity of
      12.5 GHz, by only allowing values of n that are even, and

   2. further limited to only support slot widths of 25 GHz, by only
      allowing values of m that are even.

Further details can be found in [RFC7698].

4. Protocol Extensions

   This section defines the extensions to RSVP-TE signaling for GMPLS
   [RFC3473] to support flexible-grid networks.

4.1. Traffic Parameters

   In RSVP-TE, the SENDER_TSPEC object in the Path message indicates the
   requested resource reservation. The FLOWSPEC object in the Resv
   message indicates the actual resource reservation. As described in
   Section 3.1, the slot width represents how much frequency resource is
   requested for a flexi-grid LSP. That is, it describes the end-to-end
   traffic profile of the LSP. Therefore, the traffic parameters for a
   flexi-grid LSP encode the slot width.

   This document defines new Class Types (C-Types) for the SENDER_TSPEC
   and FLOWSPEC objects to carry Spectrum-Switched Optical Network
   (SSON) traffic parameters:

      SSON SENDER_TSPEC: Class = 12, C-Type = 8.

      SSON FLOWSPEC: Class = 9, C-Type = 8.

   The SSON traffic parameters carried in both objects MUST have the
   format shown in Figure 1.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               m               |            Reserved           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

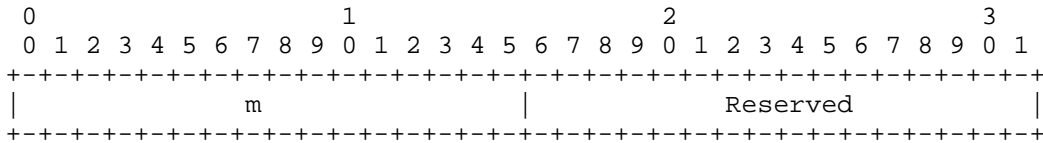   Figure 1: The SSON Traffic Parameters

   m (16 bits): a positive integer; the slot width is specified by
               m * 12.5 GHz.

   The Reserved bits MUST be set to zero and ignored upon receipt.

4.1.1. Applicability to Fixed-Grid Networks

   Note that the slot width (i.e., traffic parameters) of a fixed grid
   defined in [G.694.1] can also be specified by using the SSON traffic
   parameters. The fixed-grid channel spacings (12.5 GHz, 25 GHz,
   50 GHz, 100 GHz, and integer multiples of 100 GHz) are also the
   multiples of 12.5 GHz, so the m parameter can be used to represent
   these slot widths.

   Therefore, it is possible to consider using the new traffic parameter
   object types in common signaling messages for flexi-grid and legacy
   DWDM networks.

4.2. Generalized Label

   In the case of a flexible-grid network, the labels that have been
   requested or allocated as signaled in the RSVP-TE objects are encoded
   as described in [RFC7699]. This new label encoding can appear in any
   RSVP-TE object or sub-object that can carry a label.

   As noted in Section 4.2 of [RFC7699], the m parameter forms part of
   the label as well as part of the traffic parameters.

   As described in Section 4.3 of [RFC7699], a "compound label",
   constructed from a concatenation of the flexi-grid labels, is used
   when signaling an LSP that uses multiple flexi-grid slots.

4.3. Signaling Procedures

   There are no differences between the signaling procedures described
   for LSP control in [RFC7698] and those required for use in a
   fixed-grid network [RFC7689]. Obviously, the TSpec, FlowSpec, and
   label formats described in Sections 4.1 and 4.2 are used. The
   signaling procedures for distributed SA and centralized SA can be
   applied.

5. IANA Considerations

5.1. Class Types for RSVP Objects

   This document introduces two new Class Types for existing RSVP
   objects. IANA has made the following allocations from the "Resource
   Reservation Protocol (RSVP) Parameters" registry using the "Class
   Names, Class Numbers, and Class Types" sub-registry.

      Class Number Class Name   Reference
      ------------ ----------------------   ---------
      9   FLOWSPEC   [RFC2205]

                    Class Type (C-Type):

                    (8) SSON FLOWSPEC   RFC 7792

      Class Number Class Name   Reference
      ------------ ----------------------   ---------
      12   SENDER_TSPEC   [RFC2205]

                    Class Type (C-Type):

                    (8) SSON SENDER_TSPEC   RFC 7792

6. Manageability Considerations

   This document makes minor modifications to GMPLS signaling but does
   not change the manageability considerations for such networks.
   Clearly, protocol analysis tools and other diagnostic aids (including
   logging systems and MIB modules) will need to be enhanced to support
   the new traffic parameters and label formats.

7. Security Considerations

   This document introduces no new security considerations to [RFC3473].

   See also [RFC5920] for a discussion of security considerations for
   GMPLS signaling.

8. References

8.1. Normative References

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Contributors

   Ramon Casellas
   CTTC
   Av. Carl Friedrich Gauss n7
   Castelldefels, Barcelona 08860
   Spain

   Email: ramon.casellas@cttc.es

   Felipe Jimenez Arribas
   Telefonica Investigacion y Desarrollo
   Emilio Vargas 6
   Madrid 28045
   Spain

   Email: felipej@tid.es

   Yi Lin
   Huawei Technologies Co., Ltd.
   F3-5-B R&D Center, Huawei Base
   Bantian, Longgang District
   Shenzhen 518129
   China

   Phone: +86 755-28972914
   Email: yi.lin@huawei.com

   Qilei Wang
   ZTE

   Email: wang.qilei@zte.com.cn

   Haomian Zheng
   Huawei Technologies

   Email: zhenghaomian@huawei.com

Authors' Addresses

   Fatai Zhang
   Huawei Technologies

   Email: zhangfatai@huawei.com

   Xian Zhang
   Huawei Technologies

   Email: zhang.xian@huawei.com

   Adrian Farrel
   Old Dog Consulting

   Email: adrian@olddog.co.uk

   Oscar Gonzalez de Dios
   Telefonica Investigacion y Desarrollo
   Ronda de la Comunicacion S/N
   Madrid 28050
   Spain

   Phone: +34 913129647
   Email: oscar.gonzalezdedios@telefonica.com

   Daniele Ceccarelli
   Ericsson
   Via A. Negrone 1/A
   Genova - Sestri Ponente
   Italy

   Email: daniele.ceccarelli@ericsson.com