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Sharfuddin Syed
Rajan Rao
Marco Sosa
Biao Lu
Infinera

Bert Basch
Andrew G. Malis
Verizon Communications

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A Framework for control of Flex Grid Networks
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Abstract

This document provides a framework for applying the Generalized Multi-Protocol Label Switching (GMPLS) architecture and protocols to a Flex-Grid capable optical switching layer.

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[1.](#) Introduction

To enable scaling to data rates beyond 100 Gbps, next generation transport systems based on a super-channel concept are currently being developed. To allow efficient allocation of optical spectral bandwidth for such high bit rate systems, the International

Telecommunication Union Telecommunication Standardization Sector (ITU-T) is extending the G.694.1 grid standard beyond the traditional fixed grid assignment of a constant spectral width per channel (termed 'Fixed-Grid') to include flexible grid (termed

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'Flex-Grid') support allowing for varying spectral width per channel, to support a variety of high-bit rate channels, each optimizing the spectral bandwidth needed for its particular channel type.

Current IETF GMPLS efforts for routing and signaling on Wavelength Switched Optical Networks (WSNs) have been focused on Routing and Wavelength Assignment (RWA) for fixed grid Reconfigurable Optical Add-Drop Multiplexors (ROADMs) and line systems. This framework document is intended to set the stage on introducing the flexible grid concept, and setting the requirements and use cases to be taken into consideration for extending the GMPLS protocols to include support for flexible grid capable elements and the need for specifying blocks of spectrum, rather than just wavelengths.

[Section 2](#) of this document provides background terminology, while [section 3](#) provides an acronym list. [Section 4](#) then goes over a set of requirements that must be considered when defining the protocol extensions to support flexible grid elements. [Section 5](#) then provides further background with a set of use cases. [Section 6](#) goes over protocol implications; [section 7](#) covers security considerations; [section 8](#) lists IANA considerations. [Section 9](#) provides a list of references. Acknowledgements and contact information is provided in sections [10-12](#).

[2](#). Terminology

A. Frequency Slot:

A frequency range allocated to a given channel and unavailable to other channels within the same flexible grid [FLEX-GRID]

It is a contiguous portion of the spectrum available for an optical passband filter. A frequency slot is defined by its nominal central frequency and its slot width.

B. Spectral Slice:

The minimum granularity of a frequency slot (e.g. 12.5GHz).

C. Slot width:

The full width of a frequency slot in a flexible grid [FLEX-

GRID].

The slot width is equal to number of spectral slices in the slot times the width of spectral slice.

D. Super-channel:

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A super-channel is a collection of one or more frequency slots to be treated as a unified entity for management and control plane purposes (Ref to figure-1).

E. Contiguous Spectrum Super-channel:

A contiguous spectrum super-channel is a super-channel with a single frequency slot (Ref to figure-1).

F. Split-Spectrum super-channel:

A split-Spectrum super-channel is a super-channel with multiple frequency slots.

Each frequency slot will be allocated an independent passband filter, irrespective of whether frequency slots are adjacent or not.

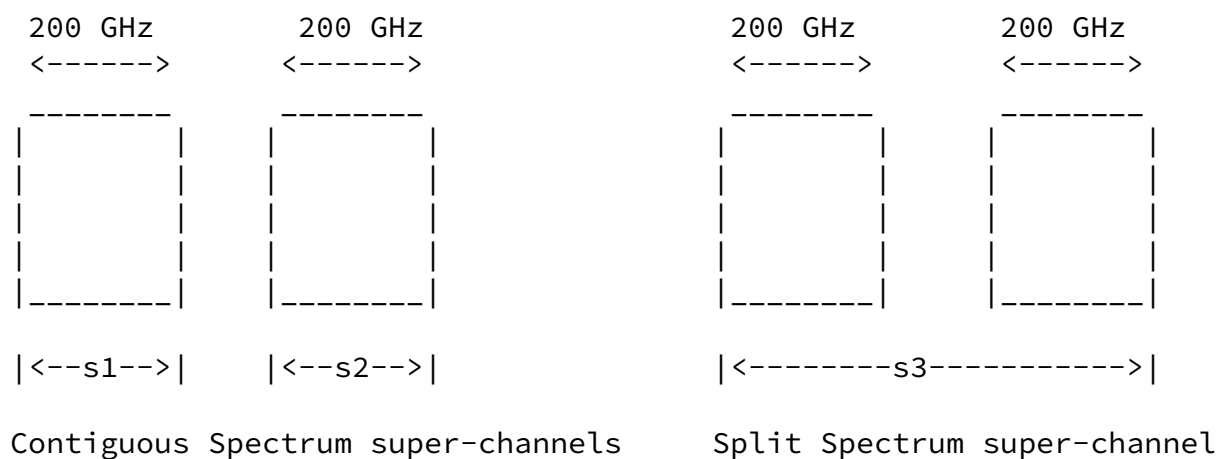


Figure 1: Super-Channel

[3.](#) Acronyms

OCG: Optical Carrier Group

SCH: Super Channel

OCh: Optical Channel

OCC: Optical Channel Carrier

OTUk: Optical channel Transport Unit level k

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ODUk: Optical channel Data Unit Level k

ODUj: Optical channel Data Unit Level j

CDC: Colorless, Directionless and Contentionless

CD: Colorless and Directionless

ROADM: Reconfigurable Optical Add-Drop Multiplexer

[4.](#) Requirements and constraints

This section covers the high level requirements for the support of super-channels over flexible grid infrastructure (Flex-Grid). Specifically, the scope of requirements and constraints listed in this section covers the functionality that shall be supported by the control plane sub-system. The Features are listed as a list of Requirements Tagged as Rn, for better traceability and coverage in other related drafts and/or for references by other related standards across other standard bodies.

R1: Flexible size of super-channel

The protocol shall allow the super-channels on the Flex-Grid to be of different size/width. The number of slices and the granularity of each slice shall be flexible.

R2: Flexible mapping of super-channel

The super-channels shall be allowed to be mapped to any spectrum location in the ITU Grid.

The frequency slots allocation of super-channels on the ITU-Grid shall confirm to [FLEX-GRID]

R3: Contiguous Spectrum and Split Spectrum super-channel

The protocol shall allow the use of super-channels which can be contiguous or non-contiguous.

Example: consider a system supporting 500GHz super-channel.

In case of contiguous spectrum, the super-channel is allocated with 40 slices of 12.5GHz granularity. This super-channel is placed directly on the Flex-Grid at any location.

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In case of split spectrum, the super-channel is divided into multiple members. Considering the same example scenario, the 500GHz super-channel can be divided into 2 member split spectrum channels. Each member is allocated a different flexible location on the Flex-Grid. Each frequency slot can be 250GHz, 20x12.5GHz slices allocated for frequency slot.

R4: Co-routing of split-spectrum super-channel

The protocol shall support the co-routing of frequency slots within the split-spectrum super-channels.

Please refer to the Figure 5 and Use Case 3, depicting the co-routing of split-spectrum super-channels.

R5: Flexible Modulation Formats and polarization mode for different super-channels on the same Flex-Grid

Each super-channel mapped on to the Flex-Grid system shall have the capability to support different modulation formats with either single or dual polarization modes.

R6: Fixed vs Flexible Grid super-channel interworking

The Control Plane protocol shall handle nodes which support flex-grid functionality in addition to nodes that only support fixed grid functionality. The enhanced control plane protocol with the flex-grid extensions shall also be able to work with fixed grid network in a backwards compatible manner.

This requirement is to enable introduction of flex-grid systems into existing fixed-grid network. This can also be used to deploy flex-grid system in certain segments of the network. Please also refer to the use case section of this document.

R7: Support for the CDC based super-channels over Flex-Grid

The super-channel over the Flex-Grid control plane frame work shall support CDC (Connectionless, Directionless and Contentionless) architecture. Further, flexibility of control shall be provided, such that, depending on deployment scenarios and application, a subset of CDC features are used on a given network segment. Hence, each type of ROADMs shall be supported.

R8: Directionless/Contentionless super-channels

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The protocol shall allow for routing the super-channels in different fiber directions/degrees, based on the following criteria:

- a) Based on spectral slices
- b) Based on fibers/nodes

The super-channels with the same frequency slot mapping are not allowed to be provisioned over a given fiber direction.

Please refer to the Figure 5 and Use Case 3, depicting the handling of same super-channel at a CDC node.

R9: Resizing of super-channel bandwidth

Depending on the spectral bandwidth changes, the protocol shall allow super-channels resizing.

R10: super-channel LSP restoration

The protocol shall support the super-channel based LSP restoration feature, with the following features:

- a) During the restoration process, it shall be possible for the protocol to pick different frequency slots of super-channel, keeping the number and size of slices the same.

- b) LSP restoration with optional pre-computed path (with or without resource reservation) shall be supported.
- c) Revertive and Non-Revertive restoration options shall be provided.

R11: Embedded Control Channel for super-channel routing and signaling

The system shall continue to use the standard mechanism for ECC defined in [ref: OSC based control channel], for OAM features required to be supported between network elements deploying super-channel over Flex-Grid.

R12: Management Plane and Control Plane feature interaction for super-channel

The system shall keep track of important bandwidth related parameters for the Flex-Grid based system. Important parameters include (but not limited to):

- a) Available Spectral Slices
- b) Provisioned super-channels along with provisioned spectral-slices

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5. Use cases

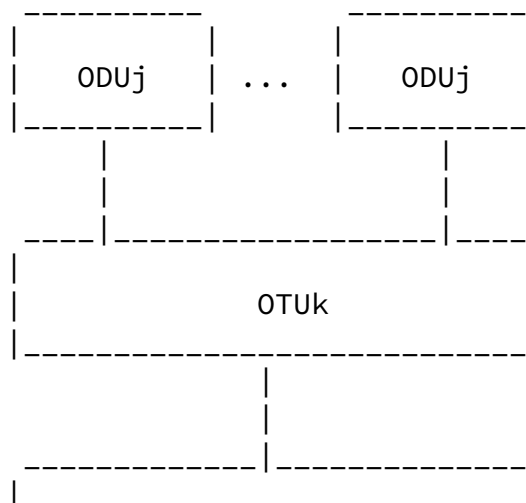
The use cases described in this section are for information only. The OTN hierarchy described in this section is sure to be discussed in ITU SG-15 Q6 & Q14. Within the scope of this frame-work document, the main focus is super-channel entity. The remaining layers are described to illustrate the relationship with the digital layers.

With respect to the mapping hierarchy in the OTN layers, multiple OCHs are mapped to the SCH, and multiple OCCs (Optical Channel Carriers) are mapped to an OCH. This hierarchy is depicted in Figure 2 below. Specifically, the following flexibility of number of instances that are mapped between the layers shall be supported.

X number of OCC mapped to OCH

Y number of OCH mapped to SCH

Z number of SCH mapped to OCG



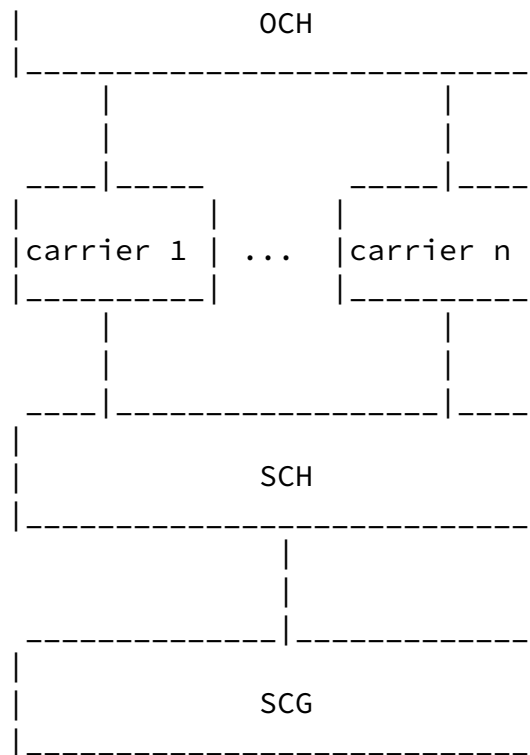
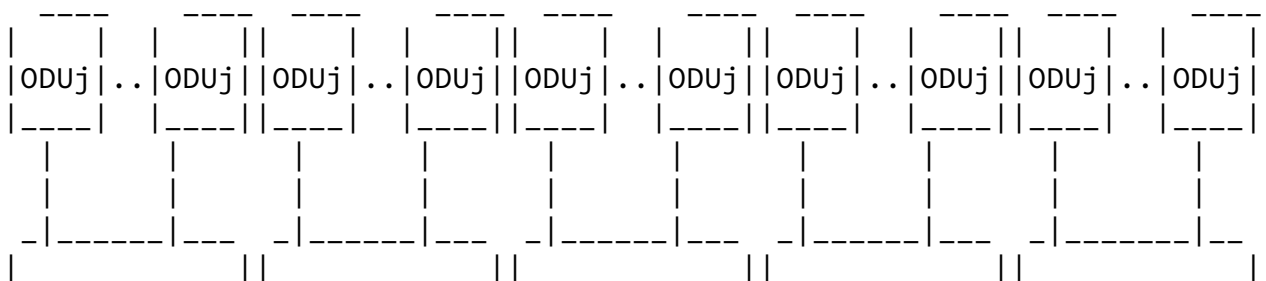


Figure 2: Super-Channel mapping to OTN hierarchy

Example Use Case 1: Super-Channel with multiple OCHs and multiple carriers per OCHs.

The following Figure 3 gives an example use case where multiple OCH are carrier over a single SCH. Please note that this is an example use case only. In general, the system shall be capable of supporting flexible mapping where there is flexible number of carriers mapped into an OCH and a flexible number of OCHs mapped to a single Super-Channel.



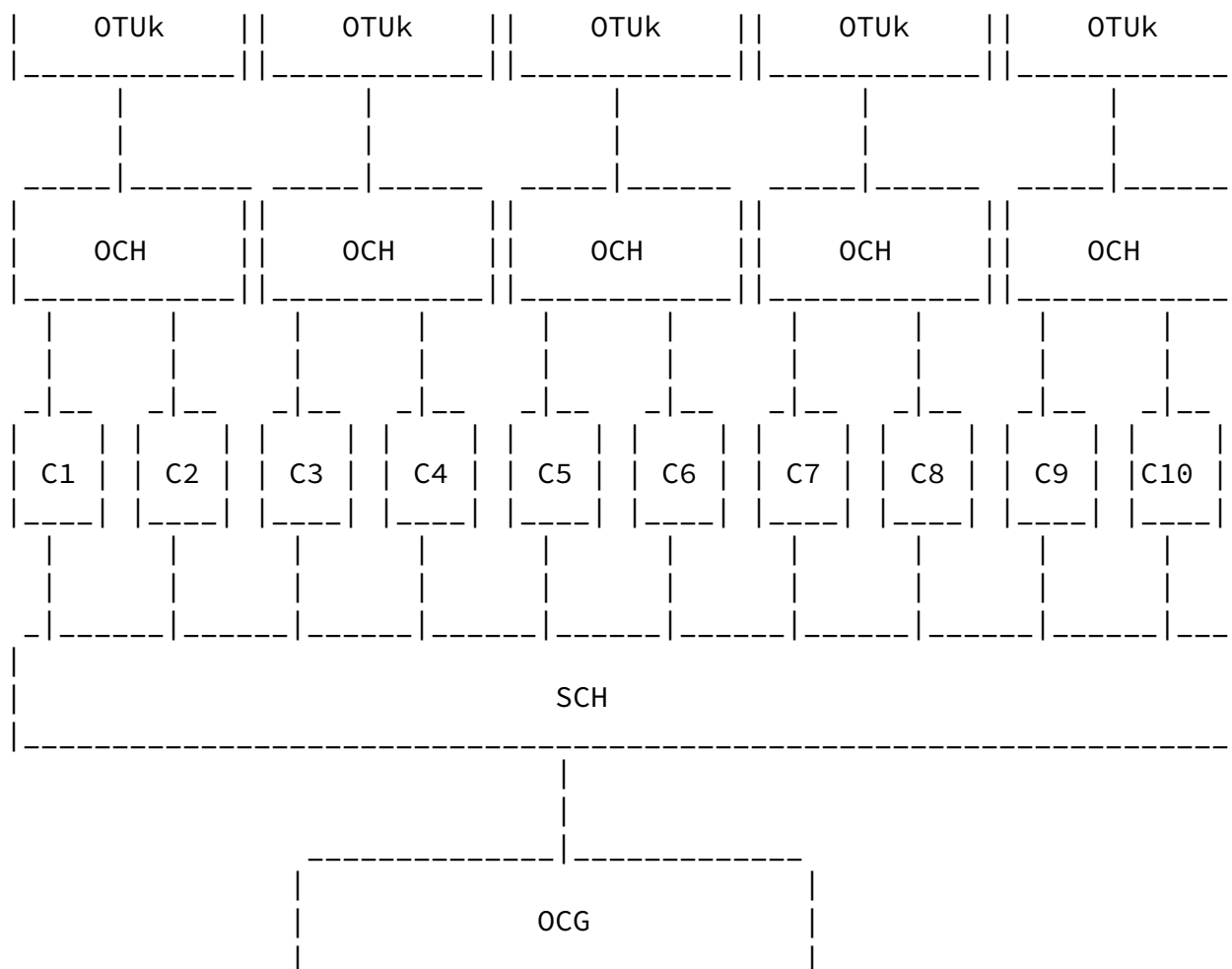


Figure 3: Super-Channel use case showing multiple OCH and multiple carriers per

Example Use Case 2:

The following Figure 4 shows the case where multiple OCHs are carried over separate super-channels.

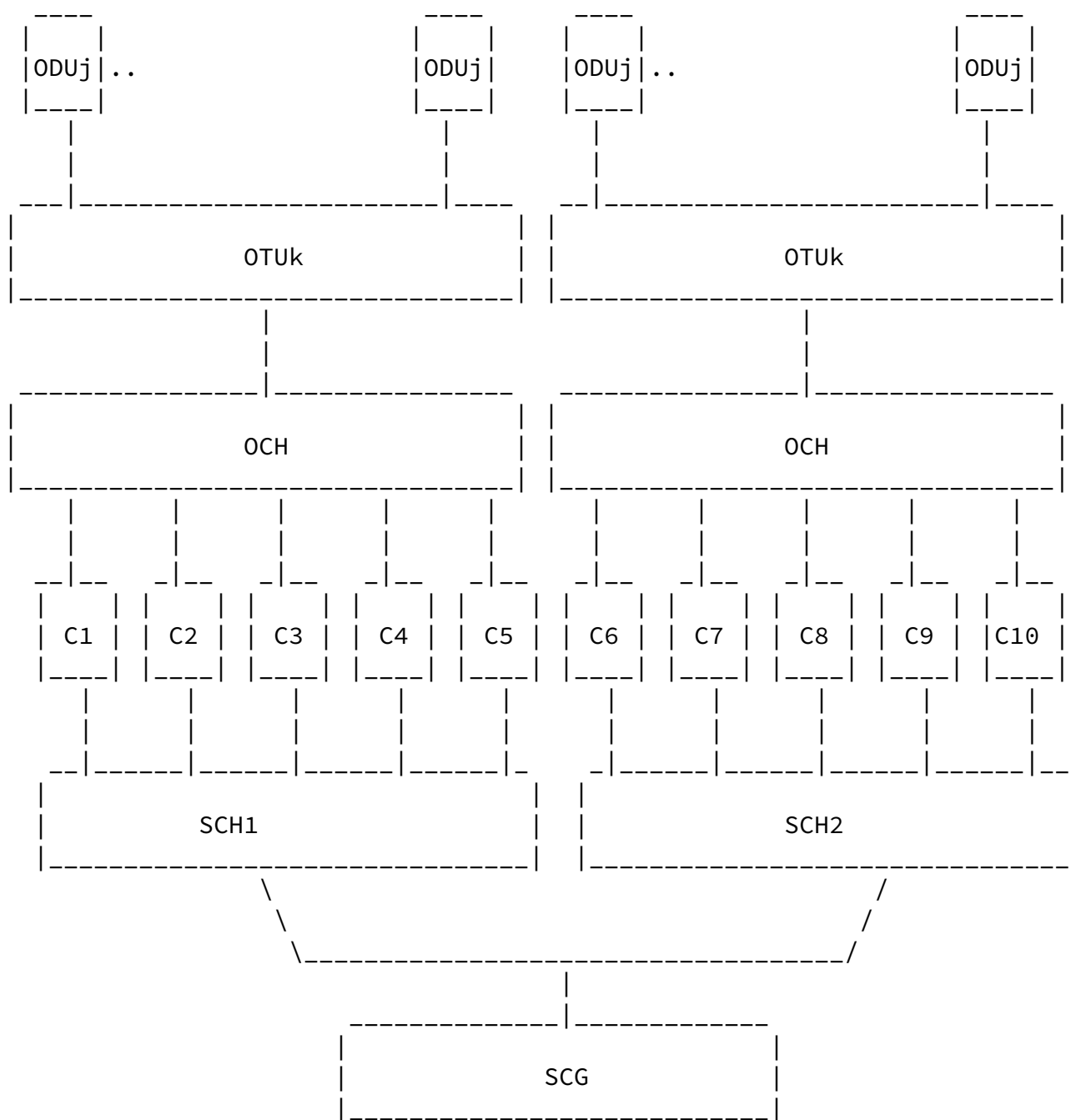


Figure 4: Split-Spectrum Super-Channel use case showing multiple OCH and multiple carriers per OCH

Example Use Case 3: Network Level Use Case of super-channel

A network level diagram to illustrate the use of CDC based super-channel (contiguous spectrum and split-spectrum) is shown in Figure 5 below. In this scenario, N1 and N2 are digital/TDM nodes, where the client services originate. N2, N3, N4 and N5 are Optical/WDM nodes on which the super-channels are provisioned. Node N2 is CDC ROADM and Nodes N3, N4 and N5 are Colorless ROADMs only.

Four super-channels are provisioned in this example network. Super-Channels S1 are contiguous spectrum super-channels, both using the same frequency slots, and are added/dropped at Node N2. The contention for the same super-channel (with exactly the same frequency slot mapping) is avoided by routing these super-channels in different degrees of the network. Alternatively, if these super-channels have to go through the same fiber path, then the frequency slots occupied on the Flex-Grid shall be different.

Super-channels S2-1 and S2-2 illustrates the split-spectrum super-channel that is co-routed over the same fibers in the network.

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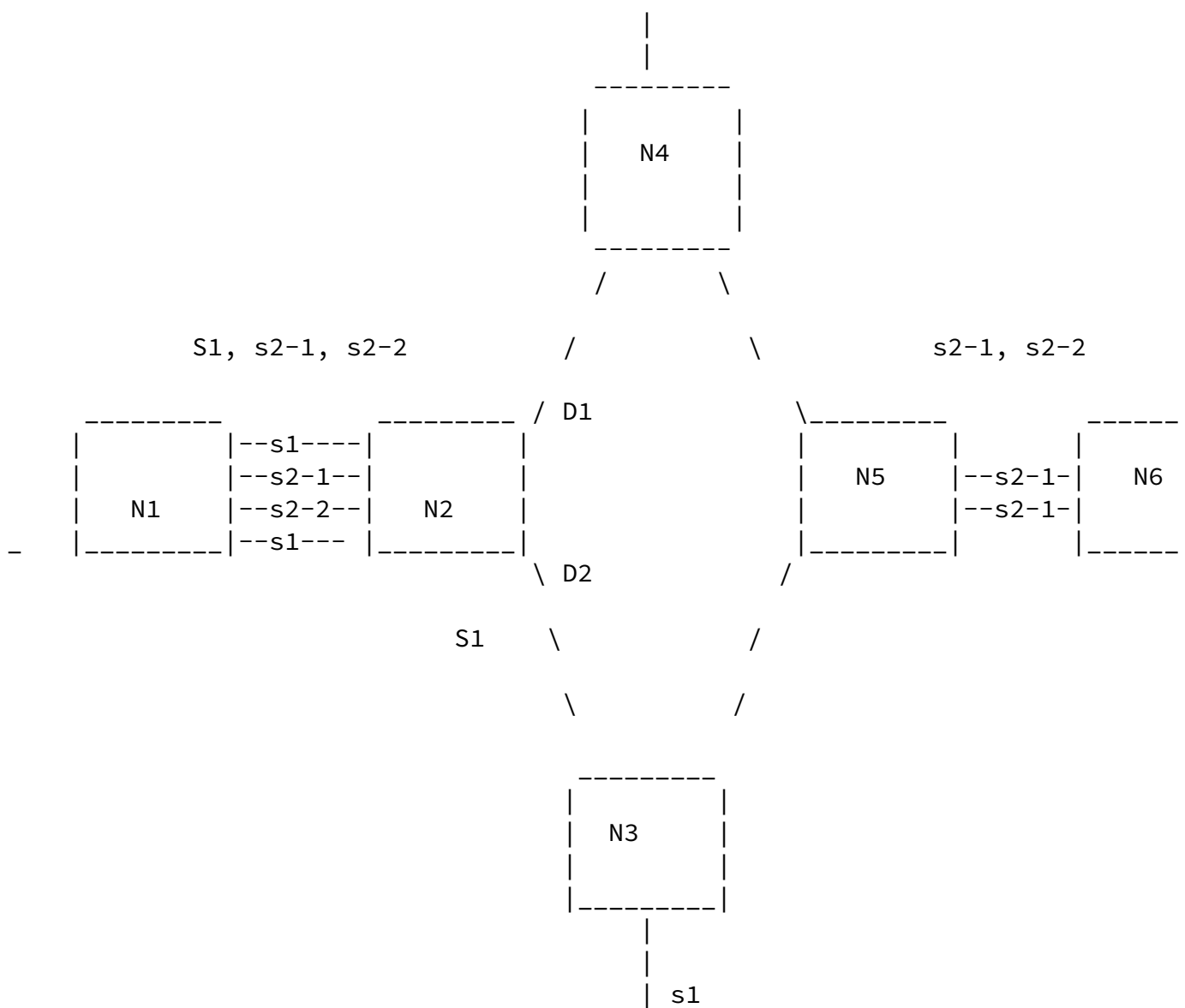


Figure 5: Super-Channel Network Level use case

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Example Use Case 4: Fixed and Flexible Grid Interworking

- In Figure 6:
 - o The Nodes N2 and N3 are Flex-Grid and Fixed grid capable nodes
 - o The Nodes N1 and N4 are fixed grid capable nodes.
- Fixed and Flexible support on the same interface
 - o In Figure 6, this is represented by Link L3
- BW advertisement that include both fixed and flexible grid by Flex Grid capable nodes
- Signaling support for both fixed and flex-grid.

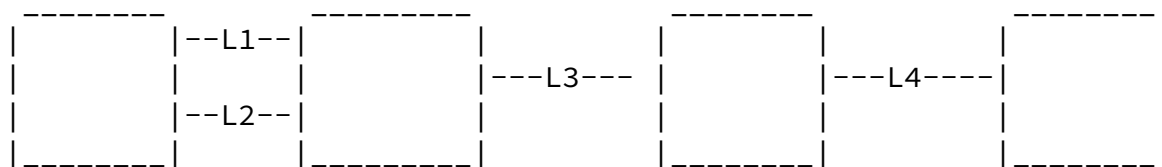


Figure 6: Use case for fixed and flex-grid interworking

6. Protocol Implications

Support GMPLS Routing extensions to satisfy requirements in [section 4.0](#).

Support GMPLS Signaling extensions to satisfy requirements in [section 4.0](#).

7. Security Considerations

<Add any security considerations>

8. IANA Considerations

IANA needs to assign a new Grid field value to represent ITU-T Flex-Grid.

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9. References

9.1. Normative References

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

9.2. Informative References

- [1] ITU-T Recommendation G.694.1, "Spectral grids for WDM applications: DWDM frequency grid", June 2002
- [2] [FLEX-GRID] Unpublished ITU-T Study Group-15 doc: G.694.1 [Rev-2, 12/2011]
- [3] [[RFC 6163](#)] Framework for GMPLS and Path Computation Element (PCE) Control of Wavelength Switched Optical Networks (WSONs)
- [4] [draft-ietf-ccamp-rwa-info-13.txt](#): Routing and Wavelength Assignment Information Model for Wavelength Switched Optical Networks
- [5] [draft-syed-ccamp-flexgrid-framework-ext.pdf](#) - this draft which contains figures.

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[10](#). Acknowledgments

[11](#). Authors' Addresses

Sharfuddin Syed
Infinera
140 Caspian Ct., Sunnyvale, CA 94089
Email: ssyed@infinera.com

Rajan Rao
Infinera
140 Caspian Ct., Sunnyvale, CA 94089
Email: rrao@infinera.com

Marco Sosa
Infinera
140 Caspian Ct., Sunnyvale, CA 94089
Email: msosa@infinera.com

Biao Lu
Infinera
140 Caspian Ct., Sunnyvale, CA 94089
Email: blu@infinera.com

Bert Basch
Verizon Communications

60 Sylvan Rd., Waltham, MA 02451
Email: bert.e.basch@verizon.com

Andrew G. Malis
Verizon Communications
60 Sylvan Rd., Waltham, MA 02451
Email: andrew.g.malis@verizon.com

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12. Contributor's List

Radhakrishna Valiveti
Email: rvaliveti@infinera.com

Iftekhhar Hussain
Email: IHussain@infinera.com

Abinder Dhillon
Email: ADhillon@infinera.com

Mike VanLeeuwen
Email: MVanleeuwen@infinera.com

Ping Pan
Email: ppan@infinera.com

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