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Guard Bands requirements for GMPLS controlled optical networks
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Abstract

The continuous increase of flexibility and bit rate in optical networks has higher and higher impacts on inter-channel effects (e.g. Cross-phase modulations). This effect leads to the introduction of Guard Bands between adjacent light paths in order to reduce the inter-channel detrimental effects.

This document provides requirements for the development of protocol extensions to support Generalized Multi-Protocol Label Switching (GMPLS) and Path Computation Element (PCE) management of Guard Bands.

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Guard bands in optical networks

March 2012

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Table of Contents

1.	Introduction	3
1.1.	Terminology	3
2.	Definitions	3
3.	Scenarios	4
4.	Guard Band definition	4
5.	Requirements	5
5.1.	PCE Requirements	5
5.2.	PCEP Requirements	7
5.3.	GMPLS Requirements	7
5.3.1.	OSPF-TERequirements	7
5.3.2.	RSVP-TE Requirements	7
6.	Security Considerations	8
7.	IANA Considerations	8
8.	Contributors	8
9.	Acknowledgements	8
10.	References	8
10.1.	Normative References	8
10.2.	Informative References	9
	Authors' Addresses	9

1. Introduction

Given the advancement of optical transmission technology, optical channels may use thinner granularity of the spectrum, which are configurable depending on the modulation format and bit-rate [G.FLEXIGRID]. Thus, thanks to this flexibility, the capacity of optical networks is strongly increasing. However, the spacing between channels may be limited by the inter-channel effects (e.g, cross-phase modulation - XPM) which can lead to a bit error rate increase. Typically, as the case of XPM or cross-talk, the larger the spectral distance among interfering signals, the less detrimental the effect. Thus, a guard band (i.e., a spectral distance such that detrimental effects are mitigated) may be considered to counteract inter-channel detrimental effects [[sambo-jlt](#)].

Guard Bands (GB) may be required in either fixed- [[RFC6163](#)] or flexible-grid networks [[G.694.1v1](#)] [G.FLEXIGRID]. As an example, in fixed-grid networks, high-speed signals (100Gbit/s and beyond) may be deployed together with low-speed signals (10Gb/s). In such a scenario, high-speed signals utilizing phase-modulated formats (e.g., dual polarization quadrature phase shift keying - DP-QPSK - 100Gb/s) suffer from XPM induced by low-speed signals, exploiting intensity modulation (e.g. on off keying - OOK - 10Gb/s). Thus, GB may be used to avoid problems of XPM between low- and high-speed signals. Similarly, in flex-grid networks, high-speed signals may exploit quadrature amplitude modulation (QAM), which experience both intensity and phase modulation. Also in such a scenario, XPM may be very detrimental.

The value of a guard band may depend on physical properties of the traversed links and on the bit rate and modulation format of the interfering signals. Given two interfering signals, inter-channel effects among the two signals are counteracted if they are separated by GB. This document describes the requirements of PCE and GMPLS control to account for guard bands.

[1.1.](#) Terminology

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.](#) Definitions

Demeaning LSP: an LSP which induces a detrimental effect on another LPS

Ceccarelli, et al.

Expires September 6, 2012

[Page 3]

Internet-Draft

Guard bands in optical networks

March 2012

Degraded LSP: an LSP which may be degraded by inter-channel effects induced by a demeaning GB: guard band

Working LSP: an active LSP

RSA: routing and spectrum assignment

IV: impairment validated (e.g., a route is impairment validated if its bit error rate is acceptable for any channel)

[3.](#) Scenarios

Fixed-grid network is here assumed as a particular case of flex-grid network, thus hereafter only the case of flex-grid networks will be treated. Similarly, RWA is assumed as a particular case of RSA and only RSA will be treated. The following PCE scenarios are considered [[draft-flexible](#)]:

- IV and RSA PCE : From a GB point of view there is no difference between IV+RSA and IV&RSA, so a general IV+RSA case will be considered. In this case the PCE provides the ingress node with an impairment-validated route and a set of frequency slots.
- IV PCE: PCE provides ingress node with an impairment-validated route. Then, slot assignment is distributed and performed by the egress node which may rely on collecting link status through the signaling protocol (RSVP-TE).

- IV Candidate path PCE: PCE provides ingress node with a set of candidate routes (i.e., a set of impairment-validated routes). Then, a route is selected by the ingress node. Slot assignment is distributed and performed by the egress node through the signaling protocol (RSVP-TE).

4. Guard Band definition

GB is defined as the minimum frequency range which separates two contiguous signals, S1 at bit rate B1 and modulation format M1 and S2 at a bit rate B2 and modulation format M2, such that detrimental effects are negligible.

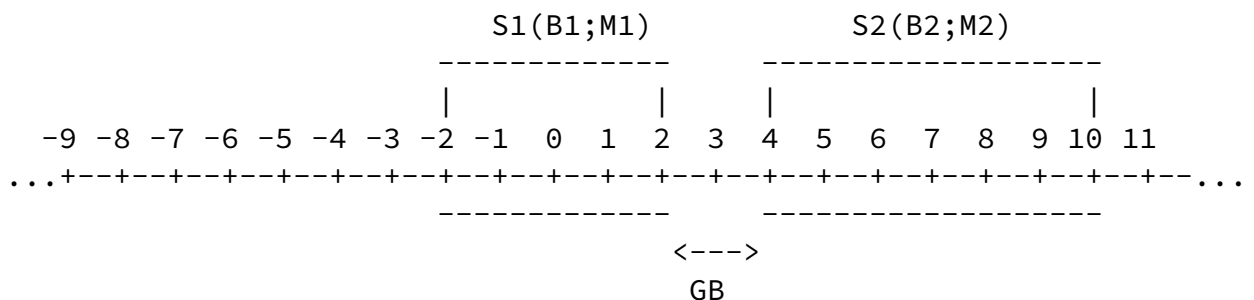


Figure 1: Guard Band

Assuming fixed-grid networks, a number of channels (e.g. of a grid spacing of 50 GHz), instead of a number of slots would be considered for GB.

The computation of GB may require the knowledge of:

- bit rate B and modulation format M of the interfering signals
- the power P values of the signals at each span. In order to limit the stored and exchanged information, an unique value of P

(worst-case scenario) may be considered for the demeaning LSP: i.e., the maximum value P experienced by an LSP of type $(B2, M2)$. Similarly, an unique value P (worst-case scenario) may be considered for the degraded LSP: the minimum value P experienced by an LSP of type $(B1, M1)$.

c. Fiber parameters: e.g. fiber attenuation, dispersion parameter, and fiber nonlinear Kerr coefficient

Bit rate and modulation format should be mandatory information for GB computation (e.g., PCE may select the value of GB from a stored set of GB values, each one associated to a bit rate and modulation format pair), thus treated in the rest of the document.

[5.](#) Requirements

[5.1.](#) PCE Requirements

- IV+RSA PCE: given an LSP request, by exploiting a TED, PCE may account for GB in the IV+RWA (or IV&RSA) process, if needed. In the case of:

- + Stateful PCE: PCE has a TED (in simple terms as disseminated by OSPF-TE) plus an LSP-DB which are the active LSPs state. (e.g., the route and the slot used by a working LSP). In order

to identify the required GB, the TED plus the LSP-DB exploited by the PCE should be extended to store the following information:

- ++ Bit rate B of any working LSP in the network

- ++ Modulation format M of any working LSP in the network

- ++ Allocated central frequency and slot width for any active LSP in the network.

- + Stateless PCE: PCE exploits a TED which includes per-link information regarding the usage of the optical spectrum resource (e.g., Available Frequency Ranges). If the PCE obtains the TED via e.g. OSPF-TE this may also add additional

requirements to OSPF-TE as detailed later on. In order to identify the required GB, the TED exploited by the PCE should be extended to store the set of required information. An example of such pieces of information could be:

- ++ Used frequency slots

- ++ Bit rate B associated to any frequency slot in use

- ++ Modulation format M associated to any frequency slot in use

- IV PCE: given an LSP request, PCE provides the ingress node with an impairment validated route. Then, wavelength or the slot assignment is distributed, e.g. performed through a signaling protocol (RSVP-TE). In this case, PCE should inform the ingress node about the requirements of GB to separate the given LSP from other LSPs of specific bit rate B and modulation format M. Thus, PCEP and RSVP-TE may require extensions to account for GB.

- IV Candidate path PCE: given an LSP request, PCE provides the ingress node with a set of impairment validated routes. A route is selected by the ingress node. Then, wavelength or the slot assignment is distributed, e.g. performed through a signaling protocol (RSVP-TE). In this case, PCE should inform, for each candidate route, the ingress node about the requirements of GB to separate the given LSP from other LSPs of specific bit rate B and modulation format M. Thus, PCEP and RSVP-TE may require extensions to account for GB.

[5.2.](#) PCEP Requirements

- IV&RSA PCE: in this case, no extensions for GB are required by PCEP because PCEP client (e.g., the ingress node) does not require to know GB information

- IV PCE: in this case, an extension may be needed in the PCEP Path Computation Reply message to inform the ingress node about

required GBs along the route. Then, GB information should be considered in the routing and slot assignment.

- IV candidate path PCE: in this case, an extension may be needed in the PCEP Path Computation Reply message to inform the ingress node, for any candidate route, about required GBs along the candidate routes. Then, GB information should be considered in the routing and slot assignment.

[5.3.](#) GMPLS Requirements

[5.3.1.](#) OSPF-TE Requirements

- Stateful PCE: the LSP-DB is not filled through OSPF-TE, thus no OSPF-TE extension is required.
- Stateless PCE: the TED may be filled through OSPF-TE, thus OSPF-TE extensions may be required to carry used frequency slot information, such as the associated bit-rate B and modulation format M.

[5.3.2.](#) RSVP-TE Requirements

If the PCE only provides the ingress node with a route (IV PCE and IV candidate path PCE), the slot assignment is performed at the egress node. To this aim, RSVP-TE Path message gathers frequency range slot availability information along the route.

- IV&RSA PCE: no extensions for GB are required by RSVP-TE
- IV PCE: extensions to RSVP-TE may be required to enable distributed RSA process which accounts for GB. In particular, extensions to RSVP-TE may be required to identify the frequency spectrum along the route that should be not selected because of GB.
- IV candidate path PCE: extensions to RSVP-TE may be required to enable distributed RSA process which accounts for GB. In particular, extensions to RSVP-TE may be required to identify frequency spectrum along the route that should be not selected

[6.](#) Security Considerations

TBD

[7.](#) IANA Considerations

TBD

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Internet-Draft

Guard bands in optical networks

March 2012

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