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PCEP Extensions for WSON Impairments

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Abstract

As an optical signal progresses along its path it may be altered by the various physical processes in the optical fibers and devices it encounters. When such alterations result in signal degradation, these processes are usually referred to as "impairments". These physical characteristics may be important constraints to consider in path computation process in wavelength switched optical networks.

This document provides PCEP extensions to support Impairment Aware Routing and Wavelength Assignment (IA-RWA) in wavelength switched optical networks.

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Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [BCP 14](#) [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

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1. Introduction

[RFC4655] defines the PCE based architecture and explains how a Path Computation Element (PCE) may compute Label Switched Paths (LSP) in Multiprotocol Label Switching Traffic Engineering (MPLS-TE) and Generalized MPLS (GMPLS) networks at the request of Path Computation Clients (PCCs). A PCC is shown to be any network component that makes such a request and may be for instance an Optical Switching Element within a Wavelength Division Multiplexing (WDM) network. The PCE, itself, can be located anywhere within the network, and may be within an optical switching element, a Network Management System (NMS) or Operational Support System (OSS), or may be an independent network server.

The PCE communication Protocol (PCEP) is the communication protocol used between PCC and PCE, and may also be used between cooperating PCEs. [RFC4657] sets out the common protocol requirements for PCEP. Additional application-specific requirements for PCEP are deferred to separate documents.

This document provides a set of application-specific PCEP requirements for support of path computation in Wavelength Switched Optical Networks (WSON) with impairments. WSON refers to WDM based optical networks in which switching is performed selectively based on the wavelength of an optical signal.

The path in WSON is referred to as an optical path. An optical path may span multiple fiber links and the path should be assigned a wavelength for each link. A transparent optical network is made up of optical devices that can switch but not convert from one wavelength to another. In a transparent optical network, an optical path operates on the same wavelength across all fiber links that it traverses. In such case, the optical path is said to satisfy the wavelength-continuity constraint. Two optical paths that share a common fiber link can not be assigned the same wavelength. To do otherwise would result in both signals interfering with each other. Note that advanced additional multiplexing techniques such as polarization based multiplexing are not addressed in this document since the physical layer aspects are not currently standardized. Therefore, assigning the proper wavelength on an optical path is an essential requirement in the optical path computation process.

When a switching node has the ability to perform wavelength conversion the wavelength-continuity constraint can be relaxed, and a may use different wavelengths on different links along its route from origin to destination. It is, however, to be noted that wavelength converters may be limited due to their relatively high cost, while the number of WDM channels that can be supported in a fiber is also limited. As a WSON can be composed of network nodes that cannot perform wavelength conversion, nodes with limited wavelength conversion, and nodes with full wavelength conversion abilities, wavelength assignment is an additional routing constraint to be considered in all optical path computation.

One of the most basic questions in communications is whether one can successfully transmit information from a transmitter to a receiver within a prescribed error tolerance, usually specified as a maximum permissible bit error ratio (BER). This generally depends on the nature of the signal transmitted between the sender and receiver and the nature of the communications channel between the sender and

receiver. The optical path utilized (along with the wavelength) determines the communications channel.

The optical impairments incurred by the signal along the fiber and at each optical network element along the path determine whether the BER performance or any other measure of signal quality can be met for this particular signal on this particular path. Given the existing standards covering optical characteristics (impairments) and the knowledge of how the impact of impairments may be estimated along a path, [[RFC6566](#)] provides a framework for impairment aware path computation and establishment utilizing GMPLS protocols and the PCE architecture.

Some transparent optical subnetworks are designed such that over any path the degradation to an optical signal due to impairments never exceeds prescribed bounds. This may be due to the limited geographic extent of the network, the network topology, and/or the quality of the fiber and devices employed. In such networks the path selection problem reduces to determining a continuous wavelength from source to destination (the Routing and Wavelength Assignment problem). These networks are discussed in [[RFC6163](#)]. In other optical networks, impairments are important and the path selection process must be impairment-aware.

In this document we first review the processes for routing and wavelength assignment (RWA) used when wavelength continuity constraints are present. We then review the processes for optical impairment aware RWA (IA-RWA). Based on selected process models we then specify requirements for PCEP to support IA-RWA. Note that requirements for PCEP to support RWA are specified in a separate document [[RFC7449](#)].

The remainder of this document uses terminology from [[RFC4655](#)].

1.1. WSON RWA Processes (no impairments)

In [[RFC6163](#)] three alternative process architectures were given for performing routing and wavelength assignment. These are shown schematically in Figure 1.

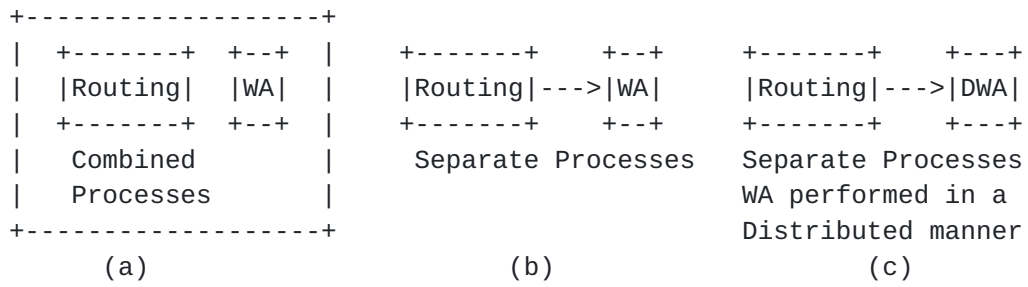


Figure 1

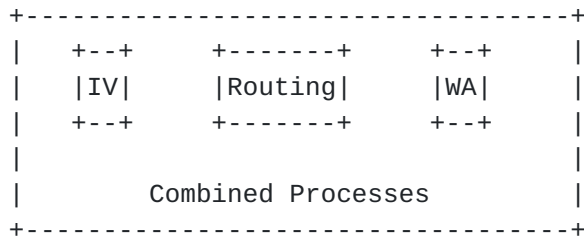
RWA process

alternatives.

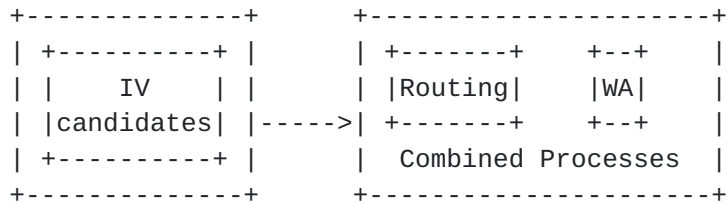
Detail description of each alternative can be found in [[RFC6163](#)].

1.2. WSON IA-RWA Processes

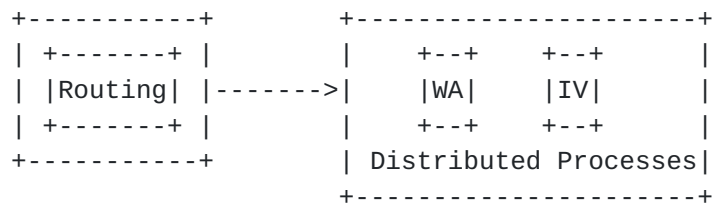
In [[RFC6566](#)] impairments were addressed by adding an "impairment validation" (IV) process. For approximate impairment validation three process alternatives were given in [[RFC6566](#)] and are shown in Figure 2. Since there are many possible alternative combinations, these are just three examples. Please note that the requirements for all possible architectures can be reduced to the cases in Figure 3 in [section 2](#).



(a)



(b)



(c)

Figure 2 Process flows for the three main approximate architectural alternatives.

These alternatives have the following properties and impact on PCEP requirements in this document.

1. Combined IV and RWA Process - Here the processes of impairment validation, routing and wavelength assignment are aggregated into a single PCE. The requirements for PCC-PCE interaction with such a combined IV-RWA process PCE is addressed in this document.
2. IV-Candidates + RWA Process - As explained in [\[RFC6566\]](#) separating the impairment validation process from the RWA process maybe necessary to deal with impairment sharing constraints. In this architecture one PCE computes impairment candidates and another PCE uses this information while performing RWA. The requirements for PCE-to-PCE interaction of this architecture will be addressed in this document.

3. Routing + Distributed WA and IV - Here a standard path computation (unaware of detailed wavelength availability or optical impairments) takes place, then wavelength assignment and impairment validation is performed along this path in a distributed manner via signaling (RSVP-TE). This alternative should be covered by existing or emerging GMPLS PCEP extensions and does not present new WSON specific requirements.

2. WSON PCE Architectures and Requirements

In the previous section we reviewed various process architectures for implementing RWA with and without regard for optical impairment. In Figure 3 we reduce these alternatives to two PCE based implementations. As specified in [[RFC6566](#)], the PCE in Figure 3(a) should be given the necessary information for RWA and impairment validation, including WSON topology, link wavelength utilization as well as impairment information such as the adjustment range of tunable parameters, etc. Similarly, RWA-PCE should be equipped with all the information other than impairment-related ones which is a necessity for IV-PCE.

In Figure 3(a) we show the three processes of routing, wavelength assignment and impairment validation accessed via a single PCE. The implementation details of the interactions of the processes are not subject to standardization; this document concerns only the PCC to PCE communications.

In Figure 3(b) the impairment validation process is implemented in a separate PCE. Here the RWA-PCE acts as a coordinator and the PCC to RWA-PCE interface will be the same as in Figure 3(a), however in this case we have additional requirements for the RWA-PCE to IV-PCE interface.

(Editor's Note: this is not a complete list of optical signal quality measure and subject to further change.)

If the PCReq Message does not include the BER limit and no BER limit information related to the specific path request is provisioned at the PCE then the PCE will return an error specifying that a BER limit must be provided.

"Margin" means "insurance" (e.g. 3~6dB) for suppliers and operators which are set against unpredictable degradation and other degradation not included in the provided estimates such as that due to fiber nonlinearity.

In non-coherent WDM networks, PMD and CD should be carefully considered. However, coherent WDM networks usually have a high tolerance with these two optical signal quality measurements and thus it may not need to be considered.

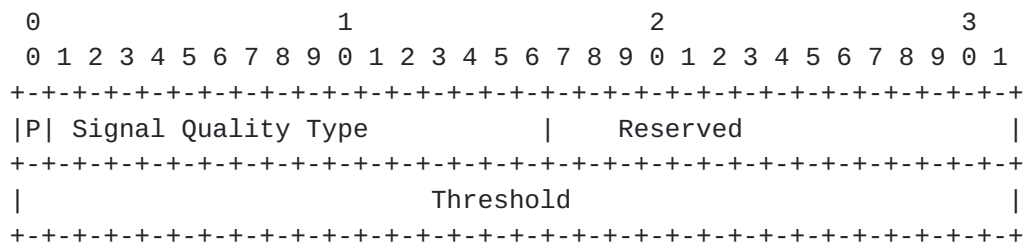
2.1.1.1. Signal Quality Measure TLV

This TLV represents all impairment constraints that need to be considered by the PCE to calculate a path that passes the requested measure of signal quality for a signal for a given source and destination.

This TLV is repeated one after another until all signal quality types are specified.

The TLV type is TBD.

The TLV data is defined as follow:



The P bit (1 bit): Indicates if the associated impairment is a path level or not.

The P bit is set to 1 indicates that the associated impairment is a path level. This means that the impairment is associated with the end-to-end path and the threshold must be satisfied on a path level.

The P bit is set to 0 indicates that the associated impairment is a link level. This means the impairment is associated with the link and the threshold must be satisfied on every link of the end-to-end path.

The Signal Quality Type (15 bits): indicates the kind of optical signal quality of interest.

0: reserved

1: BER limit

2: OSNR+ Margin

3: Power

4: PMD

5: CD

6: Q factor

7-up: Reserved for future use

Threshold (32 bits) indicates the threshold (upper or lower) to which the specified signal quality measure must satisfy for the path/link (depending on the P bit).

The reserved bits MUST be set to 0 on transmit and MUST be ignored on receive.

2.1.2. A new RWA path reply

The PCRep Message MUST include the route, wavelengths assigned to the route, and an indicator that says if the path conforms to the required quality or not. Moreover, it should also be able to specify a list of impairment compensation information along the chosen route, i.e., the value or value range of optical signal quality parameter that needs to be adjusted, such as power level, in order to achieve the resultant measure of signal quality as given in [Section 2.1.2.1](#). It is suggested to carry this information in the PCEP ERO object. According to [[RFC5440](#)], PCEP ERO object is identical to RSVP-TE ERO object. Therefore, it is suggested to modify the RSVP-TE ERO object to accommodate this need. This will be included in a separate draft in the future.

In the case where a valid path is not found, the PCRep Message MUST include why the path is not found (e.g., no route, wavelength not found, BER failure, etc.)

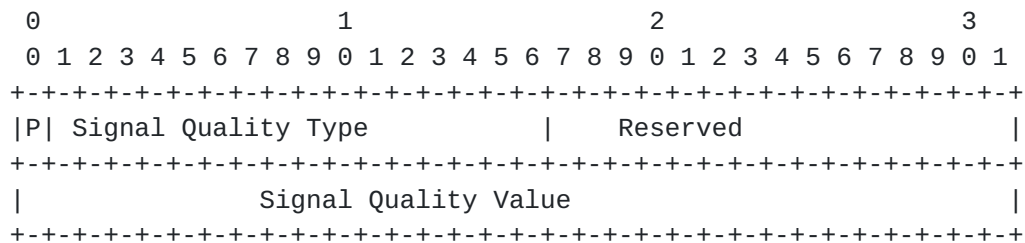
2.1.2.1. Signal Quality Measure TLV

This TLV represents the result of the requested measure of signal quality for a signal for a given source and destination.

This TLV is repeated one after another until all signal quality types are specified.

The TLV type is TBD.

The TLV data is defined as follow:



The P bit (1 bit): Indicates if the associated signal quality measure has passed the threshold or not.

The P bit is set to 1 indicates that the associated signal quality measure has passed the threshold.

The P bit is set to 0 indicates that the associated signal quality measure has failed the threshold.

The Signal Quality Type (15 bits): indicates the kind of optical signal quality of interest.

0: reserved

1: BER limit

2: OSNR_ Margin

3: Power

4: PMD

5: CD

6: Q factor

7-up: Reserved for future use

Signal Quality Value (32 bits) indicates the actual estimated value of the specified signal quality measure for the end-to-end path.

TBD: How to encode link based value needs to be determined in the revision.

The reserved bits MUST be set to 0 on transmit and MUST be ignored on reception.

2.2. RWA-PCE to IV-PCE Interface

In [RFC6566] a sequence diagram for the interaction of the PCC, RWA-PCE and IV-PCE of Figure 3(b) was given and is repeated here in Figure 4. The interface between the PCC and the RWA-PCE (acting as the coordinator) was covered in [section 2.1](#).

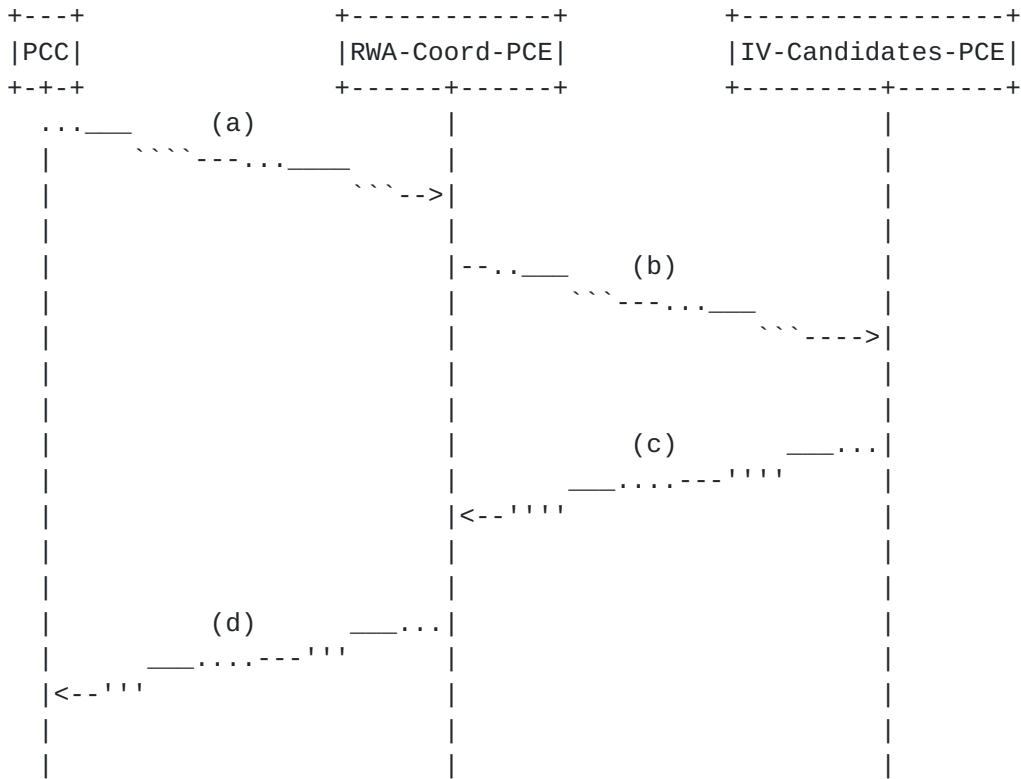


Figure 4 Sequence diagram for the interactions between PCC, RWA-Coordinating-PCE and the IV-Candidates-PCE.

The interface between the RWA-Coord-PCE and the IV-Candidates-PCE is specified by the following requirements:

1. The PCReq Message from the RWA-Coord-PCE to the IV-Candidate-PCE MUST include an indicator that more than one (candidate) path between source and destination is desired.
2. The PCReq message from the RWA-Coord-PCE to the IV-Candidates-PCE MUST include a limit on the number of optical impairment qualified paths to be returned by the IV-PCE.

3. The PCReq message from the RWA-Coord-PCE to the IV-Candidates-PCE MAY include wavelength constraints. Note that optical impairments are wavelength sensitive and hence specifying a wavelength constraint may help limit the search for valid paths. This requirement has been already covered in [[RFC7449](#)] and is presented here for an illustration purpose.
4. The PCRep Message from the IV-Candidates-PCE to RWA-Coord-PCE MUST include a set of optical impairment qualified paths along with any wavelength constraints on those paths.
5. The PCRep Message from the IV-Candidates-PCE to RWA-Coord-PCE MUST indicate "no path found" in case where a valid path is not found.
6. The PCReq Message from the RWA-Coord-PCE to the IV-Candidate-PCE MAY include one or more specified paths and wavelengths that is to be verified by the IV-PCE. This requirement is necessary when the IV-PCE is allowed to verify specific paths.

Note that once the RWA-Coord-PCE receives the resulting paths from the IV Candidates PCE, then the RWA-Coord-PCE computes RWA for the IV qualified candidate paths and sends the result back to the PCC.

2.2.1. A new impairment-validated (IV) path request

Details on encoding are TBD.

2.2.2. A new impairment-validated (IV) path reply

Details on encoding are TBD.

3. Manageability Considerations

Manageability of WSON Routing and Wavelength Assignment (RWA) with PCE must address the following considerations:

3.1. Control of Function and Policy

In addition to the parameters already listed in [Section 8.1 of \[RFC5440\]](#), a PCEP implementation SHOULD allow configuring the following PCEP session parameters on a PCC:

- o The ability to send a WSON IA-RWA request.

In addition to the parameters already listed in [Section 8.1 of \[RFC5440\]](#), a PCEP implementation SHOULD allow configuring the following PCEP session parameters on a PCE:

- o The support for WSON IA-RWA.
- o The maximum number of synchronized path requests associated with WSON IA-RWA per request message.
- o A set of WSON IA-RWA specific policies (authorized sender, request rate limiter, etc).

These parameters may be configured as default parameters for any PCEP session the PCEP speaker participates in, or may apply to a specific session with a given PCEP peer or a specific group of sessions with a specific group of PCEP peers.

[3.2. Information and Data Models, e.g. MIB module](#)

Extensions to the PCEP MIB module defined in [PCEP-MIB] should be defined, so as to cover the WSON IA-RWA information introduced in this document. A future revision of this document will list the information that should be added to the MIB module.

[3.3. Liveness Detection and Monitoring](#)

Mechanisms defined in this document do not imply any new liveness detection and monitoring requirements in addition to those already listed in [section 8.3 of \[RFC5440\]](#).

[3.4. Verifying Correct Operation](#)

Mechanisms defined in this document do not imply any new verification requirements in addition to those already listed in [section 8.4 of \[RFC5440\]](#)

[3.5. Requirements on Other Protocols and Functional Components](#)

The PCE Discovery mechanisms ([[RFC5089](#)] and [[RFC5088](#)]) may be used to advertise WSON IA-RWA path computation capabilities to PCCs.

3.6. Impact on Network Operation

Mechanisms defined in this document do not imply any new network operation requirements in addition to those already listed in [section 8.6 of \[RFC5440\]](#).

4. Security Considerations

This document has no requirement for a change to the security models within PCEP [PCEP]. However the additional information distributed in order to address the RWA problem represents a disclosure of network capabilities that an operator may wish to keep private. Consideration should be given to securing this information.

5. IANA Considerations

A future revision of this document will present requests to IANA for codepoint allocation.

6. References

6.1. Normative References

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