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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.

Status of this Memo

   This Internet-Draft is submitted to IETF in full conformance with
   the provisions of [BCP 78](BCP 78) and [BCP 79](BCP 79).

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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.

```
   +------------------+
   |  +-------+  +--+  |     +-------+    +--+      +-------+    +---+
   |  |Routing|  |WA|  |     |Routing|--->|WA|      |Routing|--->|DWA|
   |  +-------+  +--+  |     +-------+    +--+      +-------+    +---+
   |    Combined      |      Separate Processes    Separate Processes
   |    Processes     |                            WA performed in a
   +------------------+                            Distributed manner
         (a)                        (b)                    (c)
```
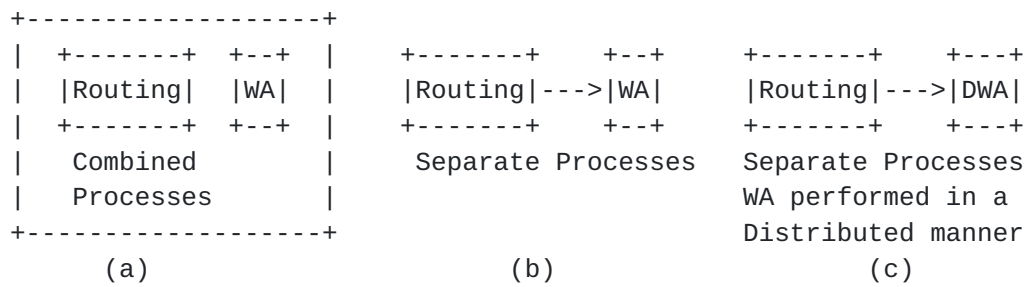
                    Figure 1   RWA process
alternatives.

   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.
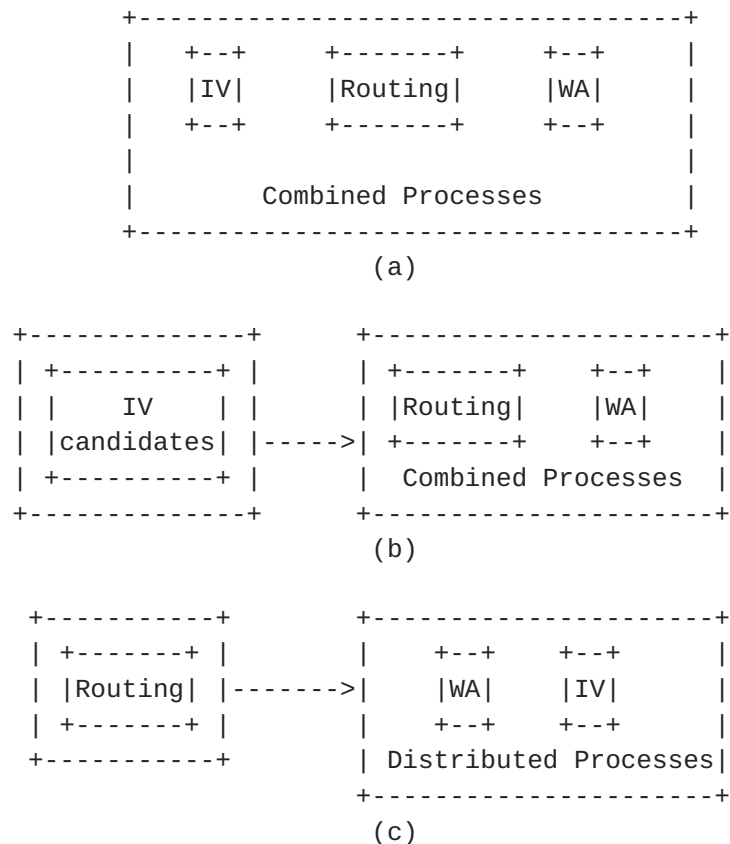
```
              +------------------------------------+
              |    +--+      +-------+      +--+    |
              |    |IV|      |Routing|      |WA|    |
              |    +--+      +-------+      +--+    |
              |                                    |
              |         Combined Processes         |
              +------------------------------------+
                             (a)

    +--------------+      +---------------------+
    | +----------+ |      | +-------+    +--+   |
    | |    IV    | |      | |Routing|    |WA|   |
    | |candidates| |----->| +-------+    +--+   |
    | +----------+ |      |   Combined Processes|
    +--------------+      +---------------------+
                     (b)

    +-----------+        +---------------------+
    | +-------+ |        |    +--+    +--+      |
    | |Routing| |------->|    |WA|    |IV|      |
    | +-------+ |        |    +--+    +--+      |
    +-----------+        | Distributed Processes|
                         +---------------------+
                     (c)
```
    Figure 2   Process flows for the three main approximate
impairment
                      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.
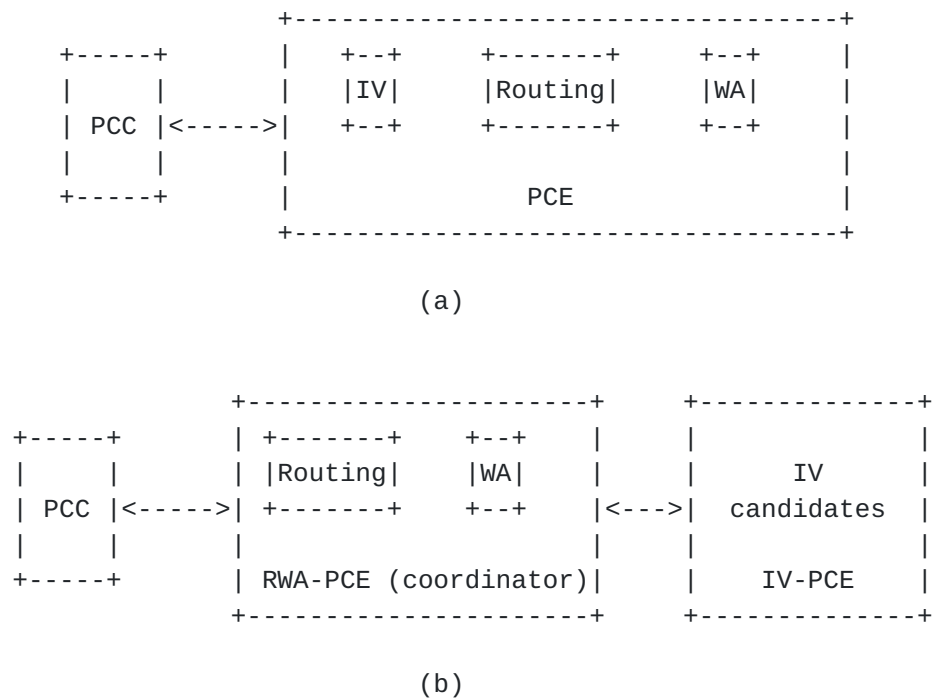
```
              +----------------------------------+
  +-----+     |    +--+      +-------+     +--+   |
  |     |     |    |IV|      |Routing|     |WA|   |
  | PCC |<----->|    +--+      +-------+     +--+   |
  |     |     |                                  |
  +-----+     |              PCE                 |
              +----------------------------------+

                         (a)


              +----------------------+     +--------------+
  +-----+     | +-------+    +--+    |     |              |
  |     |     | |Routing|    |WA|    |     |      IV      |
  | PCC |<----->| +-------+    +--+    |<--->|  candidates  |
  |     |     |                      |     |              |
  +-----+     | RWA-PCE (coordinator)|     |    IV-PCE    |
              +----------------------+     +--------------+

                         (b)
```
             Figure 3   PCE architectures
for IA-RWA.

2.1. RWA PCC to PCE Interface

   The PCC to PCE interface of Figure 3(a) and the PCC to RWA-PCE
   (coordinator) interface of Figure 3(b) are the same and we will
   cover both in this section. The following requirements for these
   interfaces are arranged by use cases:

      2.1.1. A new RWA path request

   The PCReq Message MUST include one or more specific measures of
   optical signal quality to which all feasible paths should conform:

   o BER limit

   o OSNR + Margin

   o Power

   o PMD

   o Residual Dispersion (RD)

   o Q factor

   o TBD

(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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|P| Signal Quality Type        |       Reserved                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Threshold                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|P| Signal Quality Type        |      Reserved                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Signal Quality Value                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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.

```
     +---+                    +------------+        +----------------+
     |PCC|                    |RWA-Coord-PCE|        |IV-Candidates-PCE|
     +-+-+                    +------+------+        +---------+-------+
       ...___       (a)          |                         |
       |      ````---...____     |                         |
       |                 ```-->| |                         |
       |                         |                         |
       |                         |--..___       (b)         |
       |                         |      ```---...___         |
       |                         |              ```---->|   |
       |                         |                         |
       |                         |                         |
       |                         |          (c)     ___...||
       |                         |        ___...---''''    |
       |                         |<--''''                 |
       |                         |                         |
       |                         |                         |
       |          (d)      ___...||                         |
       |        ___...---'''      |                         |
       |<--'''                   |                         |
       |                         |                         |
       |                         |                         |
```
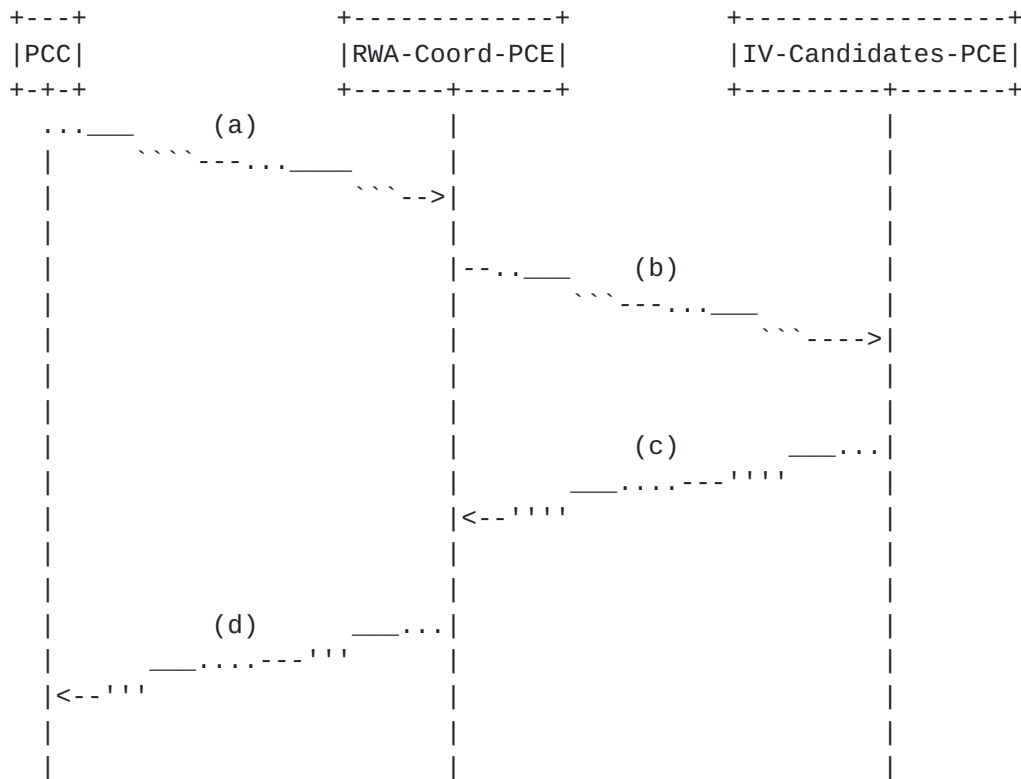
        Figure 4   Sequence diagram for the interactions between
PCC, RWA-
                Coordinating-PCE and the IV-Candidates-PCE.

   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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