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PCEP Extension for WSON Routing and Wavelength Assignment

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Abstract

This document provides the Path Computation Element communication Protocol (PCEP) extensions for the support of Routing and Wavelength Assignment (RWA) in Wavelength Switched Optical Networks (WSON). Lightpath provisioning in WSONs requires a routing and wavelength assignment (RWA) process. From a path computation perspective, wavelength assignment is the process of determining which wavelength can be used on each hop of a path and forms an additional routing constraint to optical light path computation.

Status of this Memo

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1. Terminology

This document uses the terminology defined in [RFC4655], and [RFC5440].

2. Requirements Language

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].

3. Introduction

[RFC4655] defines a PCE based path computation 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 said 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 communications Protocol (PCEP) is the communication protocol used between a PCC and a 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 the PCEP extensions for the support of Routing and Wavelength Assignment (RWA) in Wavelength Switched Optical Networks (WSON) based on the requirements specified in [RFC6163] and [RFC7449].

WSON refers to WDM based optical networks in which switching is performed selectively based on the wavelength of an optical signal. WSONs can be transparent or translucent. A transparent optical network is made up of optical devices that can switch but not convert from one wavelength to another, all within the optical domain. On the other hand, translucent networks include 3R regenerators that are sparsely placed. The main function of the 3R regenerators is to convert one optical wavelength to another. In this document, only wavelength converters that require electrical signal regeneration are considered.

A Lambda Switch Capable (LSC) Label Switched Path (LSP) may span one or several transparent segments, which are delimited by 3R regenerators (typically with electronic regenerator and optional wavelength conversion). Each transparent segment or path in WSON is referred to as an optical path. An optical path may span multiple fiber links and the path should be assigned the same wavelength for each link. In such case, the optical path is said to satisfy the wavelength-continuity constraint. Figure 1 illustrates the relationship between a LSC LSP and transparent segments (optical paths).

```
+---+       +-----+       +-----+      +-----+         +-----+
|   |I1     |     |       |     |      |     |       I2|     |
|   |o------|     |-------[(3R) ]------|     |--------o|     |
|   |       |     |       |     |      |     |         |     |
+---+       +-----+       +-----+      +-----+         +-----+
    (X  LSC)     (LSC  LSC)    (LSC  LSC)     (LSC  X)
     <-------->  <-------->      <------>    <-------->
     <-----------------------><----------------------->
      Transparent Segment         Transparent Segment
    <-------------------------------------------------->
                           LSC LSP
```

Figure 1 Illustration of a LSC LSP and transparent segments

Note that two optical paths within a WSON LSP do not need to operate on the same wavelength (due to the wavelength conversion capabilities). Two optical paths that share a common fiber link cannot be assigned the same wavelength; Otherwise, both signals would interfere 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 a lightpath 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 LSC Label Switched Path (LSP) 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 lightpath computation.

For example (see Figure 1), within a translucent WSON, a LSC LSP may be established between interfaces I1 and I2, spanning 2 transparent segments (optical paths) where the wavelength continuity constraint applies (i.e. the same unique wavelength must be assigned to the LSP at each TE link of the segment). If the LSC LSP induced a Forwarding Adjacency / TE link, the switching capabilities of the TE link would be (X X) where X refers to the switching capability of I1 and I2. For example, X can be PSC, TDM, etc.

This document aligns with GMPLS extensions for PCEP [PCEP-GMPLS] for generic property such as label, label-set and label assignment noting that wavelength is a type of label. Wavelength restrictions and constraints are also formulated in terms of labels per [RFC7579].

The optical modulation properties, which are also referred to as signal compatibility, are already considered in signaling in [RFC7581] and [RFC7688]. In order to improve the signal quality and limit some optical effects several advanced modulation processing are used. Those modulation properties contribute not only to optical signal quality checks but also constrain the selection of sender and

receiver, as they should have matching signal processing capabilities. This document includes signal compatibility constraints as part of RWA path computation. That is, the signal processing capabilities (e.g., modulation and FEC) by the means of optical interface class (OIC) must be compatible between the sender and the receiver of the optical path across all optical elements.

This document, however, does not address optical impairments as part of RWA path computation. See [RFC6566] for more information on optical impairments and GMPLS.

4. Encoding of a RWA Path Request

Figure 2 shows one typical PCE based implementation, which is referred to as the Combined Process (R&WA). With this architecture, the two processes of routing and wavelength assignment are accessed via a single PCE. This architecture is the base architecture from which the requirements have been specified in [RFC7449] and the PCEP extensions that are going to be specified in this document are based on this architecture.

```
                       +-----------------------------+
         +------+      |     +--------+     +--+     |
         |      |      |     |Routing|     |WA|     |
         | PCC  |<----->|     +--------+     +--+     |
         |      |      |                             |
         +------+      |            PCE              |
                       +-----------------------------+
```

Figure 2 Combined Process (R&WA) architecture

4.1. Wavelength Assignment (WA) Object

Wavelength allocation can be performed by the PCE by different means:

(a) By means of Explicit Label Control (ELC) where the PCE allocates which label to use for each interface/node along the path. in the sense that the allocated labels MAY appear after an interface route subobject.
(b) By means of a Label Set where the PCE provides a range of potential labels to allocate by each node along the path.

Option (b) allows distributed label allocation (performed during signaling) to complete wavelength assignment.

Additionally, given a range of potential labels to allocate, the request SHOULD convey the heuristic / mechanism to the allocation.

The format of a PCReq message after incorporating the WA object is as follows:

```
<PCReq Message> ::= <Common Header>

                       [<svec-list>]

                       <request-list>

   Where:

      <request-list>::=<request>[<request-list>]

      <request>::= <RP>

                   <ENDPOINTS>

                   <WA>

                   [other optional objects...]
```

If the WA object is present in the request, it MUST be encoded after the ENDPOINTS object. Orderings with respect to the other following objects are irrelevant.

The format of the Wavelength Assignment (WA) object body is as follows:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Reserved             |           Flags             |M|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Wavelength Selection TLV                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             Wavelength Restriction Constraint TLV             |
.                                                               .
.                                                               .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
   //                      Optional TLVs                          //
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3 WA Object

o Reserved (16 bits)

o Flags (16 bits)

The following new flags SHOULD be set

. M (Mode - 1 bit): M bit is used to indicate the mode of wavelength assignment. When M bit is set to 1, this indicates that the label assigned by the PCE must be explicit. That is, the selected way to convey the allocated wavelength is by means of Explicit Label Control (ELC) [RFC3471] for each hop of a computed LSP. Otherwise, the label assigned by the PCE needs not be explicit (i.e., it can be suggested in the form of label set objects in the corresponding response, to allow distributed WA. In such case, the PCE MUST return a Label Set Field as described in Section 2.6 of [RFC7579] in the response. See Section 5 of this document for the encoding discussion of a Label Set Field in a PCRep message.

4.2. Wavelength Selection TLV

The Wavelength Selection TLV is used to indicate the wavelength selection constraint in regard to the order of wavelength assignment to be returned by the PCE. This TLV is only applied when M bit is set in the WA Object specified in Section 4.1. This TLV MUST NOT be used when the M bit is cleared.

The encoding of this TLV is specified as the Wavelength Selection Sub-TLV in Section 4.2.2 of [RFC7689].

4.3. Wavelength Restriction Constraint TLV

For any request that contains a wavelength assignment, the requester (PCC) MUST be able to specify a restriction on the wavelengths to be used. This restriction is to be interpreted by the PCE as a constraint on the tuning ability of the origination laser transmitter or on any other maintenance related constraints. Note that if the LSP LSC spans different segments, the PCE MUST have mechanisms to know the tunability restrictions of the involved wavelength converters / regenerators, e.g. by means of the TED either via IGP or NMS. Even if the PCE knows the tunability of the transmitter, the PCC MUST be able to apply additional constraints to the request.

The format of the Wavelength Restriction Constraint TLV is as follows:

```
<Wavelength Restriction Constraint> ::=

               <Action> <Count> <Reserved>

               (<Link Identifiers> <Wavelength Restriction>)...
```

Where

```
<Link Identifiers> ::= <Link Identifier> [<Link Identifiers>]
```

See Section 4.3.1. for the encoding of the Link Identifiers Field.

The Wavelength Restriction Constraint TLV type is TBD, recommended value is TBD. This TLV MAY appear more than once to be able to specify multiple restrictions.

The TLV data is defined as follows:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Action        |    Count      |          Reserved             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Link Identifiers                          |
|                          . . .                                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Wavelength Restriction Field                   |
//                        . . . .                              //
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4 Wavelength Restriction Constraint TLV Encoding

- Action: 8 bits

  - 0 - Inclusive List indicates that one or more link identifiers are included in the Link Set. Each identifies a separate link that is part of the set.

  - 1 - Inclusive Range indicates that the Link Set defines a range of links. It contains two link identifiers. The first identifier indicates the start of the range (inclusive). The second identifier indicates the end of the range (inclusive). All links with numeric values between the bounds are considered to be part of the set. A value of zero in either position indicates that there is no bound on the corresponding portion of the range.

Note that "interfaces" such as those discussed in the Interfaces MIB [RFC2863] are assumed to be bidirectional.

- Count: The number of the link identifiers (8 bits)

Note that a PCC MAY add a Wavelength restriction that applies to all links by setting the Count field to zero and specifying just a set of wavelengths.

Note that all link identifiers in the same list must be of the same type.

- Reserved: Reserved for future use (16 bits)

- Link Identifiers: Identifies each link ID for which restriction is applied. The length is dependent on the link format and the Count field. See Section 4.3.1. for Link Identifier encoding and Section 4.3.2. for the Wavelength Restriction Field encoding, respectively.

4.3.1. Link Identifier Field

The link identifier field can be an IPv4, IPv6 or unnumbered interface ID.

<Link Identifier> ::=

<IPV4 Address> | <IPV6 Address> | <Unnumbered IF ID>

The encoding of each case is as follows:

IPv4 prefix Entry

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type = 1     |  Reserved                                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| IPv4 address (4 bytes)                                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

IPv6 prefix Sub-TLV

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type = 2     |  Reserved                                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| IPv6 address (16 bytes)                                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| IPv6 address (continued)                                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| IPv6 address (continued)                                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| IPv6 address (continued)                                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Unnumbered Interface ID Sub-TLV

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type = 3     |    Reserved                                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        TE Node ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
   |                        Interface ID                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

4.3.2. Wavelength Restriction Field

The Wavelength Restriction Field of the wavelength restriction TLV is encoded as a Label Set field as specified in Section 2.6 in [RFC7579] with base label encoded as a 32 bit LSC label, defined in [RFC6205]. See [RFC6205] for a description of Grid, C.S, Identifier and n, as well as [RFC7579] for the details of each action.

```
  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

  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  | Action|    Num Labels         |          Length               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |Grid | C.S   |    Identifier   |              n                |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |     Additional fields as necessary per action                 |
  |                                                               |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Action:

0 - Inclusive List

1 - Exclusive List

2 - Inclusive Range

3 - Exclusive Range

4 - Bitmap Set

Num Labels is generally the number of labels. It has a specific meaning depending on the action value. Num Labels is a 12 bit integer.

Length is the length in bytes of the entire label set field.

See Sections 2.6.1 - 2.6.3 of [RFC7579] for details on additional field discussion for each action.

4.4. Signal processing capability restrictions

Path computation for WSON includes the check of signal processing capabilities, those capability MAY be provided by the IGP. Moreover, a PCC should be able to indicate additional restrictions for those signal compatibility, either on the endpoint or any given link.

The supported signal processing capabilities are the one described in [RFC7446]:

- Optical Interface Class List
- Bit Rate
- Client Signal

The Bit Rate restriction is already expressed in [PCEP-GMPLS] in the BANDWIDTH object.

In order to support the Optical Interface Class information and the Client Signal information new TLVs are introduced as endpoint-restriction in the END-POINTS type Generalized endpoint:

- Client Signal TLV
- Optical Interface Class List TLV

The END-POINTS type generalized endpoint is extended as follows:

<endpoint-restrictions> ::= <LABEL-REQUEST>

<Wavelength Restriction Constraint>

[<signal-compatibility-restriction>...]

Where

signal-compatibility-restriction ::=

<Optical Interface Class List> <Client Signal>

The encoding for the Optical Interface Class List is described in Section 4.1 of [RFC7581].

The encoding for the Client Signal Information is described in Section 4.2 of [RFC7581].

4.4.1. Signal Processing Exclusion XRO Sub-Object

The PCC/PCE should be able to exclude particular types of signal processing along the path in order to handle client restriction or multi-domain path computation.

In order to support the exclusion a new XRO sub-object is defined: the signal processing exclusion:

```
    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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|X|  Type = X    |     Length    |   Reserved    | Attribute     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 sub-sub objects                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5 Signaling Processing XRO Sub-Object

Refer to [RFC5521] for the definition of X, Type, Length and Attribute.

The Attribute field indicates how the exclusion sub-object is to be interpreted. The Attribute can only be 0 (Interface) or 1 (Node).

The sub-sub objects are encoded as in RSVP signaling definition [RFC7689].

4.4.2. IRO sub-object: signal processing inclusion

Similar to the XRO sub-object the PCC/PCE should be able to include particular types of signal processing along the path in order to handle client restriction or multi-domain path computation.

This is supported by adding the sub-object "processing" defined for ERO in [RFC7689] to the PCEP IRO object.

5. Encoding of a RWA Path Reply

This section provides the encoding of a RWA Path Reply for wavelength allocation request as discussed in Section 4. Recall that wavelength allocation can be performed by the PCE by different means:

(a) By means of Explicit Label Control (ELC) where the PCE allocates which label to use for each interface/node along the path.

(b) By means of a Label Set where the PCE provides a range of potential labels to allocate by each node along the path.

Option (b) allows distributed label allocation (performed during signaling) to complete wavelength allocation.

The Wavelength Allocation TLV type is TBD, recommended value is TBD. The TLV data is defined as follows:

```
 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
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |              Type             |        Length             |M|
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Link Identifier                           |
 |                          . . .                                |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                    Allocated Wavelength(s)                    |
 //                        . . . .                              //
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6 Wavelength Allocation TLV Encoding

o Type (16 bits): The type of the TLV.

o Length (15 bits): The length of the TLV including the Type and Length fields.

o M (Mode): 1 bit

- 0 indicates the allocation is under Explicit Label Control.

- 1 indicates the allocation is expressed in Label Sets.

Note that all link identifiers in the same list must be of the same type.

o Link Identifier (variable): Identifies the interface to which assignment wavelength(s) is applied. See Section 4.3.1. for Link Identifier encoding.

o Allocated Wavelength(s) (variable): Indicates the allocated wavelength(s) to the link identifier. See Section 4.3.2 for encoding details.

This TLV is encoded as an attributes TLV, per [RFC5420], which is carried in the ERO LSP Attribute Subobjects per [RFC7570]. The type value of the Wavelength Restriction Constraint TLV is TBD by IANA.

5.1. Error Indicator

To indicate errors associated with the RWA request, a new Error Type (TDB) and subsequent error-values are defined as follows for inclusion in the PCEP-ERROR Object:

A new Error-Type (TDB) and subsequent error-values are defined as follows:

. Error-Type=TBD; Error-value=1: if a PCE receives a RWA request and the PCE is not capable of processing the request due to insufficient memory, the PCE MUST send a PCErr message with a PCEP-ERROR Object (Error-Type=TDB) and an Error-value(Error-value=1). The PCE stops processing the request. The corresponding RWA request MUST be cancelled at the PCC.

. Error-Type=TBD; Error-value=2: if a PCE receives a RWA request and the PCE is not capable of RWA computation, the PCE MUST send a PCErr message with a PCEP-ERROR Object (Error-Type=TDB) and an Error-value (Error-value=2). The PCE stops processing the request. The corresponding RWA computation MUST be cancelled at the PCC.

5.2. NO-PATH Indicator

To communicate the reason(s) for not being able to find RWA for the path request, the NO-PATH object can be used in the corresponding response. The format of the NO-PATH object body is defined in [RFC5440]. The object may contain a NO-PATH-VECTOR TLV to provide additional information about why a path computation has failed.

One new bit flag is defined to be carried in the Flags field in the NO-PATH-VECTOR TLV carried in the NO-PATH Object.

- Bit TDB: When set, the PCE indicates no feasible route was found that meets all the constraints (e.g., wavelength restriction, signal compatibility, etc.) associated with RWA.

6. Manageability Considerations

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

6.1. 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:

- The ability to send a WSON 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:

- The support for WSON RWA.

- A set of WSON 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.

6.2. Information and Data Models, e.g. MIB module

Extensions to the PCEP MIB module defined in [RFC7420] should be defined, so as to cover the WSON RWA information introduced in this document. A future revision of this document will list the information that should be added to the MIB module.

6.3. 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].

6.4. 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]

6.5. Requirements on Other Protocols and Functional Components

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

6.6. 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].

7. Security Considerations

This document has no requirement for a change to the security models within 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.

8. IANA Considerations

IANA maintains a registry of PCEP parameters. IANA has made allocations from the sub-registries as described in the following sections.

8.1. New PCEP Object

As described in Section 4.1, a new PCEP Object is defined to carry wavelength assignment related constraints. IANA is to allocate the following from "PCEP Objects" sub-registry (http://www.iana.org/assignments/pcep/pcep.xhtml#pcep-objects):

Object Class Value	Name	Object Type	Reference
TDB	WA	1: Wavelength-Assignment	[This.I-D]

8.2. New PCEP TLV: Wavelength Selection TLV

As described in Sections 4.2, a new PCEP TLV is defined to indicate wavelength selection constraints. IANA is to allocate this new TLV from the "PCEP TLV Type Indicators" subregistry (http://www.iana.org/assignments/pcep/pcep.xhtml#pcep-tlv-type-indicators).

Value	Description	Reference
TBD	Wavelength Selection	[This.I-D]

8.3. New PCEP TLV: Wavelength Restriction Constraint TLV

As described in Sections 4.3, a new PCEP TLV is defined to indicate wavelength restriction constraints. IANA is to allocate this new TLV from the "PCEP TLV Type Indicators" subregistry (http://www.iana.org/assignments/pcep/pcep.xhtml#pcep-tlv-type-indicators).

Value	Description	Reference
TBD	Wavelength Restriction Constraint	[This.I-D]

8.4. New PCEP TLV: Wavelength Allocation TLV

As described in Section 5, a new PCEP TLV is defined to indicate the allocation of wavelength(s) by the PCE in response to a request by the PCC. IANA is to allocate this new TLV from the "PCEP TLV Type Indicators" subregistry (http://www.iana.org/assignments/pcep/pcep.xhtml#pcep-tlv-type-indicators).

Value	Description	Reference
TBD	Wavelength Allocation	[This.I-D]

8.5. New PCEP TLV: Optical Interface Class List TLV

As described in Section 4.3, a new PCEP TLV is defined to indicate the optical interface class list. IANA is to allocate this new TLV from the "PCEP TLV Type Indicators" subregistry (http://www.iana.org/assignments/pcep/pcep.xhtml#pcep-tlv-type-indicators).

Value	Description	Reference
TBD	Optical Interface Class List	[This.I-D]

8.6. New PCEP TLV: Client Signal TLV

As described in Section 4.3, a new PCEP TLV is defined to indicate the client signal information. IANA is to allocate this new TLV from the "PCEP TLV Type Indicators" subregistry (http://www.iana.org/assignments/pcep/pcep.xhtml#pcep-tlv-type-indicators).

Value	Description	Reference
TBD	Client Signal Information	[This.I-D]

8.7. New No-Path Reasons

As described in Section 5.2., a new bit flag are defined to be carried in the Flags field in the NO-PATH-VECTOR TLV carried in the NO-PATH Object. This flag, when set, indicates that no feasible route was found that meets all the RWA constraints (e.g., wavelength restriction, signal compatibility, etc.) associated with a RWA path computation request.

IANA is to allocate this new bit flag from the "PCEP NO-PATH-VECTOR TLV Flag Field" subregistry (http://www.iana.org/assignments/pcep/pcep.xhtml#no-path-vector-tlv).

Bit	Description	Reference
TBD	No RWA constraints met	[This.I-D]

8.8. New Error-Types and Error-Values

As described in Section 5.1, new PCEP error codes are defined for WSON RWA errors. IANA is to allocate from the ""PCEP-ERROR Object Error Types and Values" sub-registry (http://www.iana.org/assignments/pcep/pcep.xhtml#pcep-error-object).

Error-Type	Meaning	Error-Value	Reference

TDB	WSON RWA Error	1: Insufficient Memory	[This.I-D]
		2: RWA computation Not supported	{This.I-D]

9. Acknowledgments

The authors would like to thank Adrian Farrel for many helpful comments that greatly improved the contents of this draft.

This document was prepared using 2-Word-v2.0.template.dot.

10. References

10.1. Informative References

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