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PCEP Procedures and Extension for VLAN-based Traffic Forwarding
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Abstract

This document defines the Path Computation Element Communication Protocol (PCEP) extension for VLAN-based traffic forwarding in native IP network and describes the essential elements and key processes of the data packet forwarding system based on VLAN info to accomplish the End to End (E2E) traffic assurance for VLAN-based traffic forwarding in native IP network.

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1. Introduction

[RFC8283] introduces the architecture for the PCE as a central controller as an extension to the architecture described in [RFC4655]. Based on such mechanism, the PCE can calculate the optimal path for vairous applications and send the intructions to the network equipment via PCEP protocol, thus control the packet forwarding and achive the QoS assurance effects for priority traffic.

[RFC8735] describes the scenarios of QoS assurance for hybrid cloud-based application within one domain and traffic engineering in multi-

domain. It proposes also the consideration for the potential solution, that is:

1. Should be applied both in native IPv4 and IPv6 environment.

2. Should be same procedures for the intra-domain and itner-domain scenario.

3. Should utilize the existing forwarding capabiliites of the deployed network devices.

With the large scale deployment of Ethernet interfaces in operator network and PCECC architecture, it is possilbe to utilize the VLAN information within the ethernet header to build one end-to-end dedicated path to guide the forwarding of the packet. Similar with the PCECC for LSP [RFC9050], this document defines a Path Computation Element Communication Protocol (PCEP) Extension for VLAN-based traffic forwarding by using the VLAN info contained in the Ethernet frame in native IP network and the mechanism is actually the PCECC for VSP(VLAN Switching Path). It is an end to end traffic guarantee mechanism based on the PCEP protocol in the native IP environment, which can ensure the connection-oriented network communication. It can simplifiy the calculation and forwarding process of the optimal path by blending it with elements of PCEP and without necessarily completely replacing it.

Compared with other traffic assurance technologies such as mpls or srv6 which is supported only in IPv6 environment, and has the obvious packet overhead problems, the VLAN-based traffic forwarding (VTF) mechanism uses a completely new address space which will not conflict with other existing protocols and can easily avoid these problems and be deployed in IPv4 and IPv6 environment simultaneously. It is suitable for ipv4 and ipv6 networks and can leverage the existing PCE technologies as much as possible.

2. Conventions used in this document

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. Terminology

The following terms are defined in this draft:

- PCC: Path Computation Client

- PCE: Path Computation Element

- PCEP: PCE Communication Protocol
- PCECC: PCE-based Central Controller
- LSP: Lable Switching Path
- PST: Path Setup Type

4. Procedures for VLAN-based Traffic Forwarding

The target deployment environment of VLANbased traffic forwarding mechanism is for Native IP(IPv4 and IPv6). In such scenarios, the BGP is used for the prefix distribution among underlying devices(PCCs), no MPLS is involved. In order to set up the VLAN-based traffic forwarding paths for different applications in native IP network, multiple BGP sessions should be deployed between the ingress PCC and egress PCC at the edge of the network respectively. Based on the business requirements, the PCE calculates the explict route and sends the route information to the PCCs through PCInitiate messages. When received the PCInitiate message, the ingress PCC will form a VLAN-Forwarding routing table defined in this document. The packet to be guaranteed will be matched in the table and then be labeled with corresponding VLAN tag. The labeled packet will be further sent to the PCC's specific subinterface identified by the VLAN tag and then be forwarded. Similarly, the transit PCC and the egress PCC will form a VLAN-Crossing routing table after received the PCInitiate message. The packet to be guaranteed will be relabled with new VLAN tag and then be forwarded. The whole procedures mainly forcus on the end-to-end traffic for key application which can ensure the adequacy of VLAN number for this scenario. During the whole packet forwarding process, the packet can be encapsulated with reserved multicast MAC addresses(e.g. 0180:C200:0014 for ISIS levle1, 0180:C200:0015 for ISIS levle2) and don't need to change hop by hop so as to accept by each PCC.

5. Capability Advertisement

During the PCEP Initialization Phase, PCEP Speakers (PCE or PCC) advertise their support of VLAN-based trafficforwarding extensions. This document defines a new Path Setup Type (PST)[RFC8408] for PCECC, as follows:

- PST=TBD1: Path is a VLAN-based traffic forwarding type.

A PCEP speaker MUST indicate its support of the function described in this document by sending a PATH-SETUP-TYPE-CAPABILITY TLV in the OPEN object with this new PST included in the PST list.

Because the path is set up through PCE, a PCEP speaker must advertise the PCECC capability by using PCECC-CAPABILITY sub-TLV which is used to exchange information about their PCECC capability as per PCEP extensions defined in [I-D.ietf-pce-pcep-extension-for-pce-controller]

A new flag is defined in PCECC-CAPABILITY sub-TLV for VLAN-based traffic forwarding.

V (VLAN-based-forwarding-CAPABILITY - 1 bit - TBD2): If set to 1 by a PCEP speaker, it indicates that the PCEP speaker supports the capability of VLAN based traffic forwarding as specified in this document. The flag MUST be set by both the PCC and PCE in order to support this extension.

If a PCEP speaker receives the PATH-SETUP-TYPE-CAPABILITY TLV with the newly defined path setup type, but without the V bit set in PCECC-CAPABILITY sub-TLV, it MUST:

- Send a PCErr message with Error-Type=10(Reception of an invalid object) and Error-Value TBD3(PCECC VLAN-based-forwarding-CAPABILITY bit is not set).

- Terminate the PCEP session

6. PCEP message

As per [RFC8281] ,the PCInitiate message sent by a PCE was defined to trigger LSP instantiation or deletion with the SRP and LSP object included during the PCEP initialization phase. The Path Computation LSP State Report message (PCRpt message) was defined in [RFC8231], which is used to report the current state of a LSP. A PCC can send a LSP State Report message in response to a LSP instantiation. Besides, the message can either in response to a LSP Update Request from a PCE or asynchronously when the state of a LSP changes .

[I-D.ietf-pce-pcep-extension-for-pce-controller] defines an object called Central Controller Instructions (CCI) to specify the forwarding instructions to the PCC. During the coding process used for central controller instructions, the object contains the label information and is carried within PCInitiate or PCRpt message for label download .

This document specify two new CCI object-types for VLAN-based traffic forwarding in the native IP network and are said to be mandatory in a PCEP message when the object must be included for the message to be considered valid. In addition, this document enxtends the PCEP

message to handle the VLAN-based traffic forwarding path in the native IP network with the new CCI object.

6.1. The PCInitiate message

The PCInitiate message[RFC8281] extended in[I-D.ietf-pce-pcep-extension-for-pce-controller] can be used to download or remove labels by using the CCI Object.

Based on the extended PCInitiate message and PCRpt described in [I-D.ietf-pce-pcep-extension-native-ip], the (BGP Peer Info (BPI) Object and the Peer Prefix Association (PPA) Object is used to establish multi BGP sessions and advertise route prefixes among different BGP sessions before setting up a VLAN-based traffic forwarding path.

This document extends the PCInitiate message as shown below:

```
  <PCInitiate Message> ::= <Common Header>
                              <PCE-initiated-lsp-list>
     Where:
        <Common Header> is defined in [RFC5440]

        <PCE-initiated-lsp-list> ::= <PCE-initiated-lsp-request>
                                     [<PCE-initiated-lsp-list>]

        <PCE-initiated-lsp-request> ::=
                             (<PCE-initiated-lsp-instantiation>|
                              <PCE-initiated-lsp-deletion>|
                              <PCE-initiated-lsp-central-control>)

        <PCE-initiated-lsp-central-control> ::= <SRP>
                                                <LSP>
                                                <cci-list>|
                                                ((<BPI>|<PPA>)
                                                <new-CCI>)

        <cci-list> ::=  <new-CCI>
                        [<cci-list>]
```

Where:

<cci-list> is as per [I-D.ietf-pce-pcep-extension-for-pce-controller].
<PCE-initiated-lsp-instantiation> and
<PCE-initiated-lsp-deletion> are as per [RFC8281].
<BPI> and <PPA> are as per
[draft-ietf-pce-pcep-extension-native-ip-09]

When PCInitiate message is used to create VLAN-based forwarding instructions, the SRP, LSP and CCI objects MUST be present. The error handling for missing SRP, LSP or CCI object is as per [I-D.ietf-pce-pcep-extension-for-pce-controller]. Further only one of BPI, PPA or one type of CCI objects MUST be present. If none of them are present, the receiving PCE MUST send a PCErr message with Error- type=6 (Mandatory Object missing) and Error-value=TBD4 (VLAN-based forwarding object missing). If there are more than one of BPI, PPA or one type of CCI objects are presented, the receiving PCC MUST send a PCErr message with Error-type=19(Invalid Operation) and Error-value=TBD5(Only one of BPI, PPA or one type of the CCI objects for VLAN can be included in this message).

6.2. The PCRpt message

The PCRpt message is used to report the state and confirm the VLAN info that were allocated by the PCE, to be used during the state synchronization phase or as acknowledgemnt to PCInitiate message.

The format of the PCRpt message is as follows:

```
 <PCRpt Message> ::= <Common Header>
                           <state-report-list>
      Where:

         <state-report-list> ::= <state-report>[<state-report-list>]

         <state-report> ::= (<lsp-state-report>|
                           <central-control-report>)

         <lsp-state-report> ::= [<SRP>]
                              <LSP>
                              <path>

         <central-control-report> ::= [<SRP>]
                                      <LSP>
                                      <cci-list>|
                                      ((<BPI>|<PPA>)
                                      (<new-CCI>)


        Where:
          <path> is as per [RFC8231] and the LSP and SRP object are
          also defined in [RFC8231].
          <BPI> and <PPA> are as per
          [draft-ietf-pce-pcep-extension-native-ip-09]
```

The error handling for missing LSP or CCI object is as per [I-D.ietf-pce-pcep-extension-for-pce-controller]. Further only one of BPI, PPA or one type of CCI objects MUST be present. If none of them are present, the receiving PCE MUST send a PCErr message with Error- type=6 (Mandatory Object missing) and Error-value=TBD4 (VLAN-based forwarding object missing). If there are more than one of BPI, PPA or one type of CCI objects are presented, the receiving PCC MUST send a PCErr message with Error-type=19(Invalid Operation) and Error-value=TBD5(Only one of BPI, PPA or one type of the CCI objects for VLAN can be included in this message).

7. VSP Operations

Based on [RFC8281] and [RFC9050], in order to set up a PCE-initiated VSP based on the PCECC mechanism, a PCE needs to send a PCInitiate message with the PST set to TBD1 in SRP for the PCECC to the ingress PCC.

The VLAN-forwarding instructions from the PCECC needs to be sent after the initial PCInitiate and PCRpt message exchange with the ingress PCC and the PCE needs to send a PCInitiate message to each node along the path to download the VLAN instructions. The new CCI for the VLAN operations in PCEP are done via the PCInitiate message by defining a new PCEP object for CCI operations. The LSP and the LSP-IDENTIFIERS TLV are described for the RSVP-signaled LSPs but are applicable to the PCECC VSP as well. So the LSP is included in the PCInitiate message can still be used to identify the PCECC VSP for this instruction and the process is the same.

On receipt of a PCInitiate message for the PCECC VSP, the PCC responds with a PCRpt message with the status set to 'Going-up', carrying the assigned PLSP-ID and set the D(Delegate) flag and C(Create) flag(see Figure 1). When the PCE receives this PCRpt message with the PLSP-ID, it assigns VLAN along the path and sets up the path by sending a PCInitiate message to each node along the path of the VSP, as per the PCECC technique. The ingress PCC would receive one VLAN forwarding CCI Object which contains VLAN on the logical subinterface and the Peer IP address.The transit PCC would receive two VLAN crossing CCI Objects with the O bit set for the out-VLAN on the egress subinterface and the O bit unset for the in-VLAN on the ingress subinterface. Similar with the transit PCC, the egress PCC would receive two VLAN crossing CCI Objects but the out-VLAN on the egress subinterface is set to 0. Once the VLAN operations are completed, the PCE MUST send a PCUpd message to the ingress PCC.

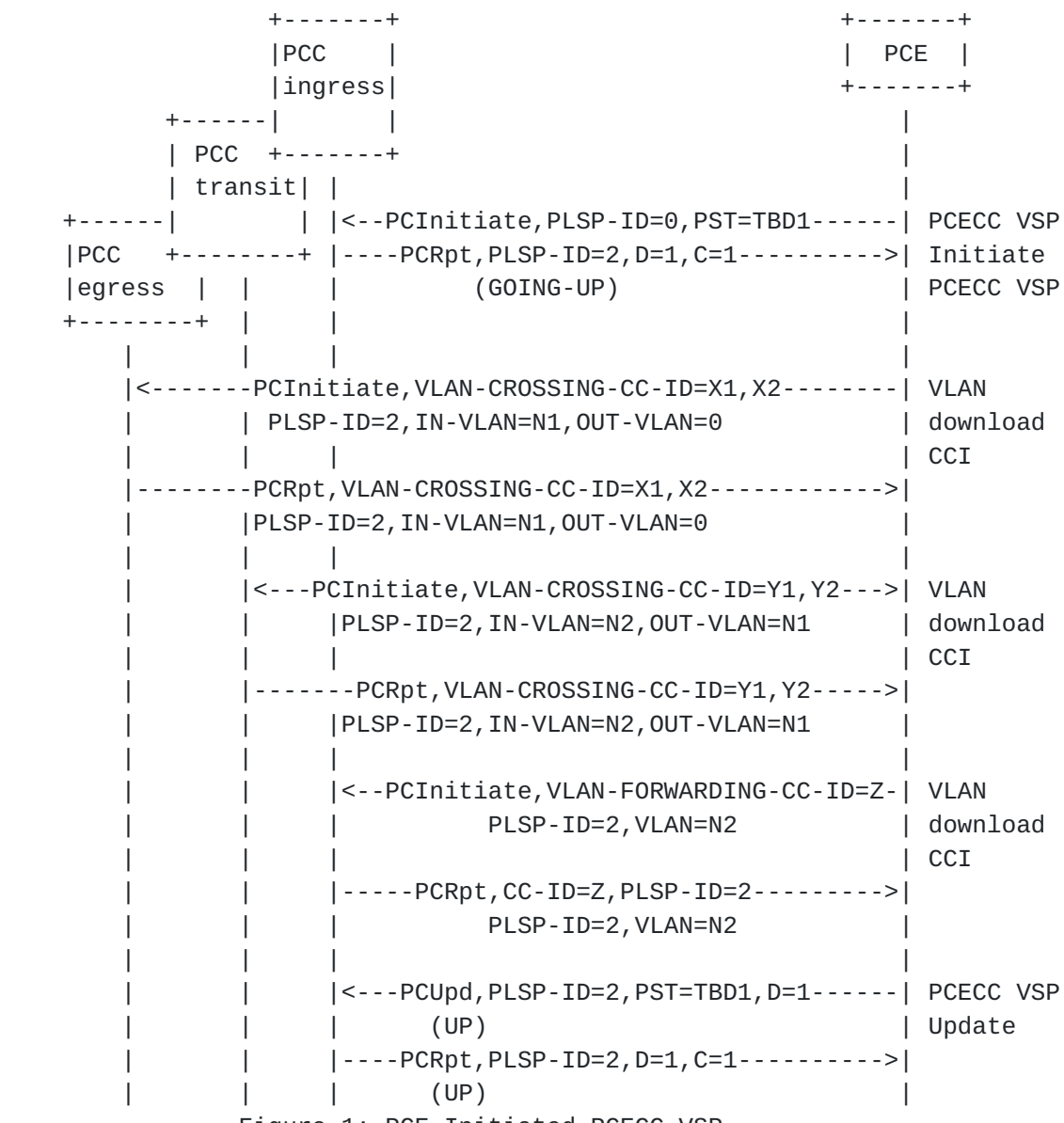
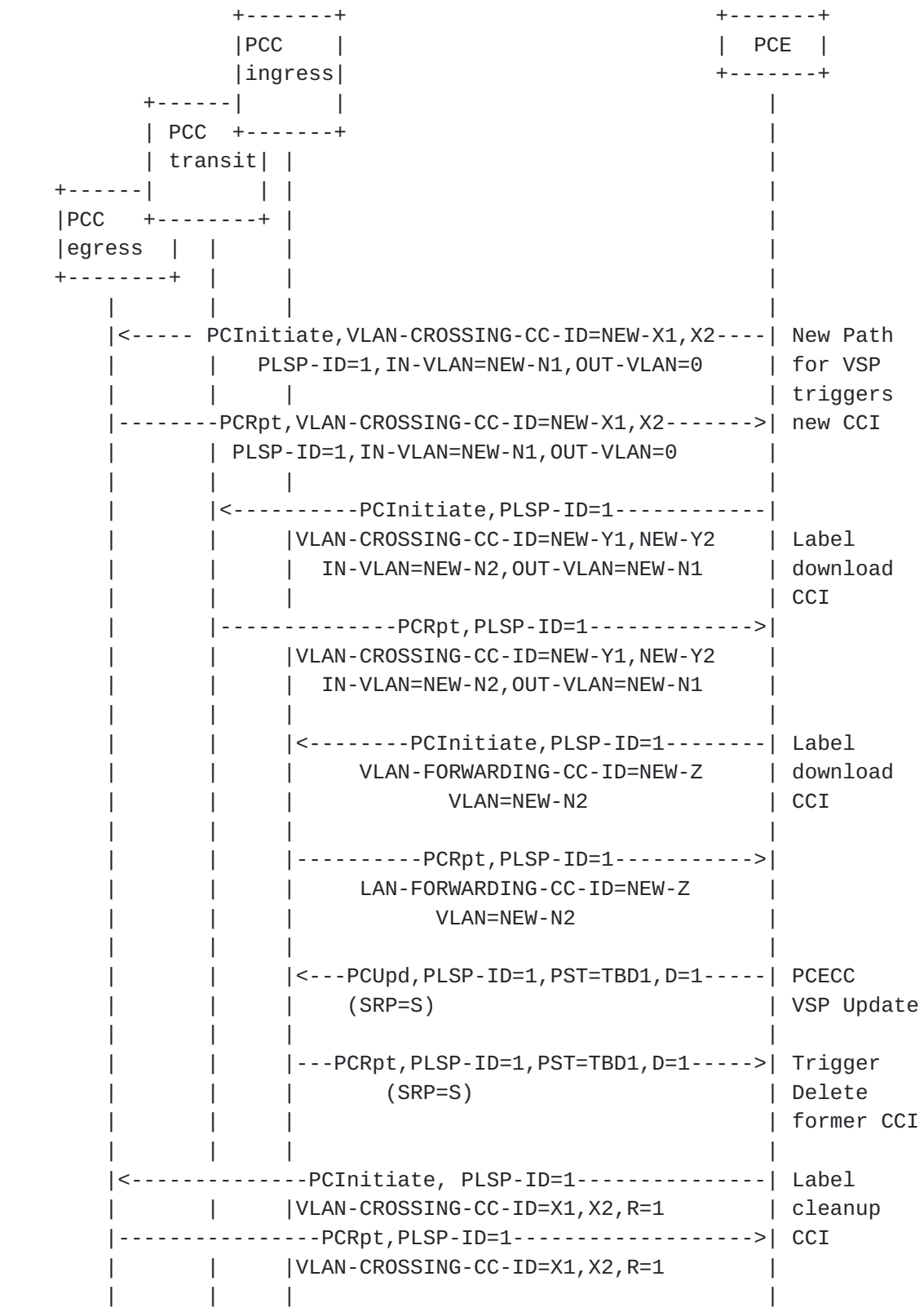


Figure 1: PCE-Initiated PCECC VSP

In order to delete an LSP based on the PCECC, the PCE sends Central Controller Instructions and SRP object with the R bit set to 1 via a PCInitiate message to each node along the path of the VSP to clean up the label-forwarding instruction.

As per [RFC9050], the PCECC VSP also follows the same make-before-break principles. As shown in the figure 2, new path for VSP triggers the new CCI Distribution process. The PCECC first updates the new VLAN instructions and informs each node along the new path through the new VLAN crossing CCI Objects and VLAN forwarding CCI Objects to download the new VSP. The PCUpd message then triggers the traffic switch on the updated path. On receipt of the PCRpt message corresponding to the PCUpd message, the PCE does the cleanup

operation for the former VSP,which is the same as the LSP update process.



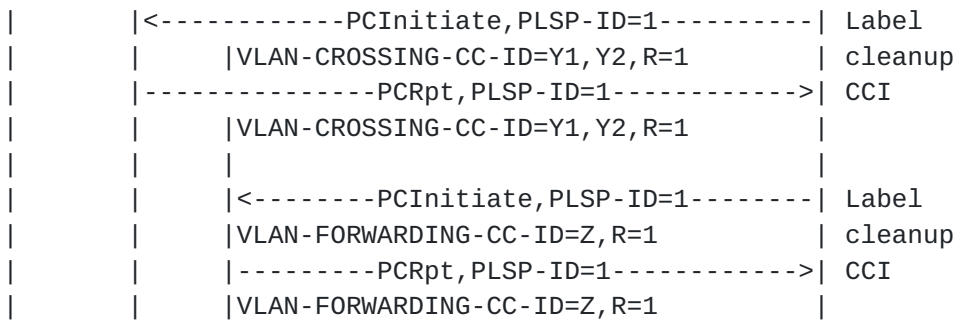


Figure 2: PCECC VSP Update

8. VXLAN-based traffic forwarding Procedures

8.1. Multiple BGP Session Establishment Procedures

As described in section 4, multiple BGP sessions should be deployed between the ingress device and egress device at the edge of the network respectively in order to carry informations of different applications. As per [I-D.ietf-pce-pcep-extension-native-ip], the PCE should send the BPI((BGP Peer Info) Object to the ingress and egress device with the indicated Peer AS and Local/Peer IP address. The Ingress and egress devices will receive multiple BPI objects to establish sessions with different next hop. The specific process is as follows:

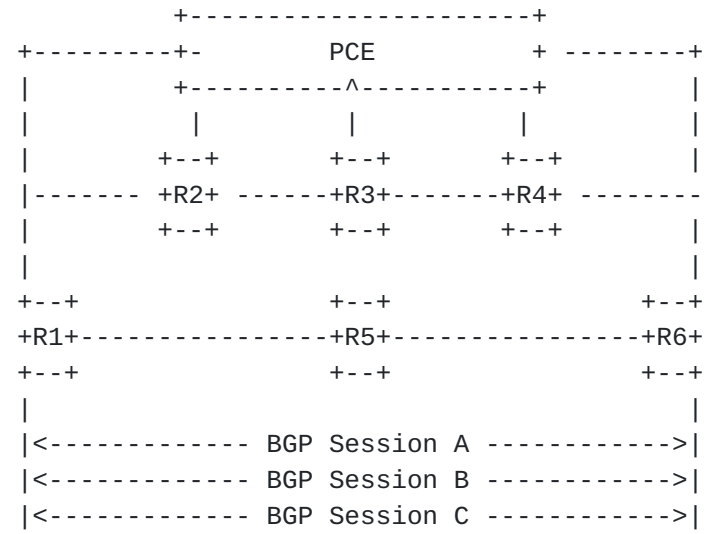


Figure 3: BGP Session Establishment Procedures

8.2. BGP Prefix Advertisement Procedures

The detail procedures for BGP prefix advertisement procedures is introduced in [I-D.ietf-pce-pcep-extension-native-ip], using PCInitiate and PCRpt message pair.

The BGP prefix for different BGP sessions should be sent to the ingress and egress device respectively. The end-to-end traffic for key application can be identified based on these BGP prefix informations and be further assured. As per [I-D.ietf-pce-pcep-extension-native-ip], the PPA(Peer Prefix Association) object with list of prefix subobjects and the peer address will be sent through the PCInitiate and PCRpt message pair.Through BGP protocol, the ingress device can learn different BGP prefix of the egress device based on the different BGP sessions.

8.3. VLAN mapping info Advertisement Procedures

After the BGP prefix for different BGP session are successfully advertised, informations of different applications should be forwarded to different VLAN-based traffic forwarding paths. In order to set up a VLAN-based traffic forwarding path, the PCE should send the VLAN forwarding CCI Object with the VLAN-ID included to the ingress PCC and the VLAN crossing CCI Object to the transit PCC and egrss PCC.

8.3.1. VLAN-Based forwarding info Advertisement Procedures

The detail procedures for VLAN-Based forwarding info advertisement contained in the VLAN forwarding CCI Object is shown below, using PCInitiate and PCRpt message pair.

The VLAN forwarding CCI Object should be sent through the PCInitiate and PCRpt message pair. After the PCC receives the CCI object (with the R bit set to 0 in SRP object) in PCInitiate message, the PCC will form a VLAN-Forwarding routing table and the PCC's subinterface will set up the specific vlan based on the VLAN forwarding CCI object, source and destination BGP prefix learnt before. When the ingress PCC receives a packet, it will look up the VLAN-Forwarding routing table based on the source and destination IP contained in the packet. The packet to be guaranteed will be matched in the table and then be labeled with corresponding VLAN tag. After that, The labeled packet will be further forwarded to the specific subinterface.

When PCC receives the VLAN forwarding CCI Object with the R bit set to 1 in SRP object in PCInitiate message, the PCC should withdraw the VLAN-Based forwarding info advertisement to the peer that indicated by this object.

On receipt of a PCInitiate message for the PCECC VSP, the PCC should report the result via the PCRpt messages, with the corresponding SRP and CCI object included.

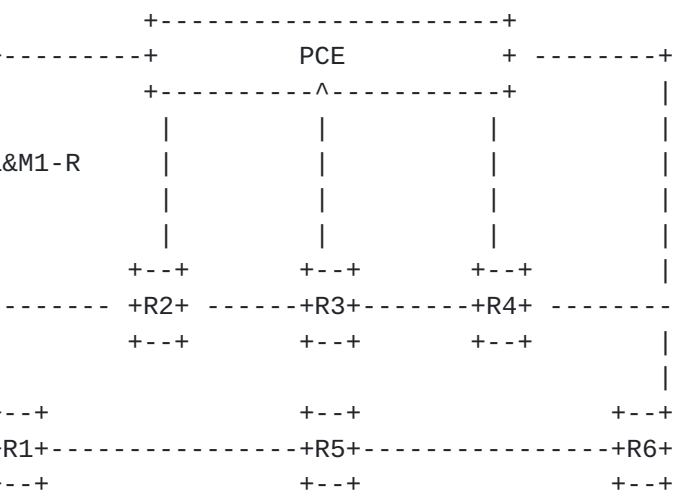


Figure 4: VLAN-Based forwarding info Advertisement Procedures for Ingress PCC

The message number, message peers, message type and message key parameters in the above figures are shown in below table:

Table 1: Message Information

No.	Peers	Type	Message Key Parameters
M1 M1-R	PCE/R1	PCInitiate PCRpt	CC-ID=X1(Symbolic Path Name=Class A) VLAN Forwarding CCI Object (Peer_IP=R6_A,Interface_Address=INF1, VLAN_ID=VLAN_R1_R2)

VLAN-Forwarding routing table maintained in the ingress PCC is as follows, which is used to match the packet to be guaranteed based on the source and destination BGP prefix.

Table 2: VLAN-Forwarding routing table

Dst Peer Prefix	Interface	VLAN
R6	INF 1	VLAN_R1_R2
RX	INF X	N
	...	

8.3.2. VLAN-Based crossing info Advertisement Procedures

The detail procedures for VLAN-Based crossing info advertisement contained in the VLAN crossing CCI Object is shown below, using PCInitiate and PCRpt message pair.

The PCC would receive VLAN crossing CCI Objects with the in-VLAN CCI without the O bit set and the out-VLAN CCI with the O bit set. After the process of VLAN-Based forwarding info advertisement mentioned above, the PCC will form a VLAN-crossing routing table and the PCC's subinterface will set up the specific vlan based on the VLAN crossing CCI Object(with the R bit set to 0 in SRP object) contained in the PCInitiate message. The VLAN-crossing routing table consists of an in-VLAN tag and an out-VLAN tag which specifies a new VLAN forwarding path. When the transit PCC receives a data packet that has been labeled with VLAN by ingress PCC before, it will look up the VLAN-Crossing routing table based on the VLAN tag. If matched, the in-VLAN tag of this data packet will be replaced by a new out-VLAN tag of the current transit PCC according to the table.The packet with the new VLAN tag will be further forwarded to the next hop.

For the egress PCC, the out-VLAN tag in the VLAN-crossing routing table should be 0 which indicates it is the last hop of the transmission. So the egress PCC will directly remove the in-VLAN tag of the packet and the packet will be forwarded.

When PCC receives the VLAN crossing CCI Object with the R bit set to 1 in SRP object in PCInitiate message, the PCC should withdraw the VLAN-Based crossing info advertisement to the peer that indicated by this object.

On receipt of a PCInitiate message for the PCECC VSP, the PCC should report the result via the PCRpt messages, with the corresponding SRP and CCI object included.

When the out-VLAN tag conflicts with a pre-defined VLAN tag or the PCC can not set up a VLAN forwarding path with the out-VLAN tag, an error (Error-type=TBD6, VLAN-based forwarding failure, Error-value=TBD7, VLAN crossing CCI Object peer info mismatch) should be reported via the PCRpt message.

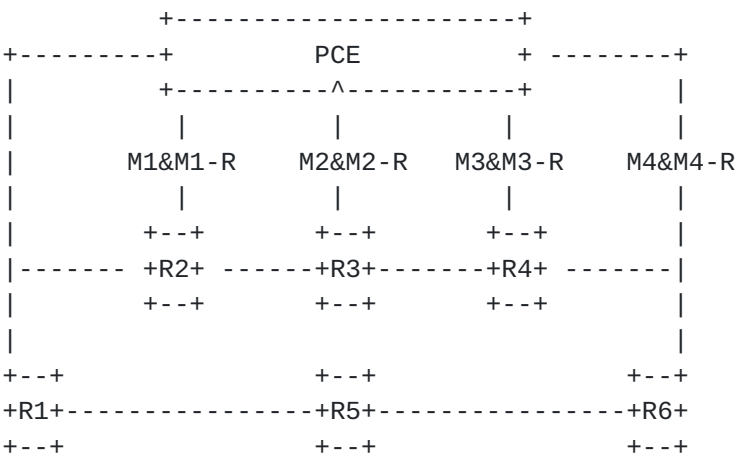


Figure 5: VLAN-Based crossing info Advertisement Procedures for transit PCC and egress PCC

The message number, message peers, message type and message key parameters in the above figures are shown in below table:

Table 3: Message Information

No.	Peers	Type	Message Key Parameters
M1	PCE/R2	PCInitiate	CC-ID=X1(Symbolic Path Name=Class A)
M1-R		PCRpt	VLAN crossing CCI Object(IN)
			(O=0,Interface_Address=INF1,IN_VLAN_ID=VLAN_R1_R2)
			VLAN crossing CCI Object(OUT)
			(O=1,Interface_Address=INF2,OUT_VLAN_ID=VLAN_R2_R3)
M2	PCE/R3	PCInitiate	CC-ID=X1(Symbolic Path Name=Class A)
M2-R		PCRpt	VLAN crossing CCI Object(IN)
			(O=0,Interface_Address=INF1,IN_VLAN_ID=VLAN_R2_R3)
			VLAN crossing CCI Object(OUT)
			(O=1,Interface_Address=INF2,OUT_VLAN_ID=VLAN_R3_R4)
M3	PCE/R4	PCInitiate	CC-ID=X1(Symbolic Path Name=Class A)
M3-R		PCRpt	VLAN crossing CCI Object(IN)
			(O=0,Interface_Address=INF1,IN_VLAN_ID=VLAN_R3_R4)
			VLAN crossing CCI Object(OUT)
			(O=1,Interface_Address=INF2,OUT_VLAN_ID=VLAN_R4_R6)
M4	PCE/R6	PCInitiate	CC-ID=X1(Symbolic Path Name=Class A)
M4-R		PCRpt	VLAN crossing CCI Object(IN)
			(O=0,Interface_Address=INF1,IN_VLAN_ID=VLAN_R4_R6)
			VLAN crossing CCI Object(OUT)
			(O=1,Interface_Address=INF2,OUT_VLAN_ID=0)

VLAN-Crossing routing table maintained in the transit PCC and egress PCC is as follows. Through the mapping of the in-VLAN and the out VLAN, the data packet to be guaranteed will be transfered to the specific interface and be switched on the out VLAN for the transit PCC or 0 for the egress PCC.

Table 4: VLAN-Crossing routing table

IN-Interface	IN-VLAN	OUT-Interface	OUT-VLAN
INF1	VLAN_R1_R2	INF2	VLAN_R2_R3
INF3	X	INF4	Y
INF5	Z	INF6	0
...			

9. New PCEP Objects

The Central Control Instructions (CCI) Object is used by the PCE to specify the forwarding instructions is defined in [I-D.ietf-pce-pcep-extension-for-pce-controller]. This document defines another two CCI object-types for VLAN-based traffic forwarding network. All new PCEP objects are compliant with the PCEP object format defined in [RFC5440].

9.1. VLAN forwarding CCI Object

The VLAN forwarding CCI Object is used to set up the specific vlan forwarding path of the logical subinterface that the traffic will be forwarded to and transfer the packet to the specific hop. Combined with this type of CCI Object and the Peer Prefix Association object(PPA) defined in [I-D.ietf-pce-pcep-extension-native-ip], the ingress PCC will form a VLAN-Forwarding routing table which is used to identify the traffic that needs to be protected. This object should only be included and sent to the ingress PCC of the end2end path.

CCI Object-Class is 44.

CCI Object-Type is TBD8 for VLAN forwarding info in the native IP network.

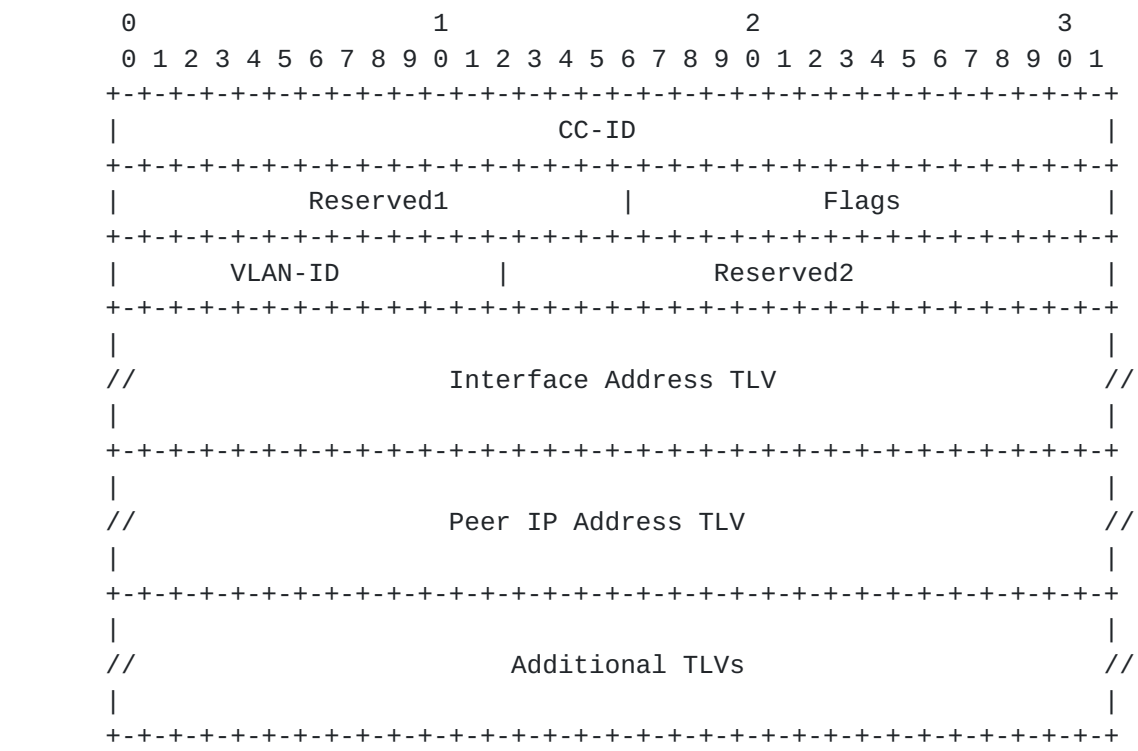


Figure 6: VLAN Forwarding CCI Object

The fields in the CCI object are as follows:

CC-ID: is as described in [I-D.ietf-pce-pcep-extension-for-pce-controller]. Following fields are defined for CCI Object-Type TBD8.

Reserved1(16 bits): is set to zero while sending, ignored on receipt.

Flags(16 bits): is used to carry any additional information pertaining to the CCI. Currently no flag bits are defined.

VLAN ID(12 bits):the ID of the VLAN forwarding path that the PCC will set up on its logical subinterface in order to transfer the packet to the specific hop.

Reserved2(20 bits): is set to zero while sending, ignored on receipt.

Interface Address TLV [RFC8779] MUST be included in this CCI Object-Type TBD8 to specify the interface which will set up the vlan defined in the VLAN Forwarding CCI Object.

The Peer IP Address TLV[RFC8779]MUST be included in this CCI Object-Type TBD8 to identify the end to end TE path in VLAN-based traffic forwarding network and MUST be unique.

9.2. Address TLVs

[RFC8779] defines IPV4-ADDRESS, IPV6-ADDRESS, and UNNUMBERED-ENDPOINT TLVs for the use of Generalized Endpoint. The same TLVs can also be used in the CCI object to find the Peer address that matches egress PCC and further identify the packet to be guaranteed. If the PCC is not able to resolve the peer information or can not find the corresponding ingress device, it MUST reject the CCI and respond with a PCErr message with Error-Type = TBD6 ("VLAN-based forwarding failure") and Error Value = TBD9 ("Invalid egress PCC information").

9.3. VLAN crossing CCI Object

The VLAN crossing CCI object is defined to control the transmission-path of the packet by VLAN-ID.This new type of CCI Object can be carried within a PCInitiate message sent by the PCE to the transit PCC and the egress PCC in the VLAN-based traffic forwarding scenarios.

CCI Object-Class is 44.

CCI Object-Type is TBD10 for VLAN crossing info in the native IP network.

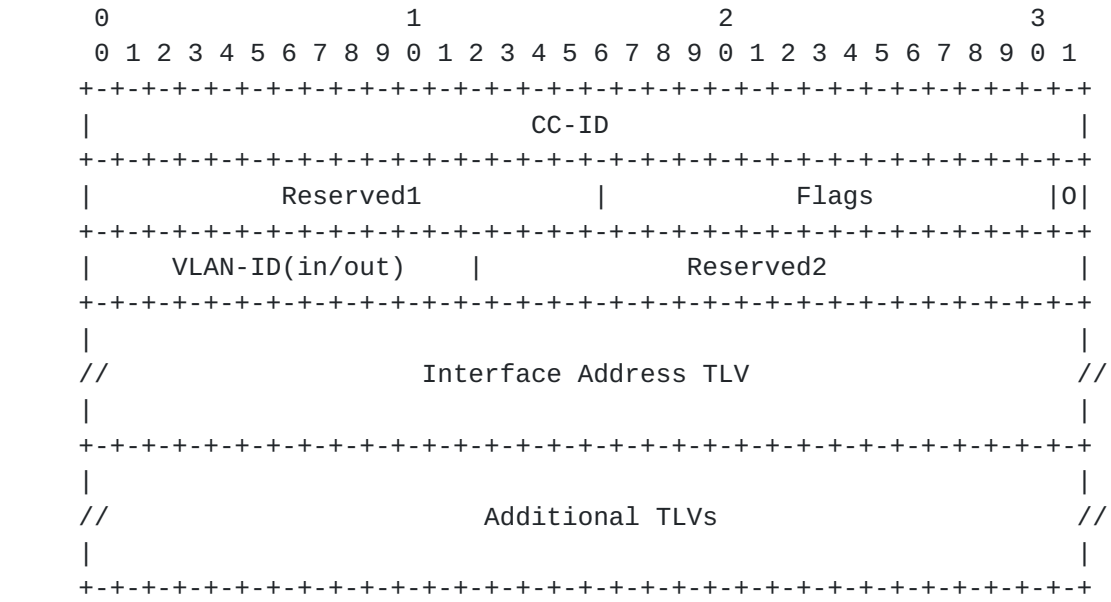


Figure 7: VLAN Crossing CCI Object

CC-ID: is as described in [I-D.ietf-pce-pcep-extension-for-pce-controller]. Following fields are defined for CCI Object-Type TBD10.

Reserved1(16 bits): is set to zero while sending, ignored on receipt.

Flags(16 bits): is used to carry any additional information pertaining to the CCI.Currently, the following flag bit are defined:

* O bit (out-label) : If the bit is set to '1', it specifies the VLAN is the out-VLAN, and it is mandatory to encode the egress interface information(via Interface Address TLVs in the CCI object). If the bit is not set or set to '0', it specifies the VLAN is the in-VLAN, and it is mandatory to encode the ingress interface information.

VLAN ID(12 bits): The ID of the VLAN switching path. When the O bit is set to 0, the VLAN is the in-VLAN and the ID indicates a VLAN forwarding path which is used to identify the traffic that needs to be protected. When the O bit is set to 1, the VLAN is the out-VLAN and it indicates the ID of the VLAN forwarding path that the PCC will set up on its logical subinterface in order to transfer the packet labeld with this VLAN ID to the specific hop.To the transit PCC, the value must not be 0 to indicate it is not the last hop of the VLAN-based traffic forwarding path. To the egress PCC, the value must be 0 to indicate it is the last hop of the VLAN-based traffic forwarding path.

Reserved2(8 bits): is set to zero while sending, ignored on receipt.

Interface Address TLV [RFC8779] MUST be included in this CCI Object-Type TBD8 to specify the interface which will set up the vlan defined in the VLAN Forwarding CCI Object.

10. Deployment Considerations

11. Security Considerations

12. IANA Considerations

12.1. Path Setup Type Registry

[RFC8408] created a sub-registry within the "Path Computation Element Protocol (PCEP) Numbers" registry called "PCEP Path Setup Types". IANA is requested to allocate a new code point within this registry, as follows:

Value	Description	Reference
TBD1	VLAN-Based Traffic Forwarding Path	This document

12.2. PCECC-CAPABILITY sub-TLV's Flag field

[I-D.ietf-pce-pcep-extension-for-pce-controller] created a sub-registry within the "Path Computation Element Protocol (PCEP) Numbers" registry to manage the value of the PCECC-CAPABILITY sub-TLV's 32-bits Flag field. IANA is requested to allocate a new bit position within this registry, as follows:

Value	Description	Reference
TBD2(V)	VLAN-Based Forwarding CAPABILITY	This document

12.3. PCEP Object Types

IANA is requested to allocate new registry for the PCEP Object Type:

Object-Class Value	Name	Reference
44	**CCI Object-Type** TBD8: VLAN forwarding CCI TBD10: VLAN crossing CCI	This document

12.4. PCEP-Error Object

IANA is requested to allocate new error types and error values within the "PCEP-ERROR Object Error Types and Values" sub-registry of the PCEP Numbers registry for the following errors:

Error-Type	Meaning	Error-value	Reference
6	**Mandatory Object missing**	TBD4:VLAN-based forwarding object missing	This document
10	**Reception of an** invalid object	TBD3:PCECC VLAN-based-forwarding -CAPABILITY bit is not set	This document
19	**Invalid Operation**	TBD5: Only one of BPI, PPA or one type of the CCI objects for VLAN can be included in this message	This document
TBD6	VLAN-based forwarding failure	TBD7: VLAN crossing CCI Object peer info mismatch	This document
		TBD9: Invalid egress PCC information	This document

13. Acknowledgement

14. Normative References

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