Functional validation of the cooperation between Virtual Network Topology Manager and Path Computation Element

O. Gonzalez de Dios, M. Cuaresma, S. Martinez, F. Muñoz, V. Lopez, J.P. Fernández-Palacios

Telefónica I+D, Spain

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01

Motivation and Introduction

Motivation

- Current core networks are based on several layers.
- Mid-term scenario: IP/MPLS network over reconfigurable wavelength switched optical network (WSON).
- Two key elements to help in the management and coordination of such multi-layer architectures:
  - **Path Computation Element (PCE)**
  - **Virtual Network Topology Manager (VNTM).**
- PCE aim is to calculate the route between endpoints, especially in complex scenarios (e.g. WSON with physical impairments, multilayer or multidomain)
- VNTM is in charge of maintaining the topology of the upper layer by connections in the lower layer.

Introduction to the experiment

- This work shows an experimental validation of cooperation between a simple NMS, a multilayer PCE and a VNTM in an IP/MPLS over WSON scenario with commercial equipment.
- Testbed is composed by Juniper routers and ADVA optical nodes.
- Telefonica I+D has developed a prototype of both a multilayer PCE and a VNTM to demostrate the feasibility of the approach.

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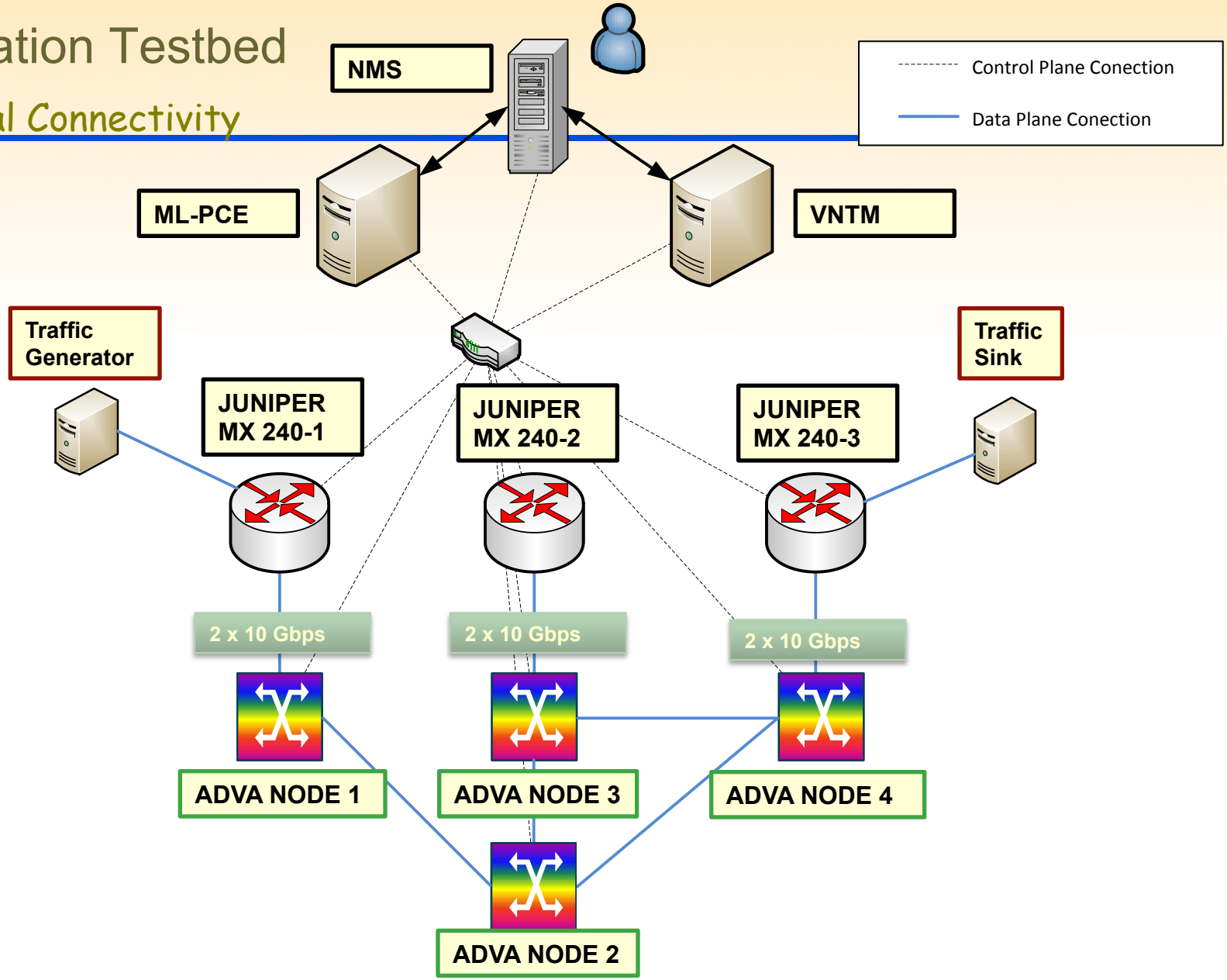
Scenario Description

Testbed

- 3 Juniper MX240 routers representing an IP/MPLS network
- 4 ADVA optical nodes with wavelength switching capabilities representing a photonic mesh
- Simple NMS to configure routers.
- Multilayer PCE:
  - MPLS & WSON topology
  - TE information
- VNTM
  - Interlayer TE Link information (not available in PCE)
  - Virtual topology.
  - No WSON information

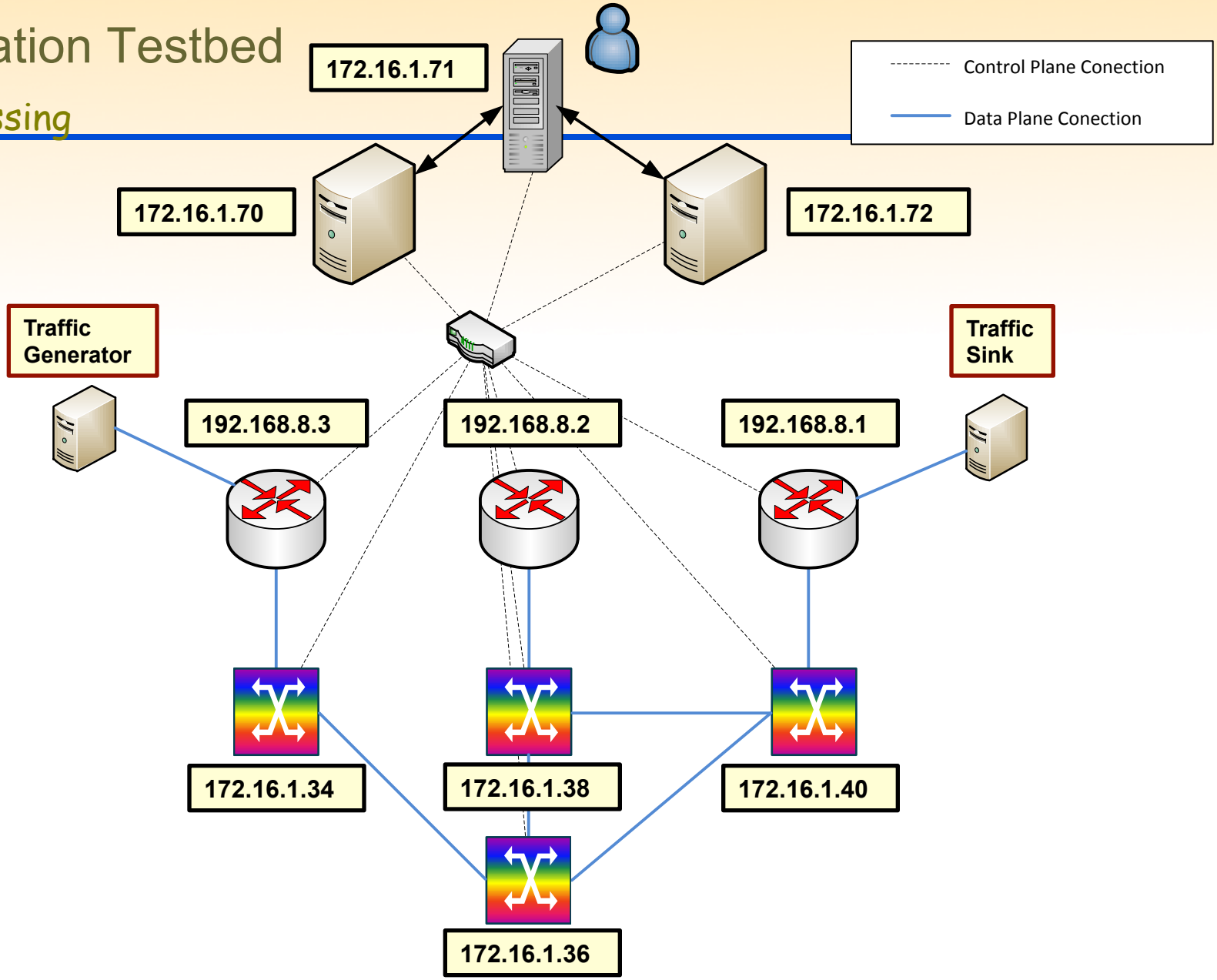
Validation Testbed

Physical Connectivity



Validation Testbed

Addressing

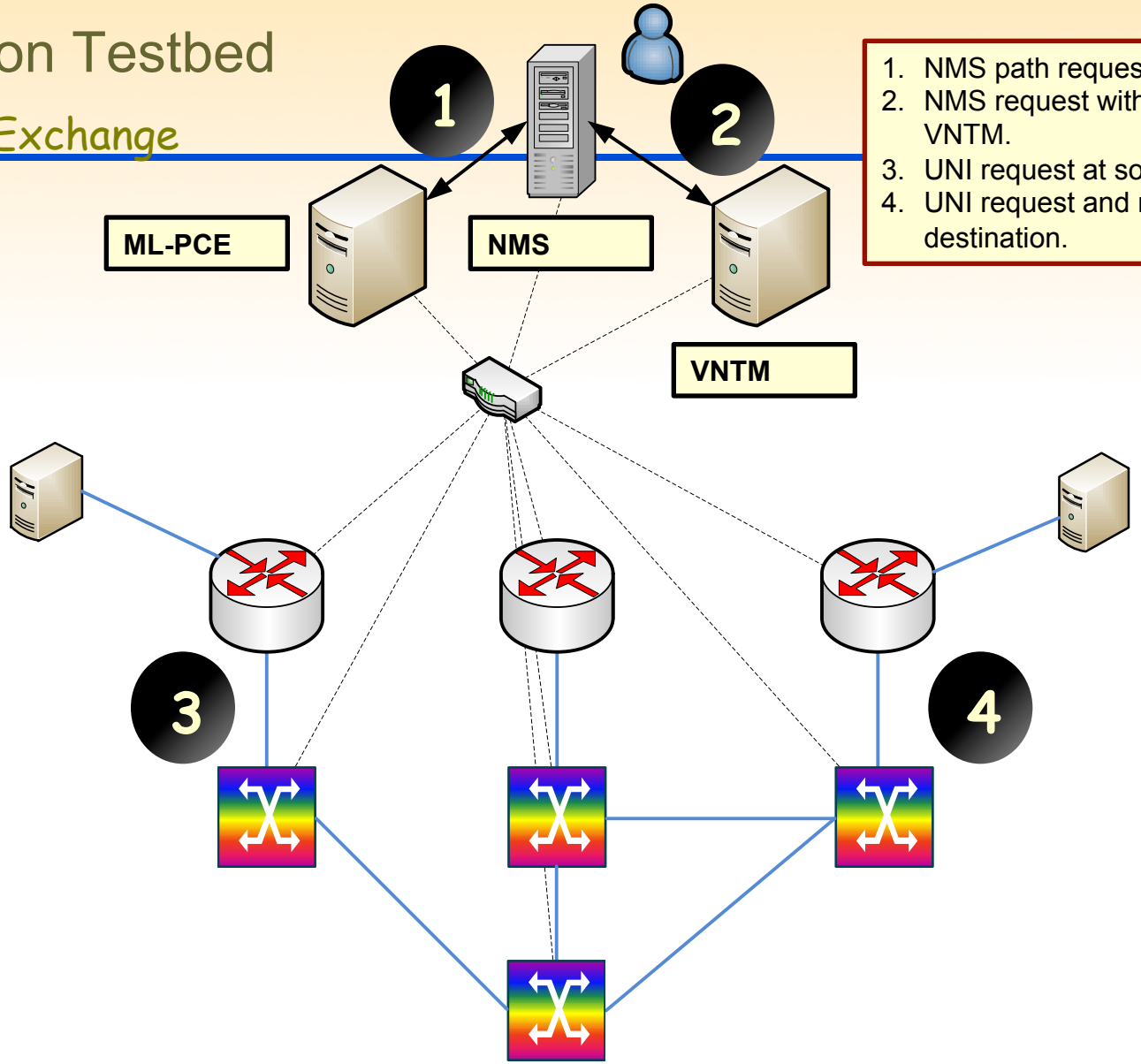


Experiment description

- The network operator wants bandwidth for a new service.
- The NMS queries the PCE for the PATH.
- Two cases:
  - A) Enough resources at MPLS layer: MPLS PATH in the response
  - B) No resources at MPLS layer: Multilayer PATH
- In case of a Multilayer PATH, the NMS sends the VNTM a TE_LINK_SUGGESTION message.
  - The NMS extracts the part of the new TE-Link from the response
- The VNTM checks the policies.
- The VNTM accepts the suggestion and configures the WSON layer LSP using the UNI of the routers.

Validation Testbed

Message Exchange



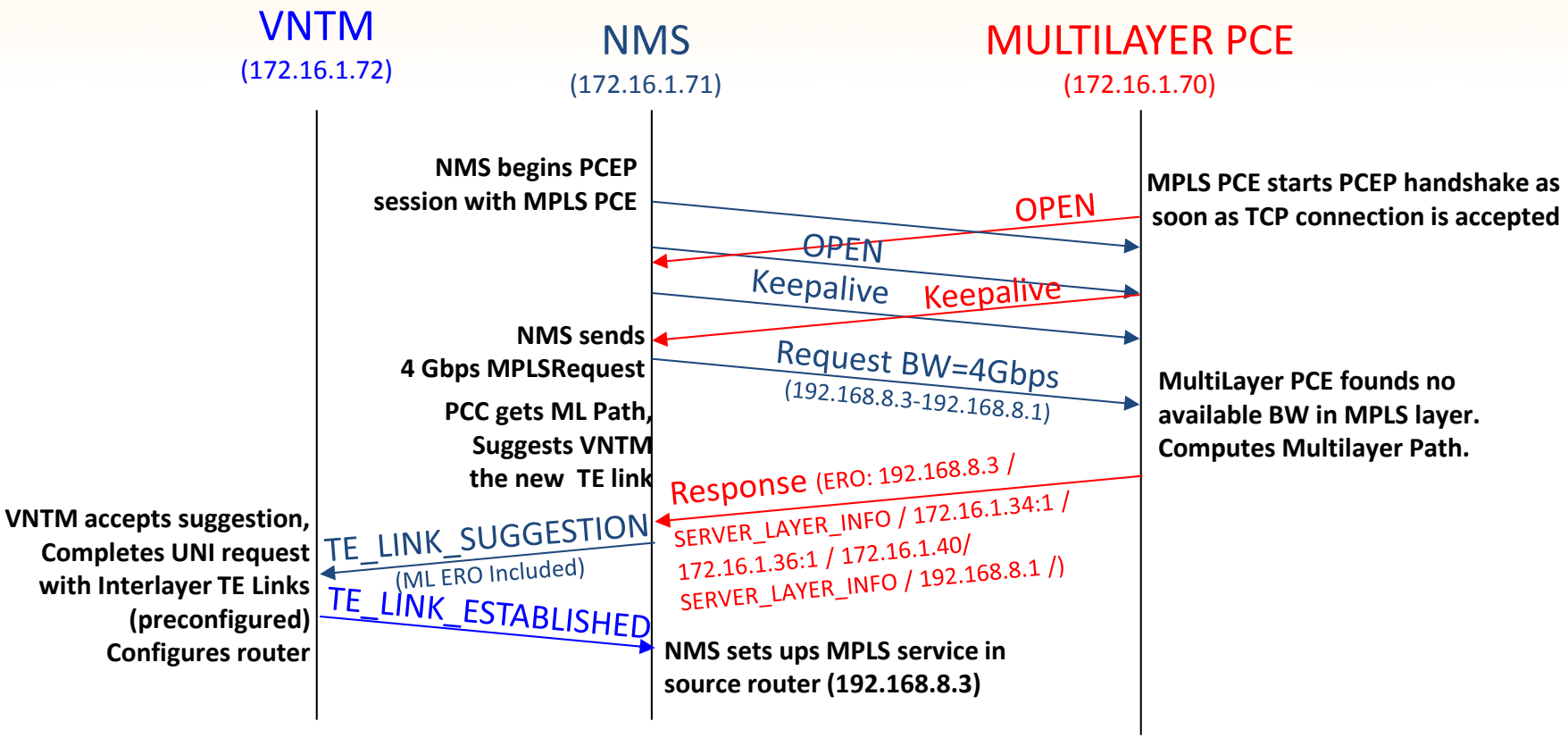
1. NMS path request to ML-PCE
2. NMS request with ML-path to VNTM.
3. UNI request at source
4. UNI request and response at destination.

03

Message Exchange

Message Exchange

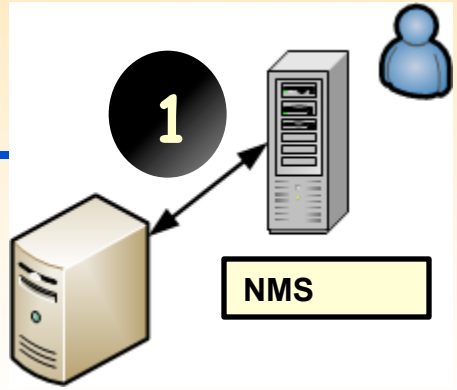
Diagram of the Message Exchange
Example shows the Multilayer Case



Message Exchange

Message Exchange 1: NMS path request to ML-PCE (MPLS resources available case)

TCP Handshake initiated
from NMS (172.16.1.71) to PCE (172.16.1.70)



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	172.16.1.71	172.16.1.70	TCP	74	35387 > pcep [SYN] Seq=0 Win=14600 L
2	0.000038	172.16.1.70	172.16.1.71	TCP	74	pcep > 35387 [SYN, ACK] Seq=0 Ack=1
3	0.005465	172.16.1.71	172.16.1.70	TCP	66	35387 > pcep [ACK] Seq=1 Ack=1 Win=1
4	0.024332	172.16.1.70	172.16.1.71	PCEP	78	OPEN MESSAGE
5	0.058848	172.16.1.71	172.16.1.70	PCEP	78	OPEN MESSAGE
6	0.059443	172.16.1.70	172.16.1.71	PCEP	70	KEEPALIVE MESSAGE
7	0.090251	172.16.1.71	172.16.1.70	PCEP	70	KEEPALIVE MESSAGE
8	3.551317	172.16.1.71	172.16.1.70	PCEP	110	PATH COMPUTATION REQUEST MESSAGE
9	3.611136	172.16.1.70	172.16.1.71	PCEP	110	PATH COMPUTATION REPLY MESSAGE
10	7.181019	172.16.1.71	172.16.1.70	PCEP	110	PATH COMPUTATION REQUEST MESSAGE
11	7.185432	172.16.1.70	172.16.1.71	PCEP	178	PATH COMPUTATION REPLY MESSAGE
12	30.109627	172.16.1.70	172.16.1.71	PCEP	70	KEEPALIVE MESSAGE
13	30.141399	172.16.1.71	172.16.1.70	PCEP	70	KEEPALIVE MESSAGE

First PCEP Request

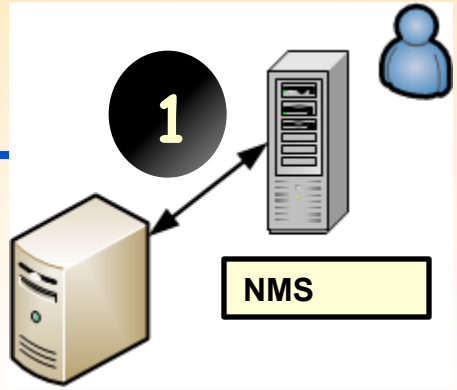
PCEP Handshake (OPEN + KA messages) between NMS (172.16.1.71) and PCE (172.16.1.70).

PCEP Messages are sent almost simultaneously

* CAPTURED AT PCE server (172.16.1.70)

Message Exchange

Message Exchange 1: Detailed PCEP Request (MPLS resources available case)




```
Path Computation Element communication Protocol
  PATH COMPUTATION REQUEST MESSAGE Header
  RP object
  END-POINT object
      Object Class: END-POINT OBJECT (4)
      Object Type: 1
    Flags
      Object Length: 12
      Source IPv4 Address: 192.168.8.3
      Destination IPv4 Address: 192.168.8.1
  BANDWIDTH object
      Object Class: BANDWIDTH OBJECT (5)
      Object Type: 1
    Flags
      Object Length: 8
      Bandwidth: 4,000000
  OBJECTIVE FUNCTION object
      Object Class: OBJECTIVE FUNCTION OBJECT (OF) (21)
      Object Type: 1
    Flags
      Object Length: 8
      OF-Code: Unknown (1100)
```

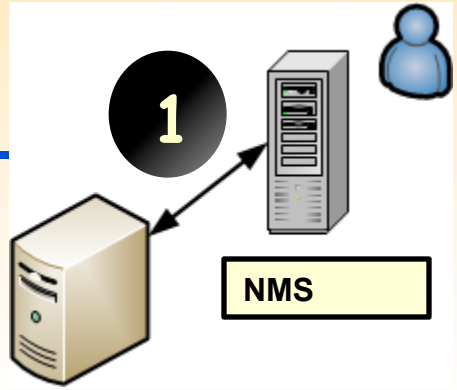
```
> pcep [SYN] Seq=0 Win=14600 L
 35387 [SYN, ACK] Seq=0 Ack=1
> pcep [ACK] Seq=1 Ack=1 Win=1
ESSAGE
ESSAGE
IVE MESSAGE
IVE MESSAGE
OMPUTATION REQUEST MESSAGE
OMPUTATION REPLY MESSAGE
OMPUTATION REQUEST MESSAGE
OMPUTATION REPLY MESSAGE
IVE MESSAGE
IVE MESSAGE
```

First PCEP Request

* CAPTURED AT PCE server (172.16.1.70)

Message Exchange

Message Exchange 1: Detailed PCEP Response (MPLS resources available case)




```
Path Computation Element communication Protocol
  PATH COMPUTATION REPLY MESSAGE Header
  RP object
  EXPLICIT ROUTE object (ERO)
    Object Class: EXPLICIT ROUTE OBJECT (ERO) (7)
    Object Type: 1
    Flags
    Object Length: 28
    SUBOBJECT: IPv4 Prefix: 192.168.8.3/0
    SUBOBJECT: IPv4 Prefix: 192.168.8.2/0
    SUBOBJECT: IPv4 Prefix: 192.168.8.1/32
```

List of router IDs

First PCEP Response: MPLS ONLY path, as resources are available at MPLS layer

					ngth	Info
					74	35387 > pcep [SYN] Seq=0 Win=14600 L
2	0.000038	172.16.1.70	172.16.1.71	TCP	74	pcep > 35387 [SYN, ACK] Seq=0 Ack=1
3	0.005465	172.16.1.71	172.16.1.70	TCP	66	35387 > pcep [ACK] Seq=1 Ack=1 Win=1
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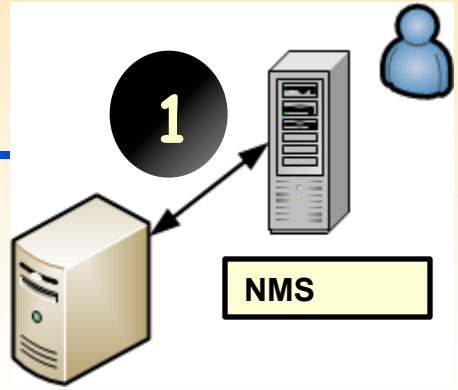
6	0.059443	172.16.1.70	172.16.1.71	PCEP	70	KEEPALIVE MESSAGE
7	0.090251	172.16.1.71	172.16.1.70	PCEP	70	KEEPALIVE MESSAGE
8	3.551317	172.16.1.71	172.16.1.70	PCEP	110	PATH COMPUTATION REQUEST MESSAGE
9	3.611136	172.16.1.70	172.16.1.71	PCEP	110	PATH COMPUTATION REPLY MESSAGE
10	7.181019	172.16.1.71	172.16.1.70	PCEP	110	PATH COMPUTATION REQUEST MESSAGE
11	7.185432	172.16.1.70	172.16.1.71	PCEP	178	PATH COMPUTATION REPLY MESSAGE
12	30.109627	172.16.1.70	172.16.1.71	PCEP	70	KEEPALIVE MESSAGE
13	30.141399	172.16.1.71	172.16.1.70	PCEP	70	KEEPALIVE MESSAGE

* CAPTURED AT PCE server (172.16.1.70)

Message Exchange

Message Exchange 1: Detailed PCEP Response




```
Path Computation Element communication Protocol
⊞ PATH COMPUTATION REQUEST MESSAGE Header
⊞ RP object
⊟ END-POINT object
    Object Class: END-POINT OBJECT (4)
    Object Type: 1
  ⊞ Flags
    Object Length: 12
    Source IPv4 Address: 192.168.8.3
    Destination IPv4 Address: 192.168.8.1
⊟ BANDWIDTH object
    Object Class: BANDWIDTH OBJECT (5)
    Object Type: 1
  ⊞ Flags
    Object Length: 8
    Bandwidth: 7,000000
⊟ OBJECTIVE FUNCTION object
    Object Class: OBJECTIVE FUNCTION OBJECT (OF) (21)
    Object Type: 1
  ⊞ Flags
    Object Length: 8
    OF-Code: Unknown (1100)
```

Second PCEP Request

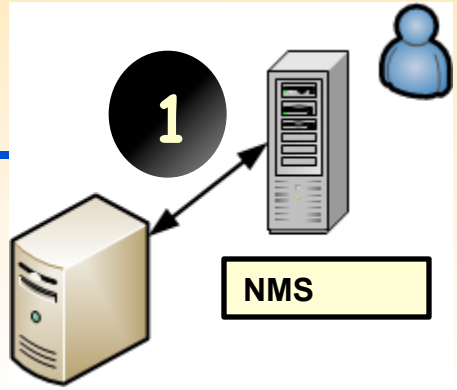
```
fo
5387 > pcep [SYN] Seq=0 Win=14600 L
cep > 35387 [SYN, ACK] Seq=0 Ack=1
5387 > pcep [ACK] Seq=1 Ack=1 Win=1
PEN MESSAGE
PEN MESSAGE
EEPALIVE MESSAGE
EEPALIVE MESSAGE
```

```
  8 3.551317 172.16.1.71   172.16.1.70   PCEP   110 PATH COMPUTATION REQUEST MESSAGE
  9 3.611136 172.16.1.70   172.16.1.71   PCEP   110 PATH COMPUTATION REPLY MESSAGE
 10 7.181019 172.16.1.71   172.16.1.70   PCEP   110 PATH COMPUTATION REQUEST MESSAGE
 11 7.185432 172.16.1.70   172.16.1.71   PCEP   178 PATH COMPUTATION REPLY MESSAGE
 12 30.109627172.16.1.70   172.16.1.71   PCEP    70 KEEPALIVE MESSAGE
 13 30.141399172.16.1.71   172.16.1.70   PCEP    70 KEEPALIVE MESSAGE
```

* CAPTURED AT PCE server (172.16.1.70)

Message Exchange

Message Exchange 2: Detailed PCEP Reply. (NO resources available at MPLS layer)




```
Path Computation Element communication Protocol
  PATH COMPUTATION REPLY MESSAGE Header
  RP object
  EXPLICIT ROUTE object (ERO)
    object Class: EXPLICIT ROUTE OBJECT (ERO) (7)
    object Type: 1
    Flags
    object Length: 96
    SUBOBJECT: IPv4 Prefix: 192.168.8.3/0
    SUBOBJECT: SERVER LAYER INFO: Switching cap Lambda Switch Capable (SC=150)
    SUBOBJECT: Unnumbered Interface ID: 172.16.1.34:0
    SUBOBJECT: Label Control
    SUBOBJECT: Unnumbered Interface ID: 172.16.1.36:0
    SUBOBJECT: Label Control
    SUBOBJECT: Unnumbered Interface ID: 172.16.1.40:0
    SUBOBJECT: Label Control
    SUBOBJECT: SERVER LAYER INFO: Switching cap Lambda Switch Capable (SC=150)
    SUBOBJECT: IPv4 Prefix: 192.168.8.1/32
      L=0 Strict Hop
      Type: SUBOBJECT IPv4 (1)
      Length: 8
      IPv4 Address: 192.168.8.1
      Prefix Length: 32
      Padding: 0x00
```

MPLS node

LAYER CHANGE

WSON PATH

LAYER CHANGE

MPLS node

Multilayer ERO from draft-ietf-pce-inter-layer-ext-05
Extensions to the Path Computation Element communication Protocol (PCEP) for Inter-Layer MPLS and GMPLS Traffic Engineering

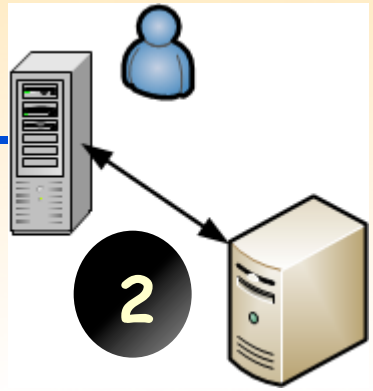
```
10 7.181019 172.16.1.71    172.16.1.70    PCEP
11 7.185432 172.16.1.70    172.16.1.71    PCEP     178 PATH COMPUTATION REPLY MESSAGE
12 30.109627172.16.1.70    172.16.1.71    PCEP      70 KEEPALIVE MESSAGE
13 30.141399172.16.1.71    172.16.1.70    PCEP      70 KEEPALIVE MESSAGE
```

* CAPTURED AT PCE server (172.16.1.70)

Second PCEP Response: Multilayer ERO Included!

Message Exchange

Message Exchange 2: TE-Link suggestion



TE LINK SUGGESTION WITH MULTILAYER ERO

```
97 13.336064 172.16.1.71    172.16.1.72    PCEP     150 TE LINK SUGGESTION MESSAGE
00 19.376315 172.16.1.72    172.16.1.71    PCEP      70 TE LINK CONFIRMATION MESSAGE
```

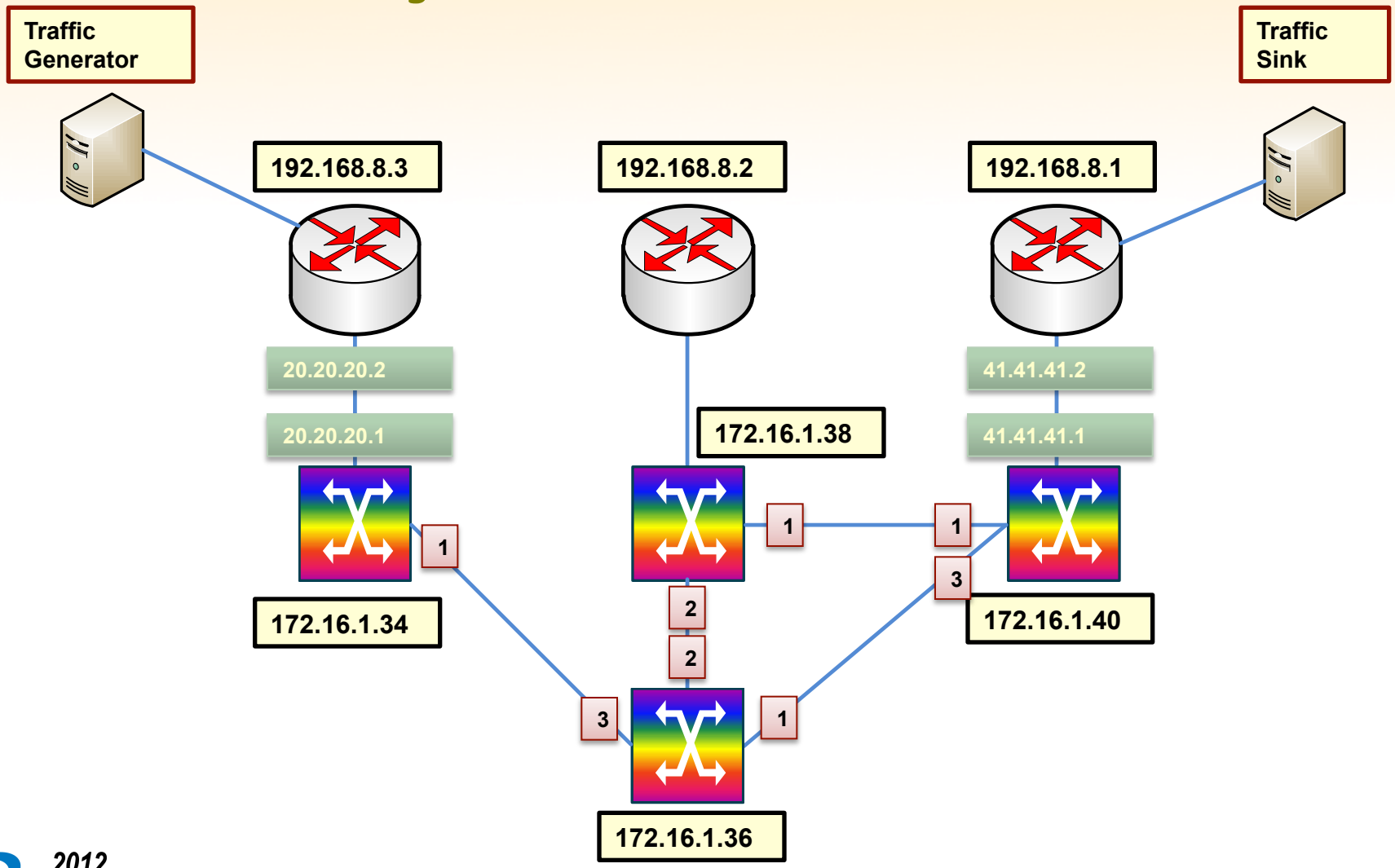
TE LINK CREATION CONFIRMATION

Two new messages proposed for the communication between to a VNTM:
→ TE LINK SUGGESTION: Includes a PATH formed by the two MPLS endpoints and the lower layer Path
→ TE LINK CONFIRMATION: Acknowledges the acceptance of a new TE-LINK suggestion

* CAPTURED AT VNTM (172.16.1.72)

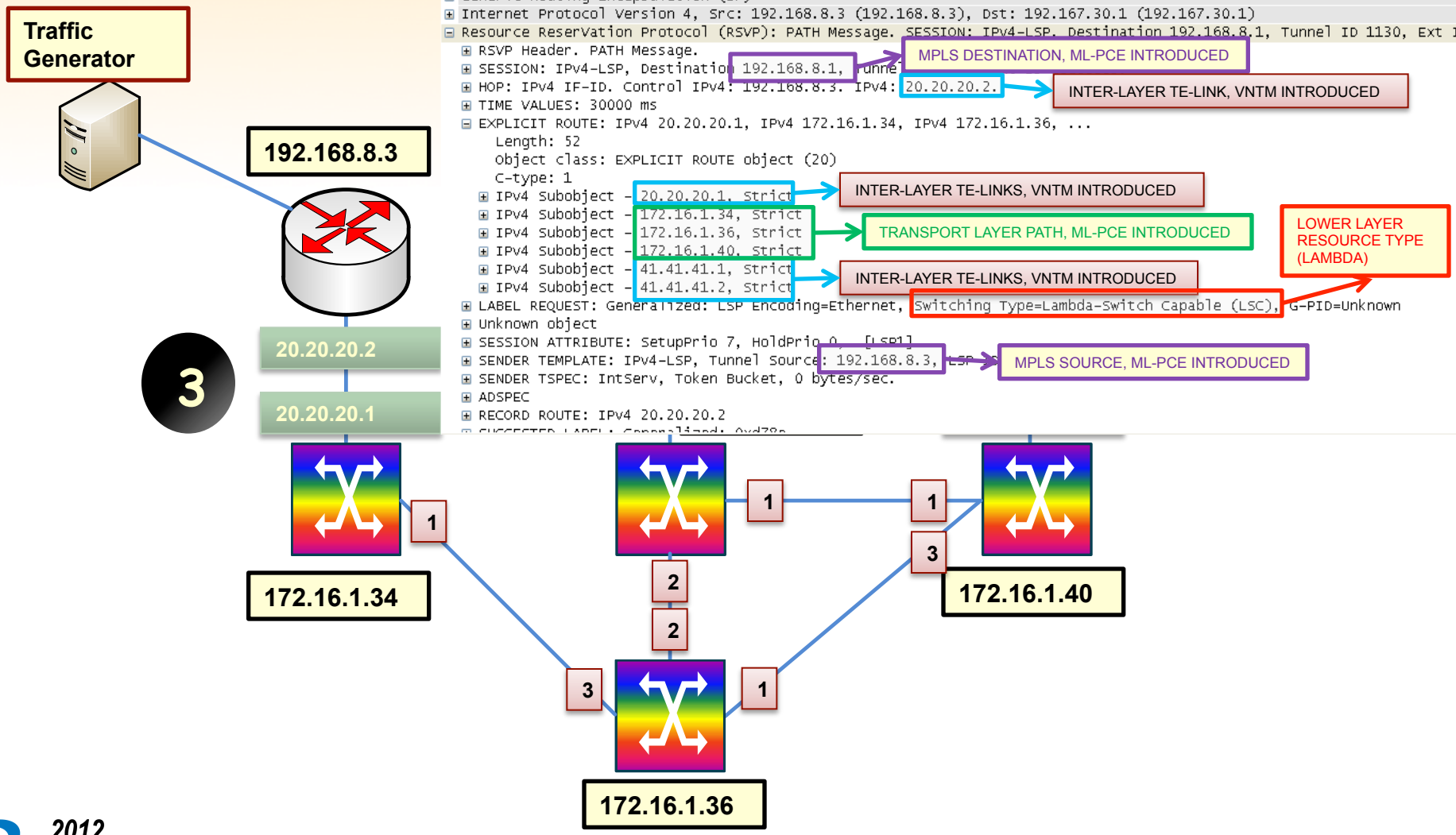
Validation Testbed

Control Plane Configuration



UNI Request

RSVP Path at Source



Message Exchange

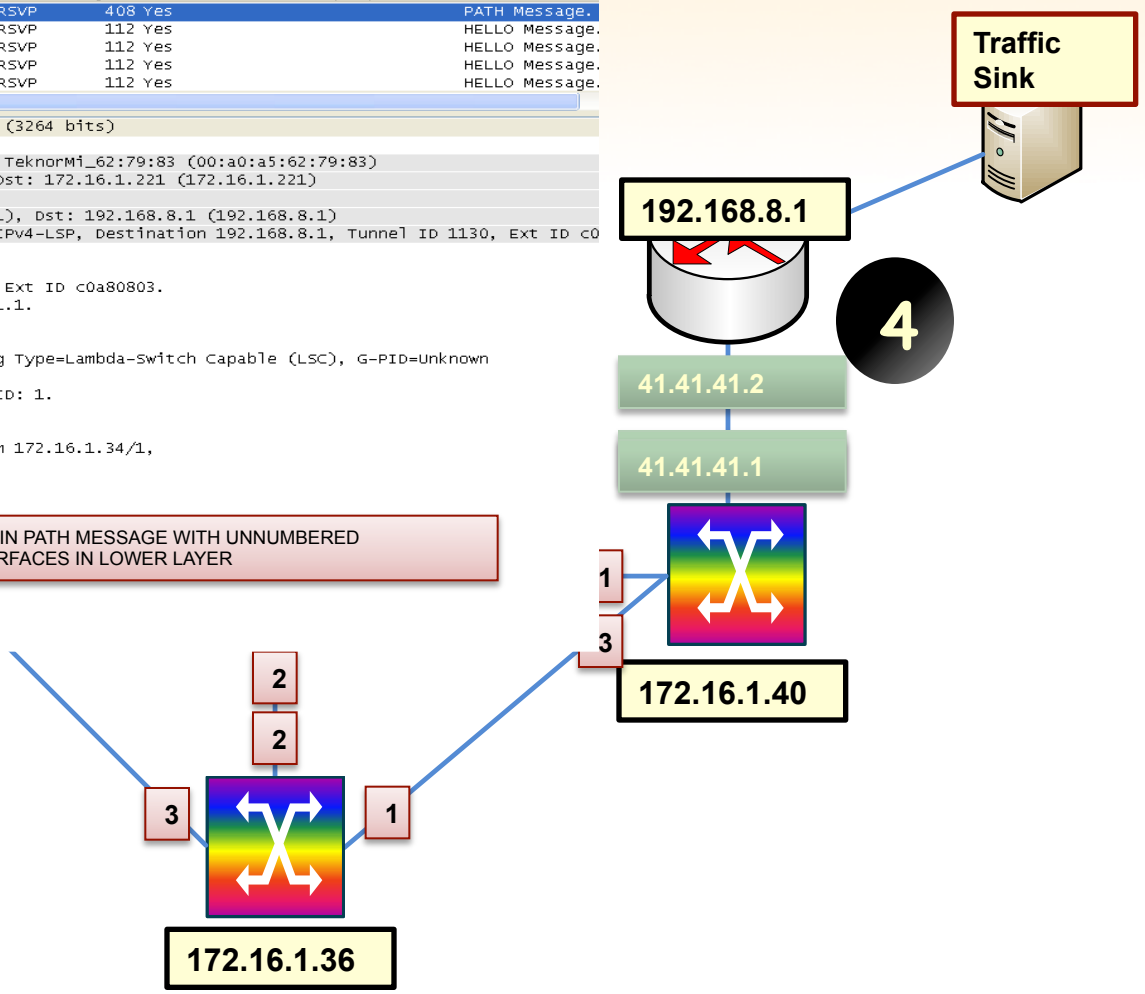
UNI Request: RSVP Path at destination

Traffic

No.	Time	Source	Destination	Protocol	Length	Resource ReserVation Protocol (RSVP)	Info
2621	246.118808	192.167.201.1	192.168.8.1	RSVP	408	Yes	PATH Message.
2693	251.939026	192.167.201.1	192.168.8.1	RSVP	112	Yes	HELLO Message.
2694	251.941082	192.168.8.1	192.167.201.1	RSVP	112	Yes	HELLO Message.
2741	258.879296	192.167.201.1	192.168.8.1	RSVP	112	Yes	HELLO Message.
2742	258.880994	192.168.8.1	192.167.201.1	RSVP	112	Yes	HELLO Message.

```
⊞ Frame 2621: 408 bytes on wire (3264 bits), 408 bytes captured (3264 bits)
⊞ Juniper Ethernet
⊞ Ethernet II, Src: AdvaOpti_10:7f:60 (00:80:ea:10:7f:60), Dst: TeknorMi_62:79:83 (00:a0:a5:62:79:83)
⊞ Internet Protocol Version 4, Src: 172.16.1.40 (172.16.1.40), Dst: 172.16.1.221 (172.16.1.221)
⊞ Generic Routing Encapsulation (IP)
⊞ Internet Protocol Version 4, Src: 192.167.201.1 (192.167.201.1), Dst: 192.168.8.1 (192.168.8.1)
⊟ Resource ReserVation Protocol (RSVP): PATH Message. SESSION: IPv4-LSP, Destination 192.168.8.1, Tunnel ID 1130, Ext ID c0
  ⊞ RSVP Header. PATH Message.
  ⊞ MESSAGE-ID: 12
  ⊞ SESSION: IPv4-LSP, Destination 192.168.8.1, Tunnel ID 1130, Ext ID c0a80803.
  ⊞ HOP: IPv4 IF-ID. Control IPv4: 192.167.201.1. IPv4: 41.41.41.1.
  ⊞ TIME VALUES: 30000 ms
  ⊞ EXPLICIT ROUTE: IPv4 41.41.41.2, IPv4 41.41.41.2
  ⊞ LABEL REQUEST: Generalized: LSP Encoding=Ethernet, Switching Type=Lambda-Switch Capable (LSC), G-PID=Unknown
  ⊞ SESSION ATTRIBUTE: SetupPrio 7, HoldPrio 0,  [LSP1]
  ⊞ SENDER TEMPLATE: IPv4-LSP, Tunnel Source: 192.168.8.3, LSP ID: 1.
  ⊞ SENDER TSPEC: IntServ, Token Bucket, 0 bytes/sec.
  ⊞ ADSPEC
  ⊟ RECORD ROUTE: IPv4 192.167.201.1, Unnum 172.16.1.36/1, Unnum 172.16.1.34/1,
      Length: 44
      Object class: RECORD ROUTE object (21)
      C-type: 1
    ⊞ IPv4 Subobject - 192.167.201.1
    ⊞ Unnumbered Interface-ID - 172.16.1.36, 1,
    ⊞ Unnumbered Interface-ID - 172.16.1.34, 1,
    ⊞ IPv4 Subobject - 20.20.20.2
  ⊞ SUGGESTED LABEL: Generalized: 0x320c8
  ⊞ UPSTREAM LABEL: Generalized: 0x320c8
  ⊞ Unknown object
  ⊞ Unknown object
```

RRO IN PATH MESSAGE WITH UNNUMBERED INTERFACES IN LOWER LAYER



Message Exchange

UNI: RSVP Resv at destination

Traffic

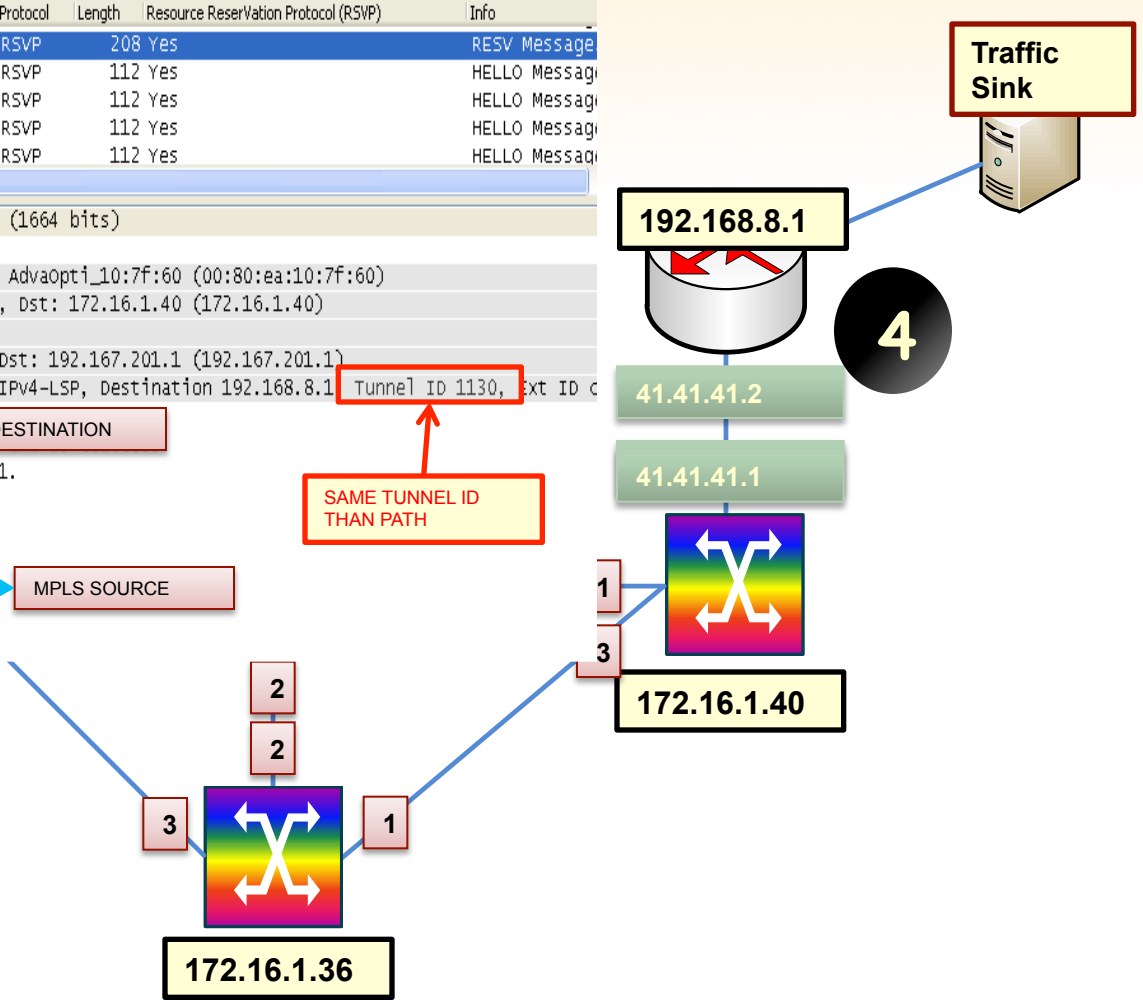
No.	Time	Source	Destination	Protocol	Length	Resource ReserVation Protocol (RSVP)	Info
2858	270.143425	192.168.8.1	192.167.201.1	RSVP	208	Yes	RESV Message
2860	270.380364	192.167.201.1	192.168.8.1	RSVP	112	Yes	HELLO Messag
2861	270.382188	192.168.8.1	192.167.201.1	RSVP	112	Yes	HELLO Messag
2899	275.220558	192.167.201.1	192.168.8.1	RSVP	112	Yes	HELLO Messag
2900	275.222428	192.168.8.1	192.167.201.1	RSVP	112	Yes	HELLO Messag

```
⊞ Frame 2858: 208 bytes on wire (1664 bits), 208 bytes captured (1664 bits)
⊞ Juniper Ethernet
⊞ Ethernet II, Src: TeknorMi_62:79:83 (00:a0:a5:62:79:83), Dst: AdvaOpti_10:7f:60 (00:80:ea:10:7f:60)
⊞ Internet Protocol Version 4, Src: 172.16.1.221 (172.16.1.221), Dst: 172.16.1.40 (172.16.1.40)
⊞ Generic Routing Encapsulation (IP)
⊞ Internet Protocol Version 4, Src: 192.168.8.1 (192.168.8.1), Dst: 192.167.201.1 (192.167.201.1)
⊟ Resource ReserVation Protocol (RSVP): RESV Message. SESSION: IPv4-LSP, Destination 192.168.8.1  Tunnel ID 1130,  Ext ID c
  ⊞ RSVP Header. RESV Message.
  ⊞ SESSION: IPv4-LSP, Destinatio 192.168.8.1, Tunnel
  ⊞ HOP: IPv4 IF-ID. Control IPv4: 192.168.8.1. IPv4: 41.41.41.1.
  ⊞ TIME VALUES: 30000 ms
  ⊞ STYLE: Fixed Filter (10)
  ⊞ FLOWSPEC: Controlled Load: Token Bucket, 0 bytes/sec.
  ⊞ FILTERSPEC: IPv4-LSP, Tunnel Source: 192.168.8.3, LSP ID: 1
  ⊞ LABEL: Generalized: 0xd78f
  ⊞ RECORD ROUTE: IPv4 41.41.41.2
```

MPLS DESTINATION

SAME TUNNEL ID THAN PATH

MPLS SOURCE



04

Conclusions

Conclusions

- Multilayer PCE, VNTM and UNI can cooperate together
- They have proven to be feasible elements for the automatic operation of an overlay MPLS over WSON network.
- PCEP is a suitable protocol to communicate to the VNTM.
- The current standards need to be extended to suggest new configurations (e.g. new TE-Links) to the VNTM.

This work was supported by the ONE project in the FP7 Program, contract number INFSO-ICT-258300.

THANK YOU!!
QUESTIONS?