Ethernet OAM Technologies

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APRICOT-APAN 2011

Operations, Administration & Maintenance

- **F** – Fault Management
- **C** – Configuration Management
- **A** – Accounting
- **P** – Performance Management
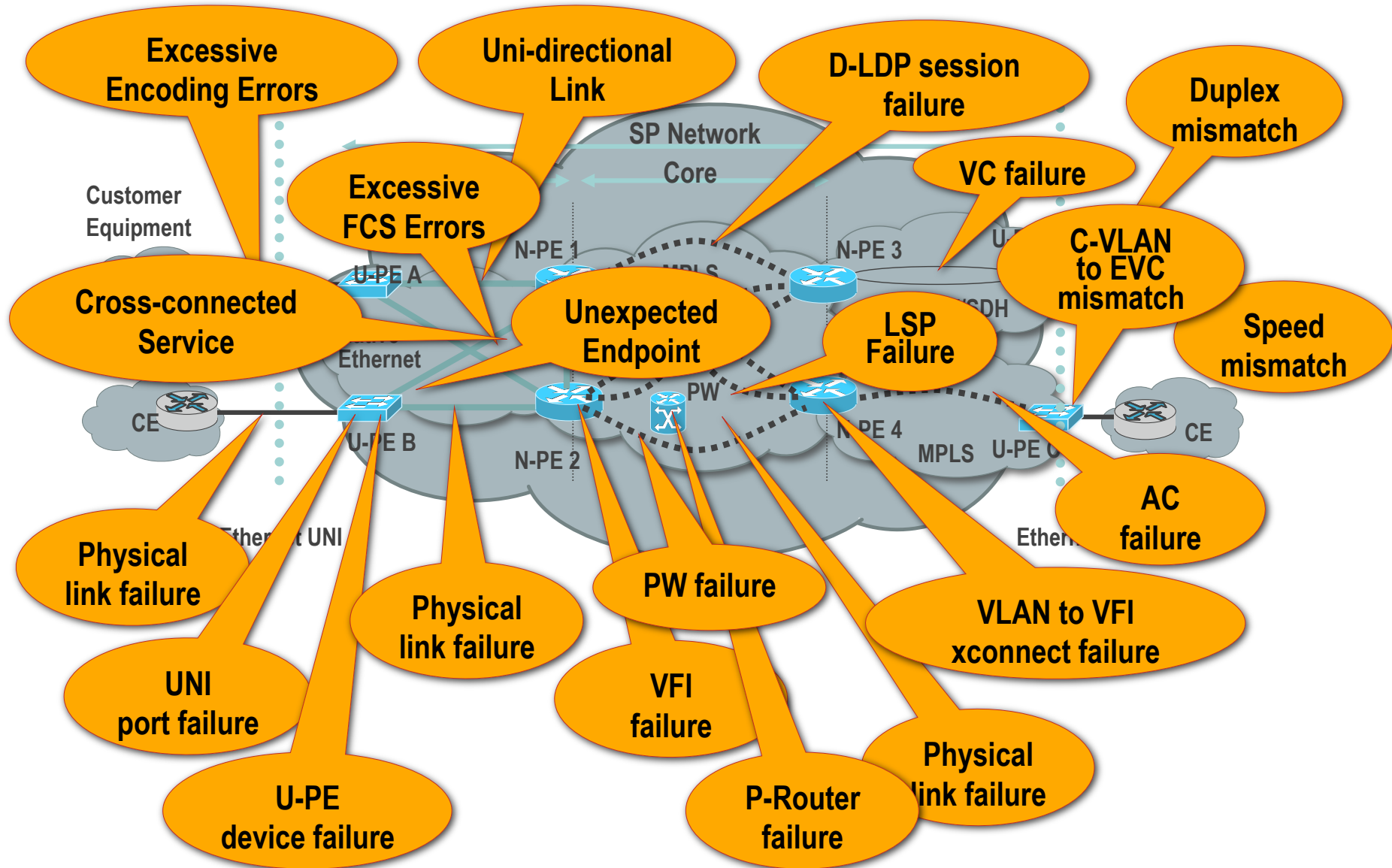- **S** – Security Management

FCAPS

OAM Protocols and Mechanisms helps operator to achieve some of the FCAPS functionality

OAM capability is one of the key differentiator to make a SP network truly "Carrier Grade"
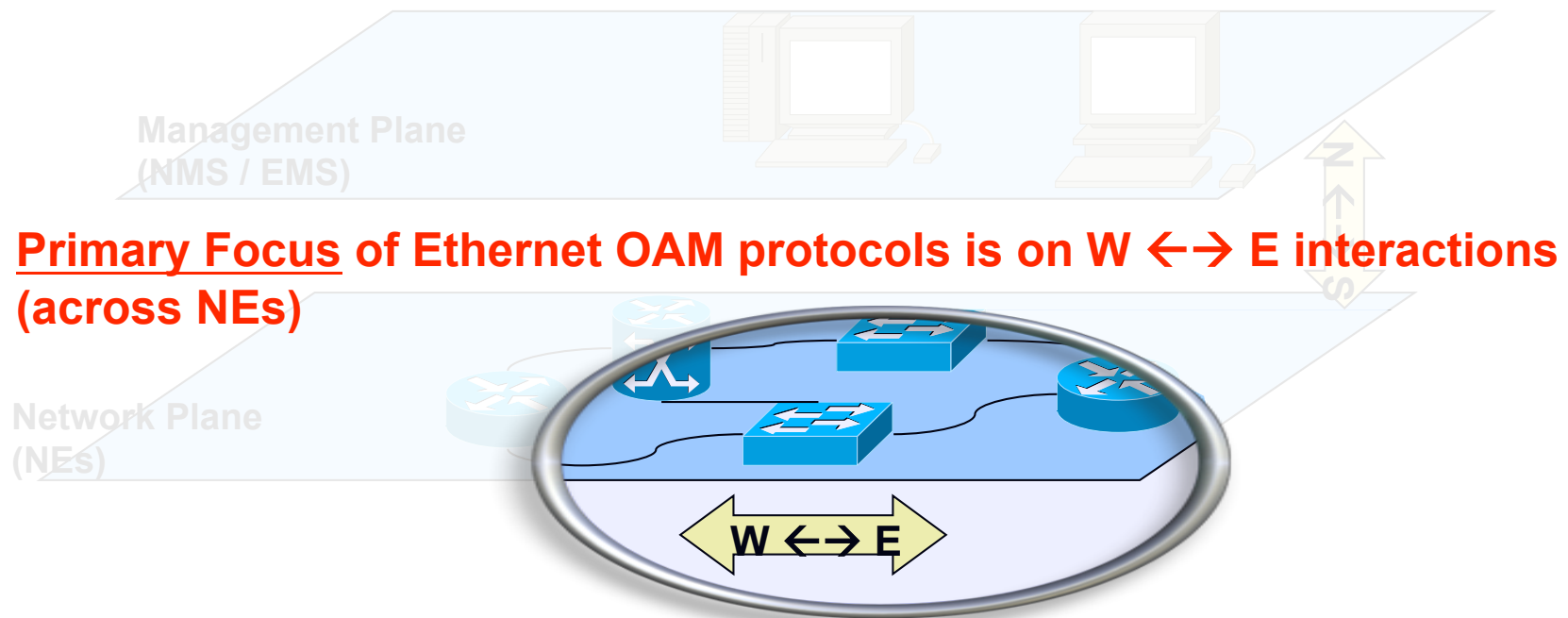
Problem Scope
A few possible scenarios

Excessive Encoding Errors

Uni-directional Link

D-LDP session failure

Duplex mismatch

SP Network Core

Excessive FCS Errors

VC failure

Customer Equipment

C-VLAN to EVC mismatch

N-PE 1

MPLS

N-PE 3

U-PE A

Cross-connected Service

Unexpected Endpoint

LSP Failure

Speed mismatch

Ethernet

CE

PW

U-PE B

N-PE 2

N-PE 4

MPLS

U-PE

CE

Ethernet UNI

AC failure

Physical link failure

Physical link failure

PW failure

Ethernet

VLAN to VFI xconnect failure

UNI port failure

VFI failure

U-PE device failure

P-Router failure

Physical link failure

OAM: The Concept

- **O**perations, **A**dministration, **M**aintenance & Provisioning:
    - − **fault indication**
    - − **performance monitoring**
    - − **security management**
    - − **diagnostic functions**
    - − **configuration & service provisioning**
- **OAM covers both N← → S and W←→E interfaces**

**Management Plane
(NMS / EMS)**

N ↕ S

**Network Plane
(Elements)**

W ← → E
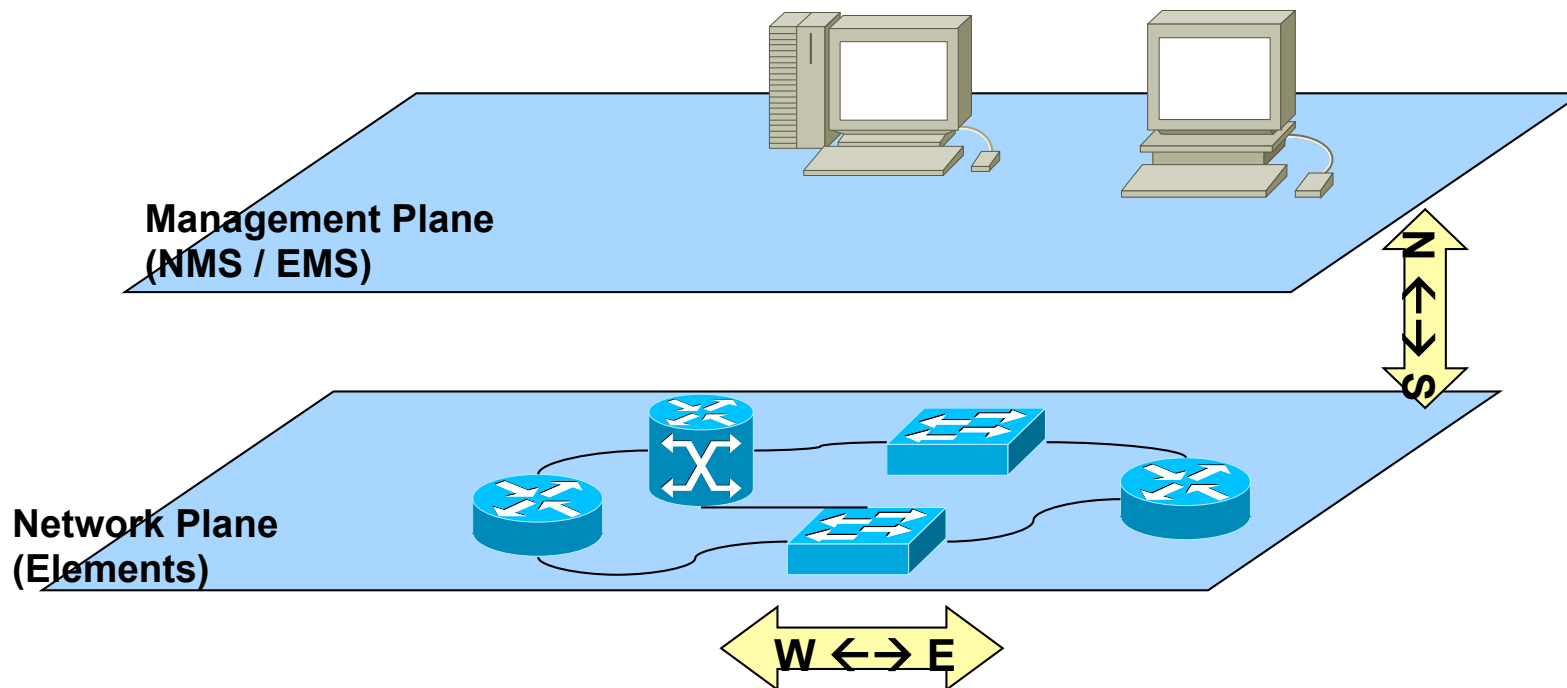
Scope of Ethernet OAM

- **O**perations, **A**dministration, **M**aintenance & Provisioning:
  - − fault indication
  - − performance monitoring
  - − security management
  - − diagnostic functions
  - − configuration & service provisioning
- OAM covers both N←→ S and W←→E interfaces

Management Plane
(NMS / EMS)

Primary Focus of Ethernet OAM protocols is on W ←→ E interactions (across NEs)

Network Plane
(NEs)

W ←→ E

Drivers for Ethernet OAM

- **OAM benchmarks**

  Set by TDM and existing WAN technologies

- **Operational Efficiency**

  Reduce OPEX, avoid truck-rolls

  Downtime cost

- **Management Complexity**

  Large Span Networks

  Multiple constituent networks belong to disparate organizations/companies

Agenda

- Protocol Overview

  CFM or IEEE 802.1ag

  ITU Y.1731

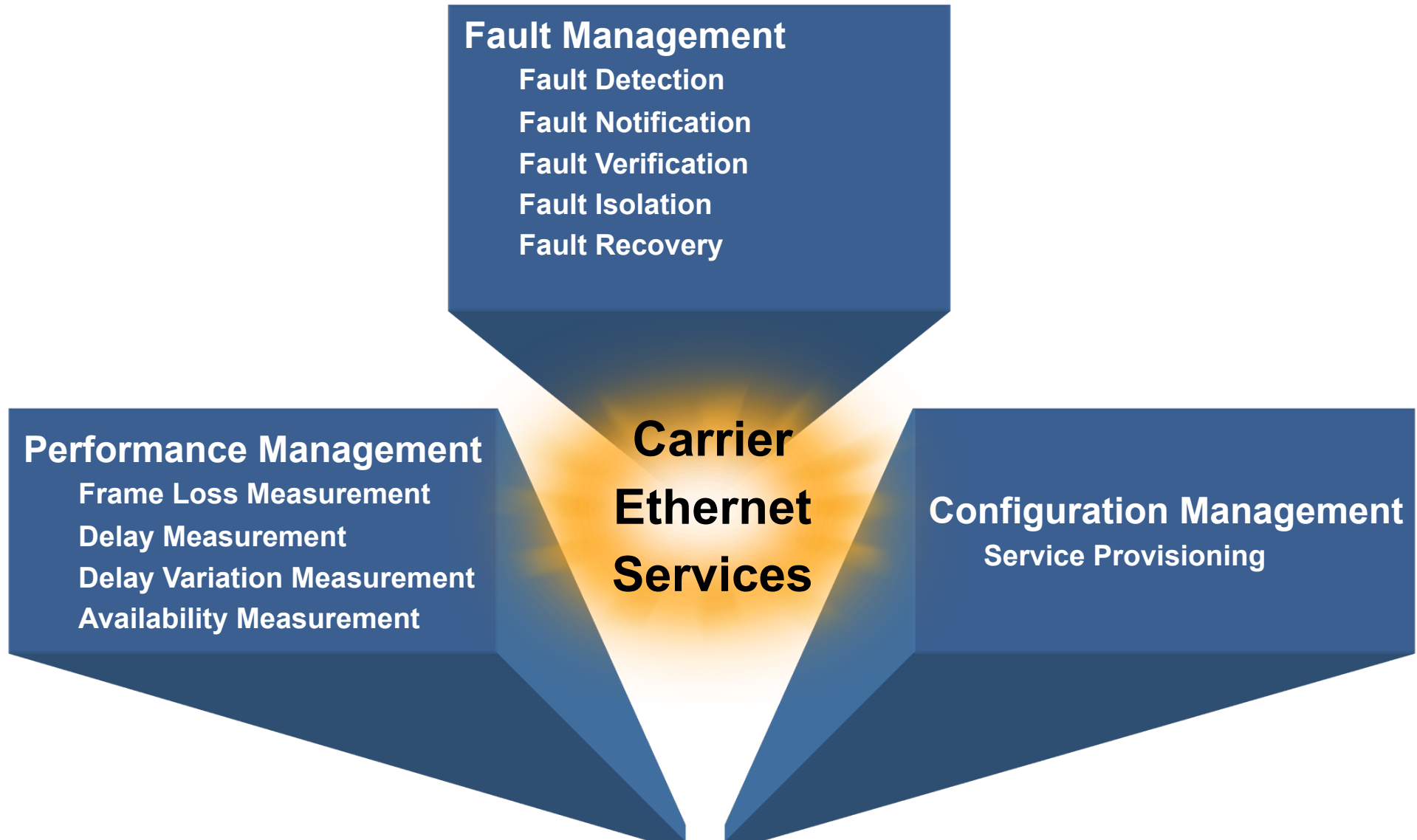 Link OAM or IEEE 802.3ah (clause 57)

  MEF E-LMI

- OAM Inter-Working

- Fault Management scenarios
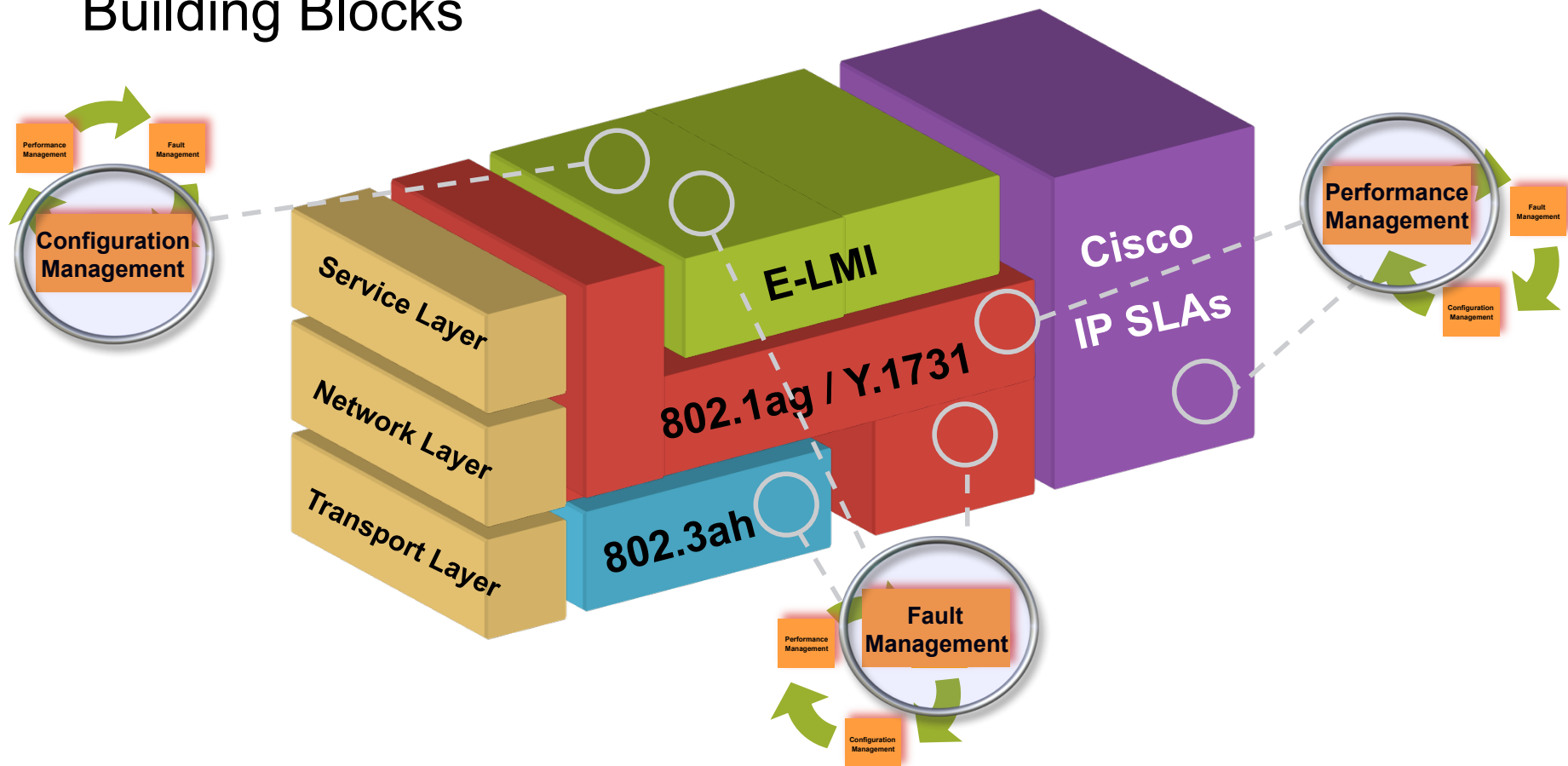
- Performance Management

Ethernet OAM Protocol Overview

Problem Taxonomy

Fault Management
- **Fault Detection**
- **Fault Notification**
- **Fault Verification**
- **Fault Isolation**
- **Fault Recovery**

Carrier Ethernet Services

Performance Management
- **Frame Loss Measurement**
- **Delay Measurement**
- **Delay Variation Measurement**
- **Availability Measurement**

Configuration Management
- **Service Provisioning**

Ethernet OAM
Building Blocks

- IEEE 802.1ag: Connectivity Fault Management (CFM)
- IEEE 802.3ah: Ethernet Link OAM (EFM OAM)
- ITU-T Y.1731: OAM functions and mechanisms for Ethernet based networks
- MEF E-LMI: Ethernet Local Management Interface
- Cisco IP SLA's: Performance Management using CFM and Y.1731 mechanisms

Cisco Carrier Ethernet OAM
Protocol Positioning
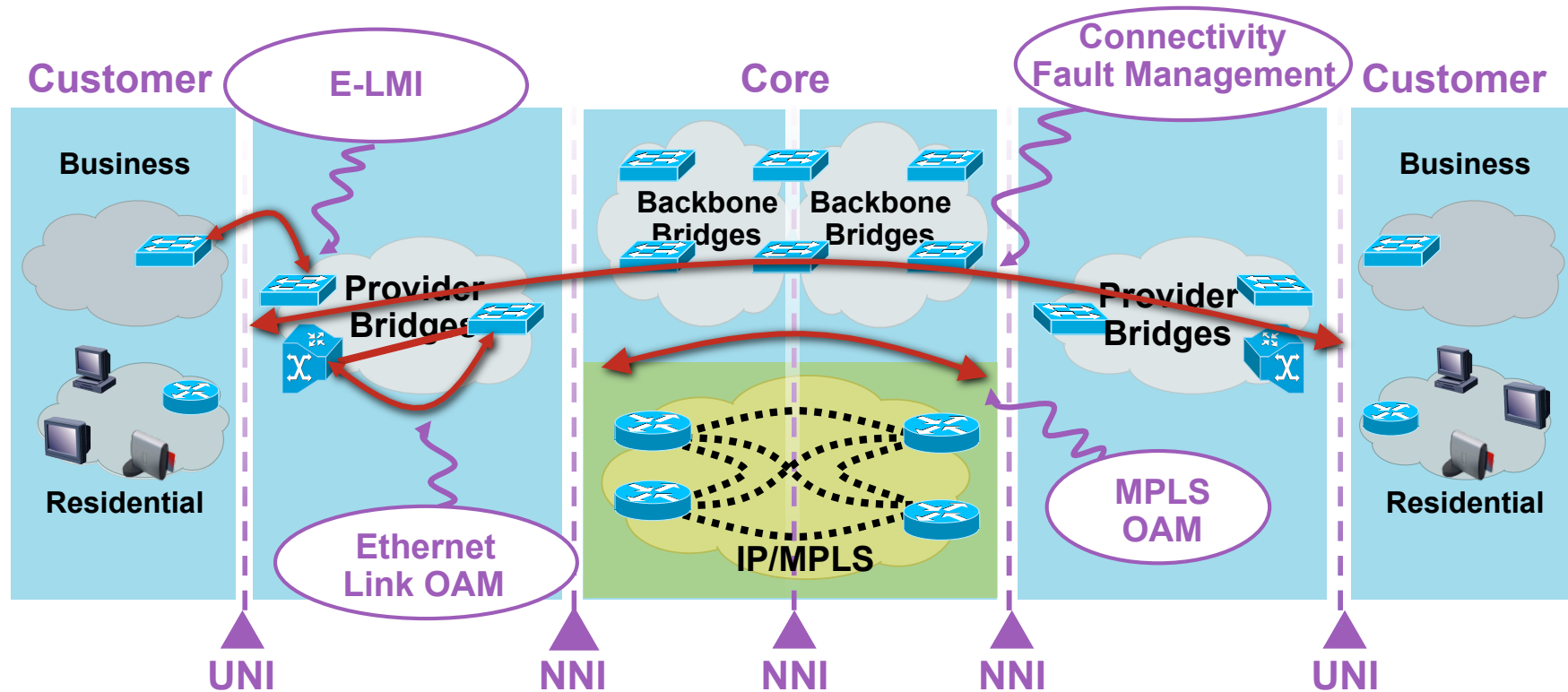
- E-LMI—User to Network Interface (UNI)

- Link OAM—Any point-point 802.3 link

- CFM—End-to-End UNI to UNI

- MPLS OAM—within MPLS cloud

Connectivity Fault Management

IEEE 802.1ag

CFM Overview

- Family of protocols that provides capabilities to detect, verify, isolate and report end-to-end ethernet connectivity faults

- Employs regular Ethernet frames that travel in-band with the customer traffic

  Devices that cannot interpret CFM Messages forward them as normal data frames

- CFM frames are distinguishable by Ether-Type (0x8902) and dMAC address (for multicast messages)

- Standardized by IEEE in late 2007

  IEEE std. 802.1ag-2007

CFM Overview (Cont.)

- Key CFM mechanisms include:

    Nested Maintenance Domains (MDs) that break up the responsibilities for network administration of a given end-to-end service
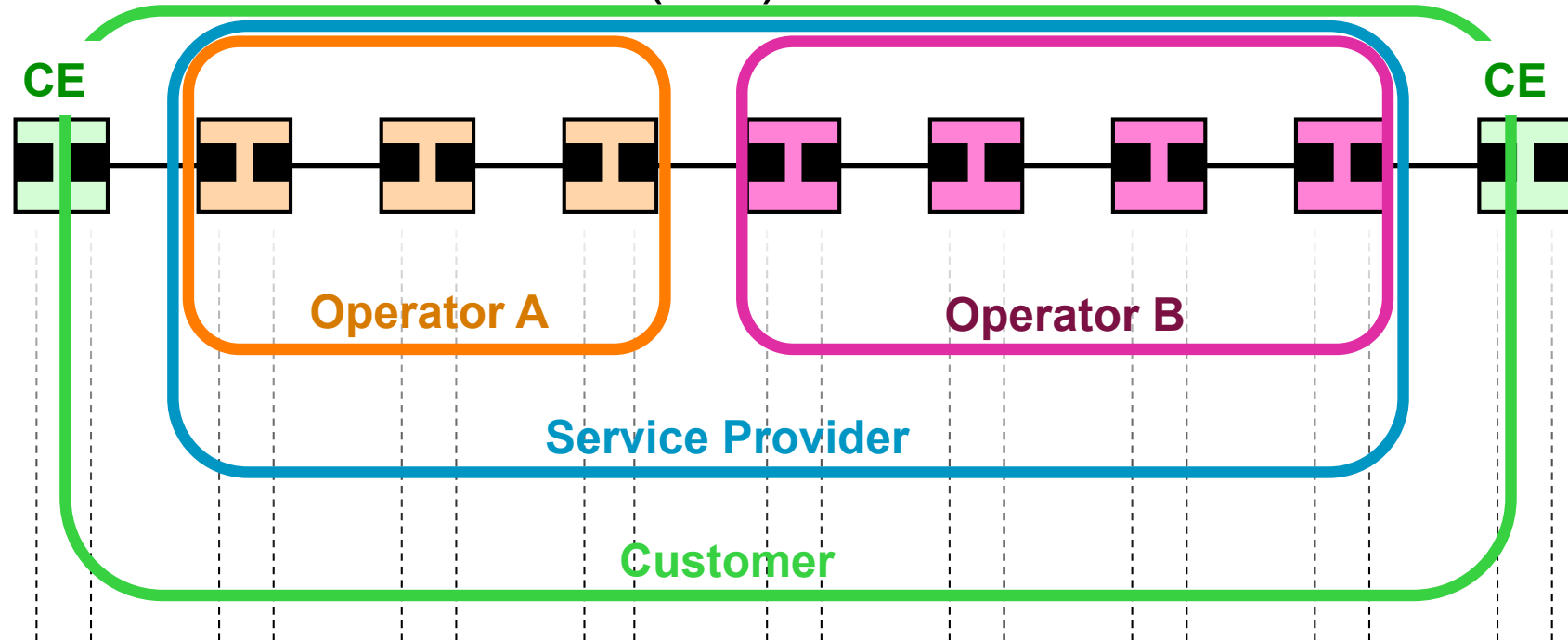
    Maintenance Associations (MAs) that monitor service instances under a given MD

    Maintenance Points (MPs) that generate and respond to CFM PDUs

    Protocols (Continuity Check, Loopback and Linktrace) used for Fault Management activities

CFM Concepts

Maintenance Domain (MD)

- Defined by Operational/Contractual Boundaries
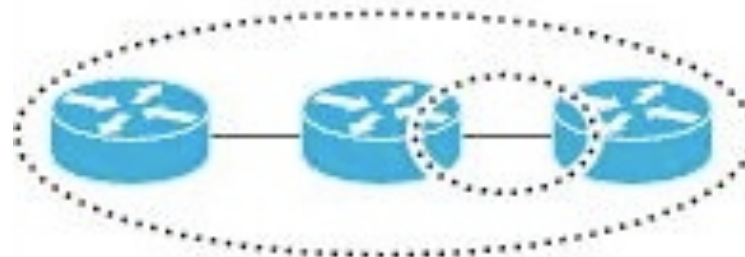   e.g. Customer/Service Provider/Operator
- MD may nest and touch, but never intersect
- Up to 8 levels of "nesting": MD Level (0..7)
    The higher the level, the broader its reach
- MD Name Format: null, MAC address, DNS or string-based

Maintenance Domain Nesting

Scenario A:
Touching Domains OK

Scenario B:
Nested Domains OK

Scenario C:
Intersecting Domains
Not Allowed

CFM Concepts

Maintenance Association (MA)
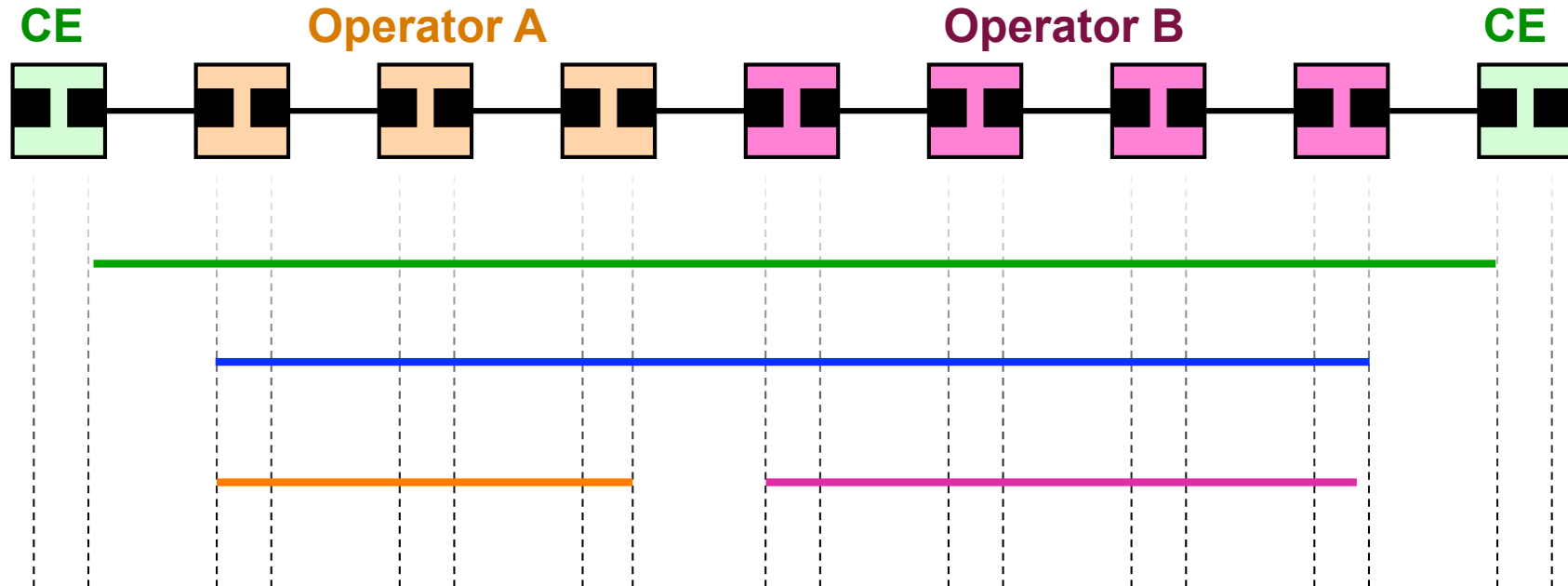
- Monitors connectivity of a particular service instance in a given MD (e.g. 1 service traversing 4 MDs = 4 MAs)
- Defined by a set of Maintenance End Points (MEP) at the edge of a domain
- Identified by MAID == "Short MA" Name + MD Name
- Short MA Name Format: Vlan-ID, VPN-ID, integer or string-based

CFM Concepts

Maintenance Point (MP)—MEP
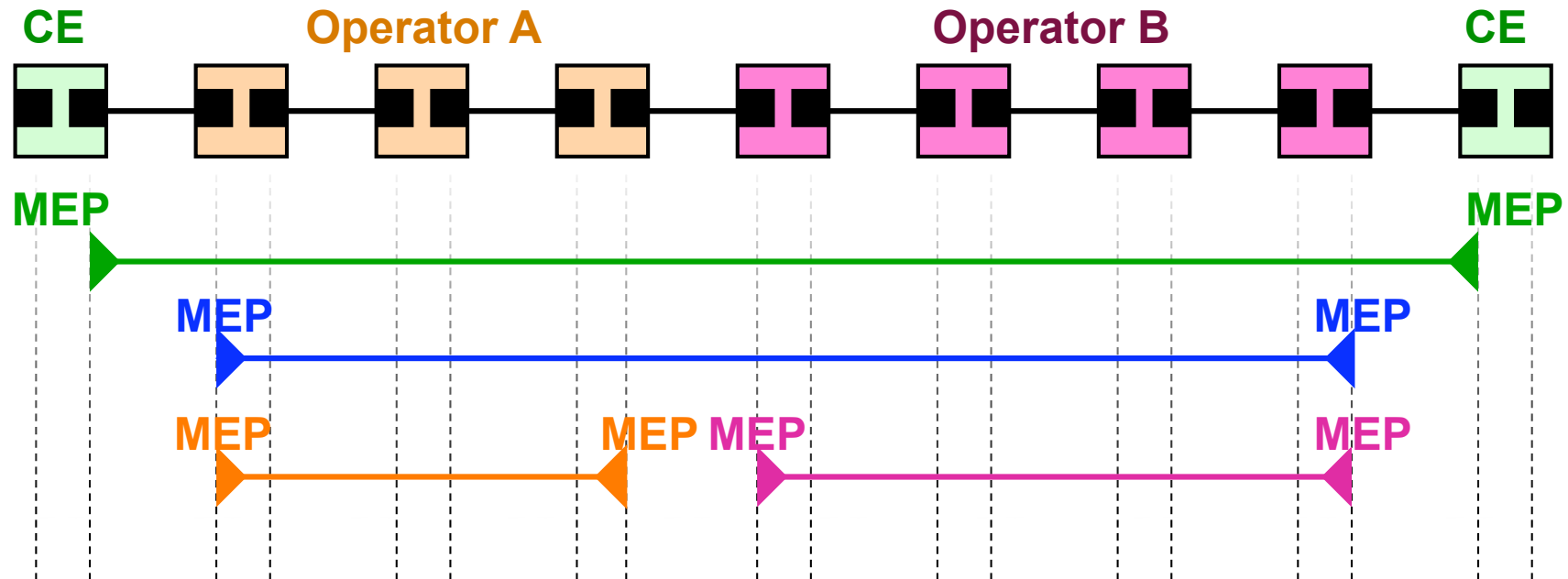
- **Maintenance Association End Point (MEP)**
- Define the boundaries of a MD
- Support the detection of connectivity failures between any pair of MEPs in an MA
- Associated per MA and identified by a MEPID (1-8191)
- Can initiate and respond to CFM PDU's (Active Components)

CFM Concepts
Maintenance Point (MP)—MIP
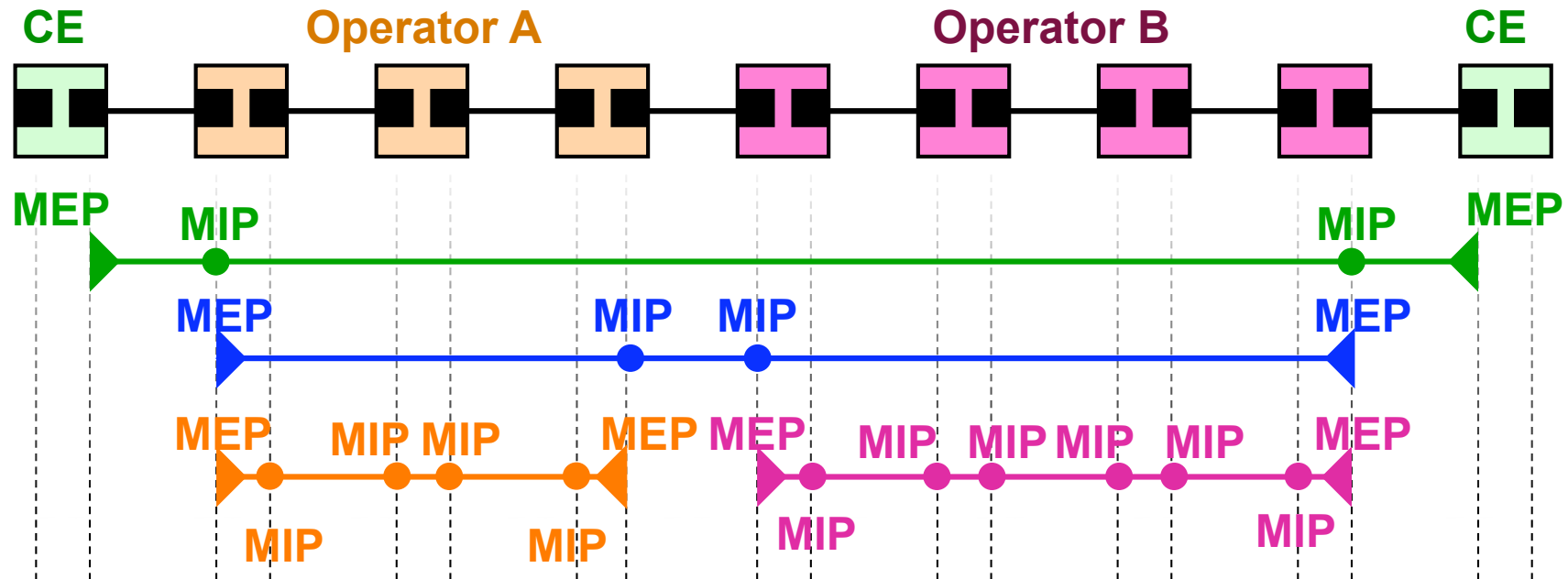
- **M**aintenance Domain **I**ntermediate **P**oint (MIP)

- Support the discovery of paths among MEPs and location of faults along those paths

- Can be associated per MD and VLAN / EVC

- Can add, check and respond to received CFM PDU's (Passive)

CFM Concepts
UP / Inward-facing MEP

- **CFM PDUs** generated by the MEP are sent towards the Bridge's Relay Function and not via the wire connected to the port where the MEP is configured

- **CFM PDUs** to be responded by the MEP are expected to arrive via the Bridge's Relay Function

- Applicable to switches

Bridge

Relay Entity

Port A

Port B
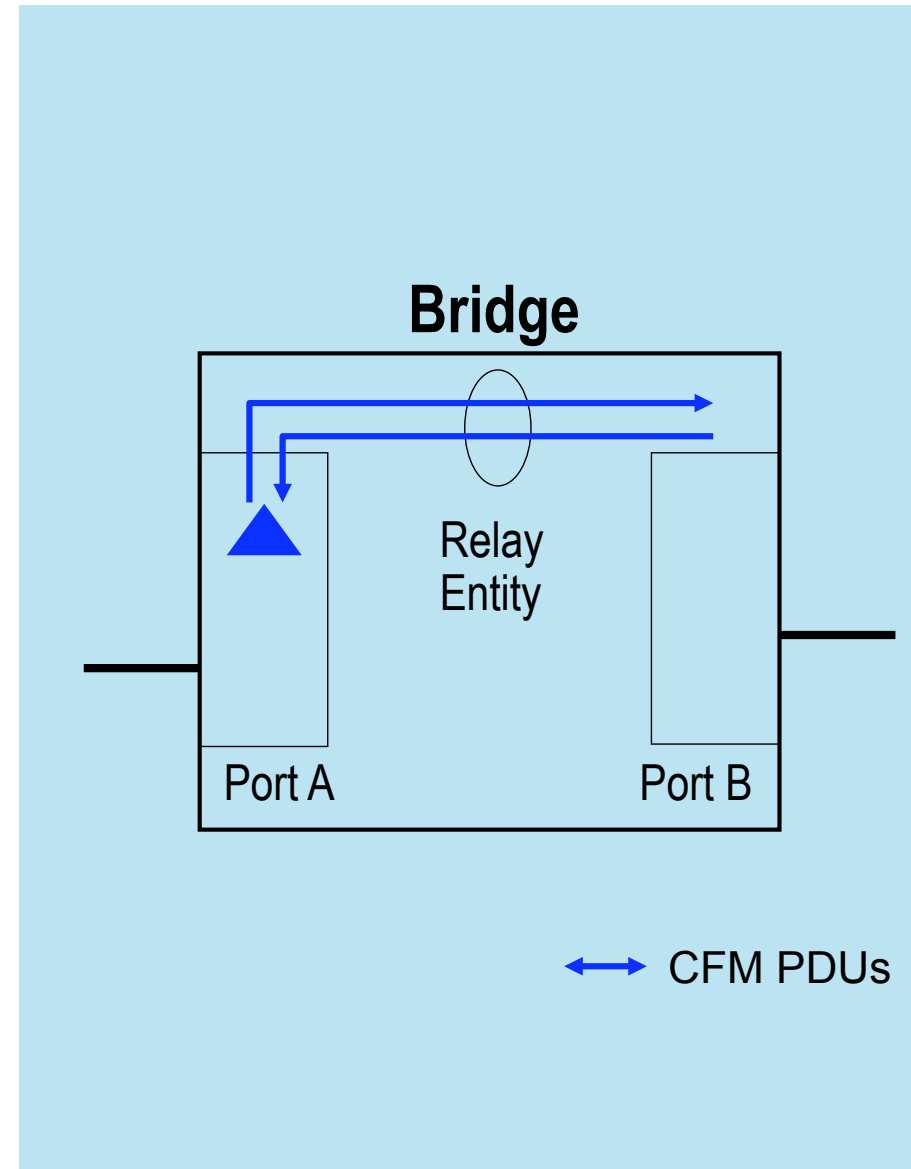
← → CFM PDUs

CFM Concepts
DOWN / Outward-facing MEP

- CFM PDUs generated by the MEP are sent via the wire connected to the port where the MEP is configured

- CFM PDUs to be responded by the MEP are expected to arrive via the wire connected to the port where the MEP is configured

- Port MEP – special Down MEP at level zero (0) used to detect faults at the link level (rather than service)

- Applicable to routers and switches

Bridge / Router

Relay Entity

Port A

Port B

← → CFM PDUs
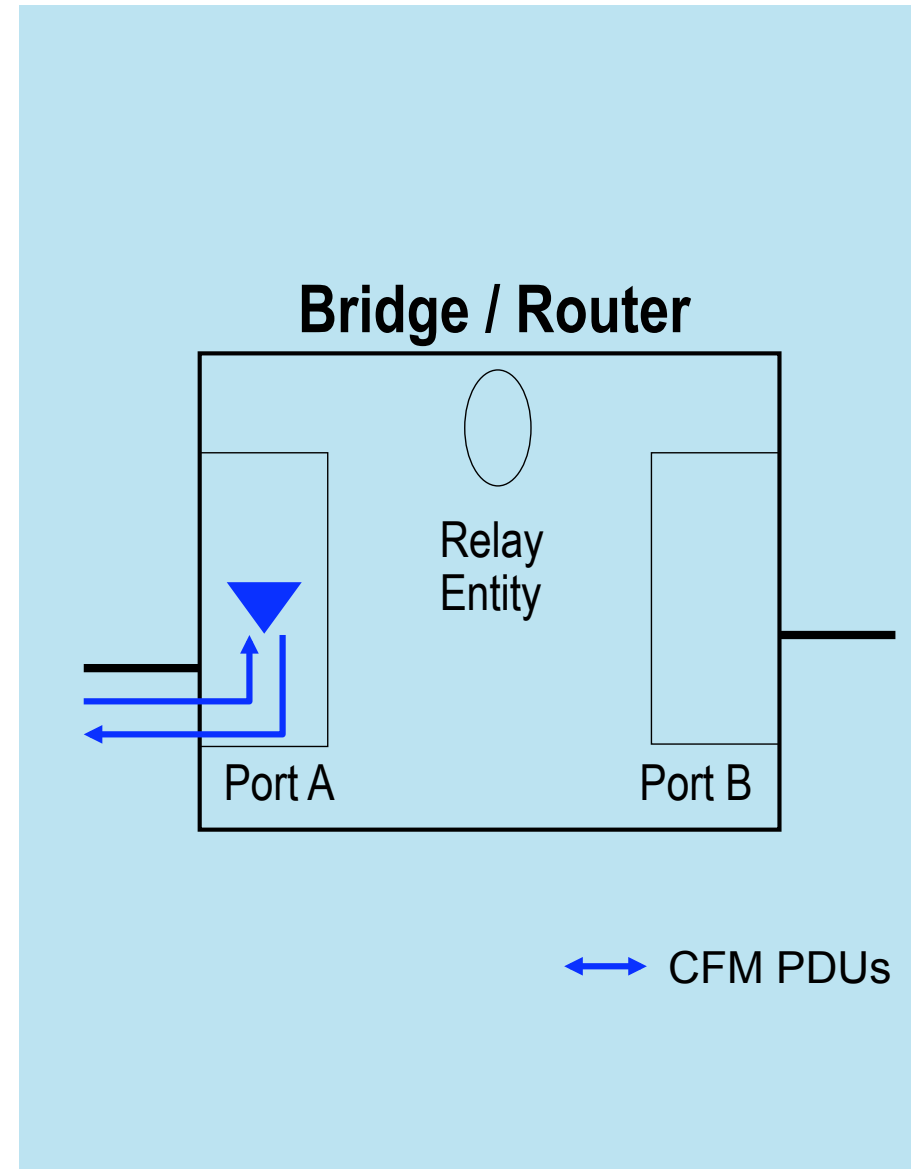
CFM Concepts
MAs and UP/DOWN MEPs

- Applicability of UP/DOWN MEPs in switches:

  DOWN MEPs are typically used for MAs spanning a single link

  UP MEPs are commonly used for MAs with a wider reach (e.g. end-to-end, beyond a single link

DOWN MEP to UP MEP

Bridge 1 | Bridge 2

Bridge Port | Relay Entity | Bridge Port | Bridge Port | Relay Entity | Bridge Port

Monitored area

DOWN MEP to DOWN MEP

Bridge 1 | Bridge 2

Bridge Port | Relay Entity | Bridge Port | Bridge Port | Relay Entity | Bridge Port

Monitored area

UP MEP to UP MEP

Bridge 1 | Bridge 2

Bridge Port | Relay Entity | Bridge Port | Bridge Port | Relay Entity | Bridge Port

Monitored area

CFM Protocols

- There are three (3) protocols defined by CFM

- Continuity Check Protocol

    Fault Detection

    Fault Notification

- Loopback Protocol

    Fault Verification

- Linktrace Protocol

    Path discovery & Fault Isolation

CFM Protocols
Continuity Check Protocol
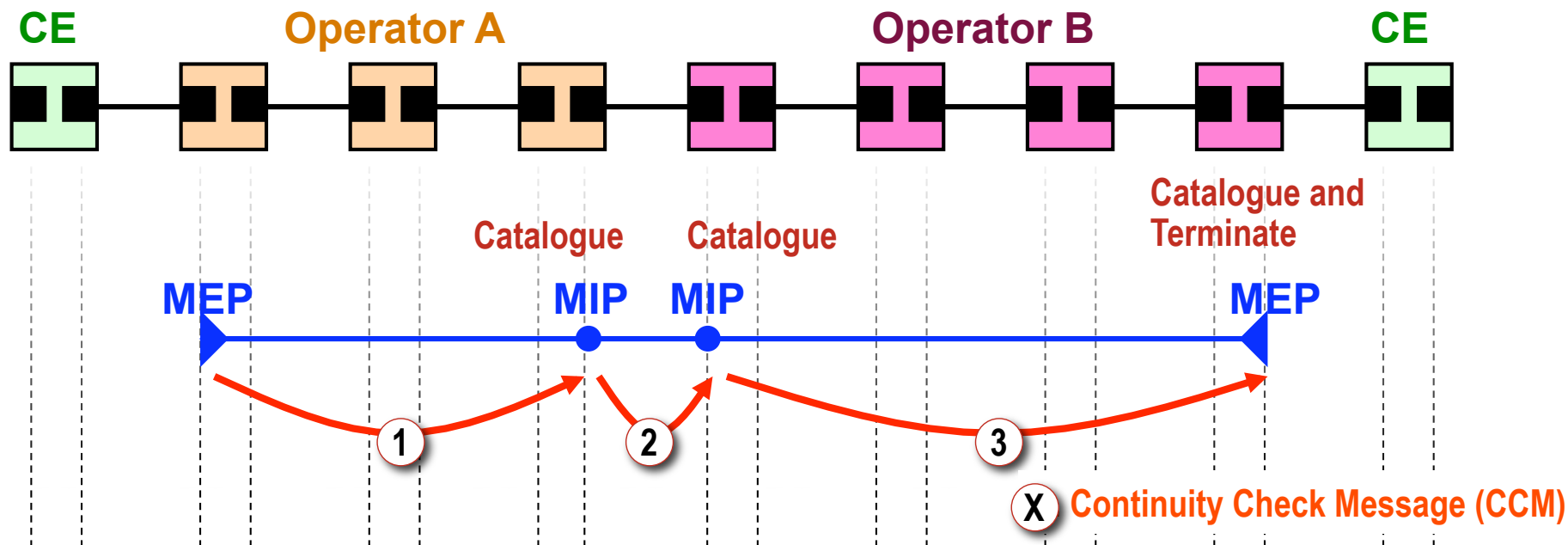
- Used for Fault Detection and Notification
- Per-Maintenance Association multicast "heart-beat" messages
  - Transmitted at configurable periodic interval by MEPs (3.3ms, 10ms, 100ms, 1s, 10s, 1m, 10m)
  - Uni-directional (no response required)
  - Carries status of port on which MEP is configured
- Catalogued by MIPs at the same MD-Level, Terminated by remote MEPs in the same MA

CFM Protocols
Continuity Check Protocol—Fault Detection

CCM-based Events	IOS Alarm Name	IEEE Alarm Name
Discovery of a remote MEP for the first time	CCM MEP UP (New)	none
Re-discovery of a previously expired remote MEP	CCM MEP UP (Returning)	none
Reception by a MEP of a CCM containing a UP Port Status TLV or Interface Status TLV (Remote port recovery)	CCM MEP UP (portstate change)	none
Reception by a MEP of CCM's from ALL remote MEPs configured in a static list	Crosscheck Service Up	none
Expiration of CCM entry with an incorrect mpid	CCM MEP Down (configClear)	none
Expiration of looped CCM entry	CCM MEP Down (loopClear)	none
Expiration of CCM entry with an incorrect MAID	CCM MEP Down (xconnectClear)	none
Expiration of CCM entry from a MEP not included in a static list	CCM MEP Down (unknownClear)	none

MEF working on to address this

CFM Protocols

Loopback Protocol
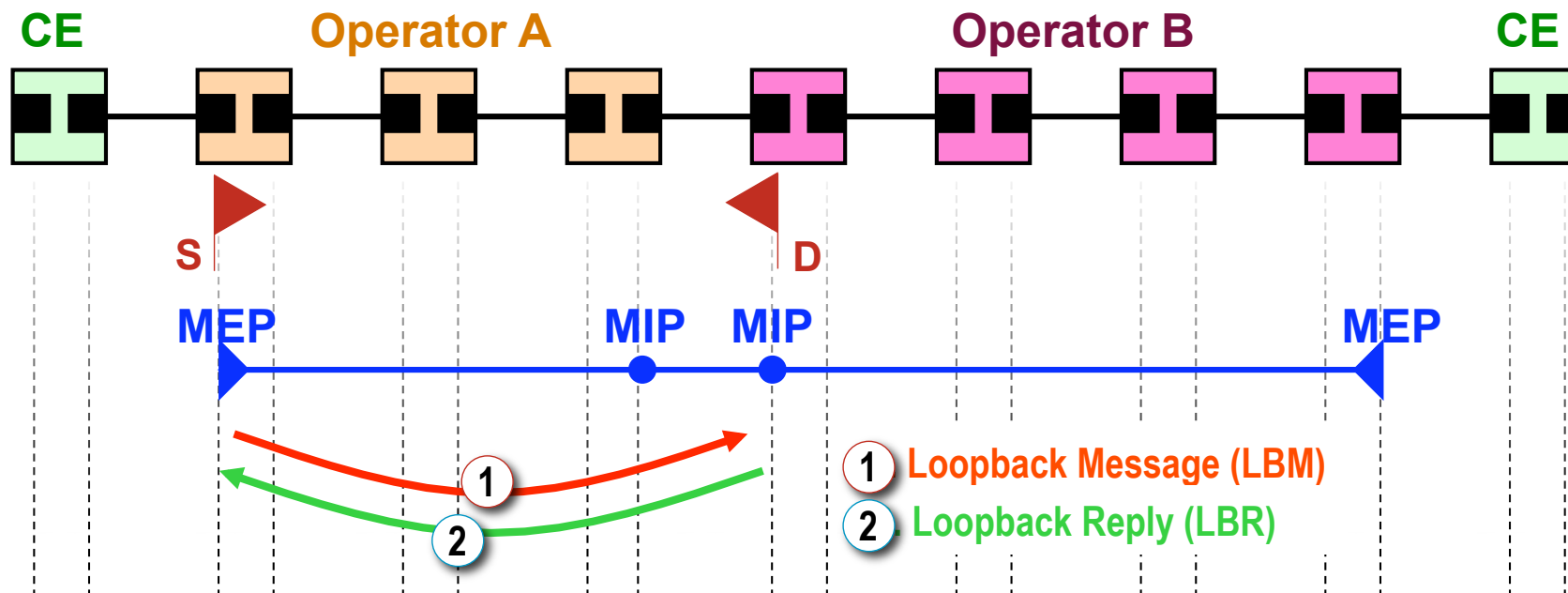
- Used for Fault Verification—Ethernet Ping

- MEP can transmit a unicast LBM to a MEP or MIP in the same MA

- Receiving MP responds by transforming the LBM into a unicast LBR sent back to the originating MEP

CFM Protocols
Linktrace Protocol

CE Operator A Operator B CE

S D

MEP MIP MIP MEP

6
4
2

1 3 5

X 1, 3, 5 Linktrace Message (LTM)
Y 2, 4, 6 Linktrace Reply (LTR)
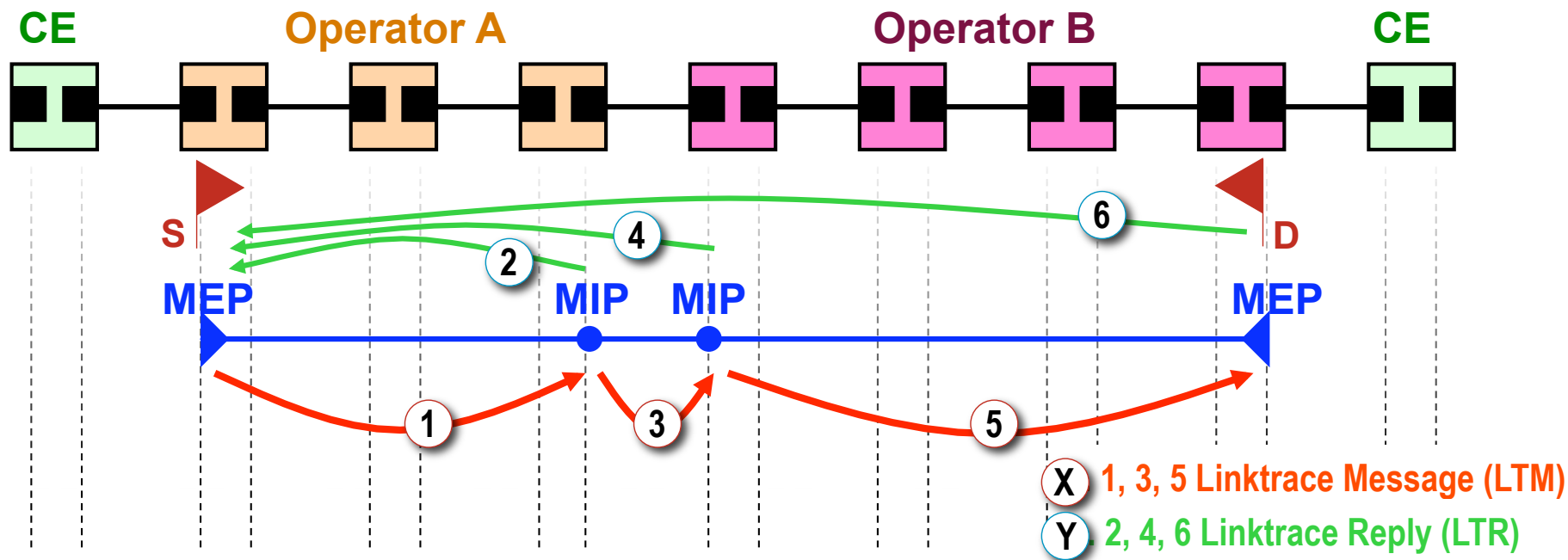
- Used for Path Discovery and Fault Isolation—Ethernet Traceroute

- MEP can transmit a multicast message (LTM) in order to discover the MPs and path to a MIP or MEP in the same MA

- Each MIP along the path and the terminating MP return a unicast LTR to originating MEP

Connectivity Fault Management
Troubleshooting Example

Customer

Service Provider

CE 1   uPE B   nPE B   nPE A   uPE A   CE 2

PE-Agg B

Ethernet Access

MPLS Core

MPLS Access

Loopback & Link Trace Tests

Defect Locality Zone

'Uncertainty' Zone shrinks with every lower level Domain

Customer Domain

Defect successfully isolated

Service Provider Domain

Operator Domains
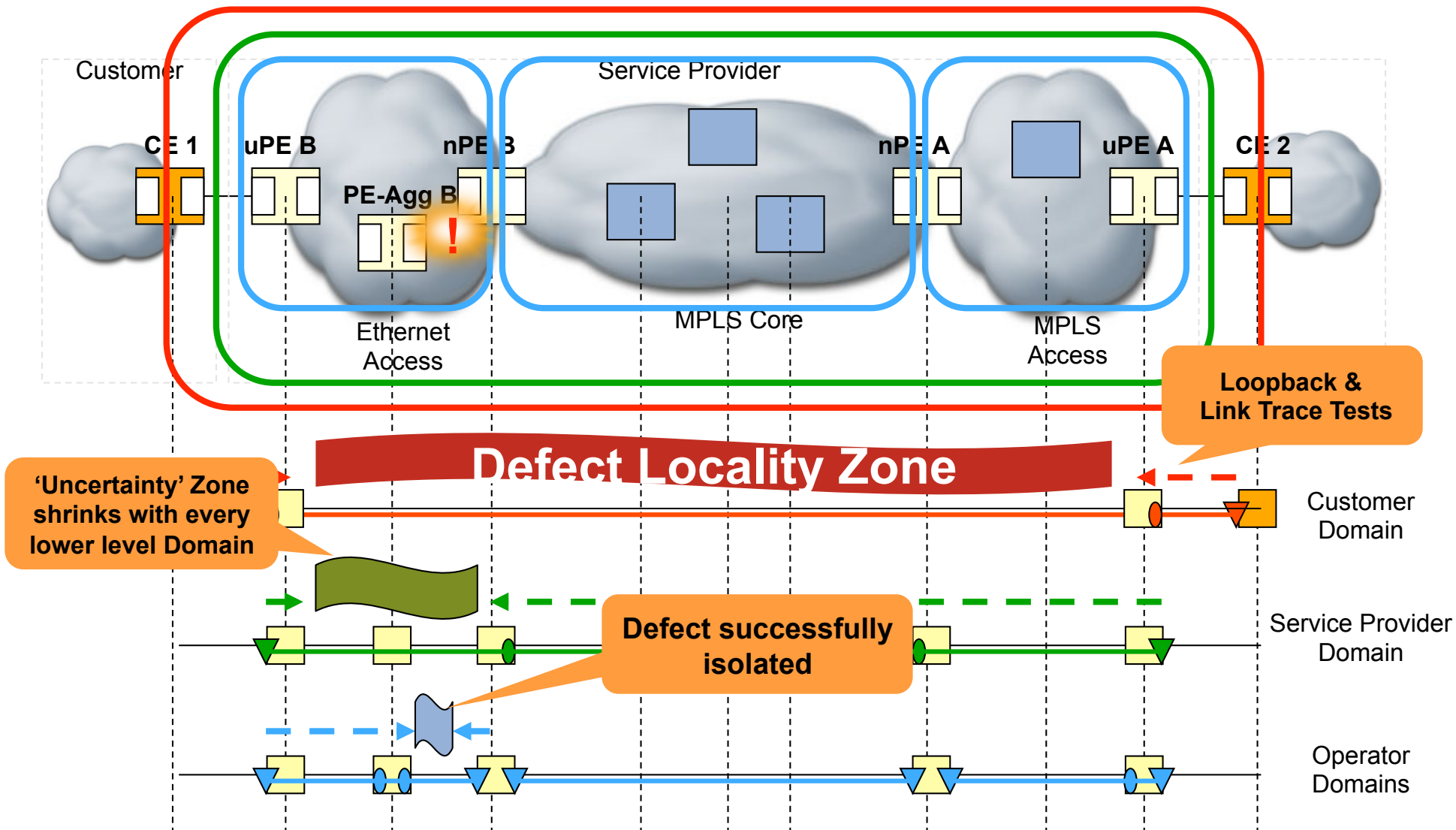
CFM Protocols

Putting Everything Together

1. Run Connectivity Check to proactively detect a soft or hard failure

2. Upon a failure detection, use Loopback to verify it

3. Upon verification, run Traceroute to isolate it; multiple segment LPs can also be used to isolate the fault

4. If the isolated fault points to a virtual circuit, then the OAM tools for that technology can be used to further fault isolation—e.g., for MPLS PW, VCCV and MPLS ping can be used

ITU-T Y.1731

Cisco Public

ITU-T Y.1731 Overview

- ITU-T recommendation that provides mechanisms for user-plane OAM functionality in Ethernet networks Covers:

    Fault Management mechanisms

    Performance Management mechanisms

- Standardized by ITU-T SG 13 in May 2006

    Latest published version dated Feb. 2008 after IEEE 802.1ag standardization

- Frames format (Multicast Address, Ethertype, and common OAM PDU fields) and base functionality are mostly agreed across IEEE 802.1ag and Y.1731

ITU-T Y.1731 Overview
OAM Functions for Fault Management

Feature	ITU-T Y. 1731	IEEE CFM	Comments
Ethernet Continuity Check	ETH-CC	CC	Proactive fault detection, fault notification Not compatible. Different formats for short MA / MEG ID IEEE defines mcast DA CCM, ITU defines mcast/ucast DA CCM
Ethernet Loopback	ETH-LB	LB	On-demand service / fault verification Compatible operations between IEEE and ITU IEEE defines ucast DA LBM, ITU defines mcast/ucast DA LBM
Ethernet Link Trace	ETH-LT	LT	On-demand path discovery / fault isolation Compatible operations between IEEE and ITU
Ethernet Remote Defect Indication	ETH-RDI	RDI	Fault propagation in the backward direction (opposite direction of the fault). IEEE RDI flag and Y.1731 ETH-RDI are in the same position in CCM header. However, CCM formats are not compatible
Ethernet Alarm Indication Signal	ETH-AIS	--	Fault propagation in the forward direction (same direction of the fault) Also used to suppress Loss of Continuity alarms following detection of defect conditions

ITU-T Y.1731 Overview
OAM Functions for Fault Management

Feature	ITU-T Y. 1731	IEEE CFM	Comments
Ethernet Locked Signal	**ETH-LCK**	--	Communicates administrative locking of a MEP Allows intrusive OAM loopback tests (e.g. during turn up)
Ethernet Test Signal	**ETH-Test**	--	One-way on-demand diagnostics
Ethernet Automatic Protection Switching	**ETH-APS**	--	Applications defined in ITU-T G.8031 and G.8032 (Ethernet Linear and Ring Protection Switching)
Ethernet Maintenance Communication Channel	**ETH-MCC**	--	No application / use defined in Y.1731
Ethernet Experimental OAM	**ETH-EXP**	--	No application / use defined in Y.1731
Ethernet Vendor-specific OAM	**ETH-VSP**	--	No application / use defined in Y.1731

Link OAM

IEEE 802.3ah (Clause 57)

 Cisco Public

Link OAM (IEEE 802.3ah, Clause 57)

- Provides mechanisms useful for "monitoring link operation", such as:

  - Link Monitoring

  - Remote Failure Indication

  - Remote Loopback Control

- Defines an optional OAM sublayer

- Intended for single point-to-point IEEE 802.3 links

- Uses "Slow Protocol"[1] frames called OAMPDUs which are never forwarded by MAC clients

- Standardized: IEEE 802.3ah, clause 57 (now in IEEE 802.3-2005)

OSI Model
Application
Presentation
Session
Transport
Network
Data Link
Physical

LAN CSMA/CD Layers

Higher Layers
LLC
OAM (Optional)
MAC
Physical Layer
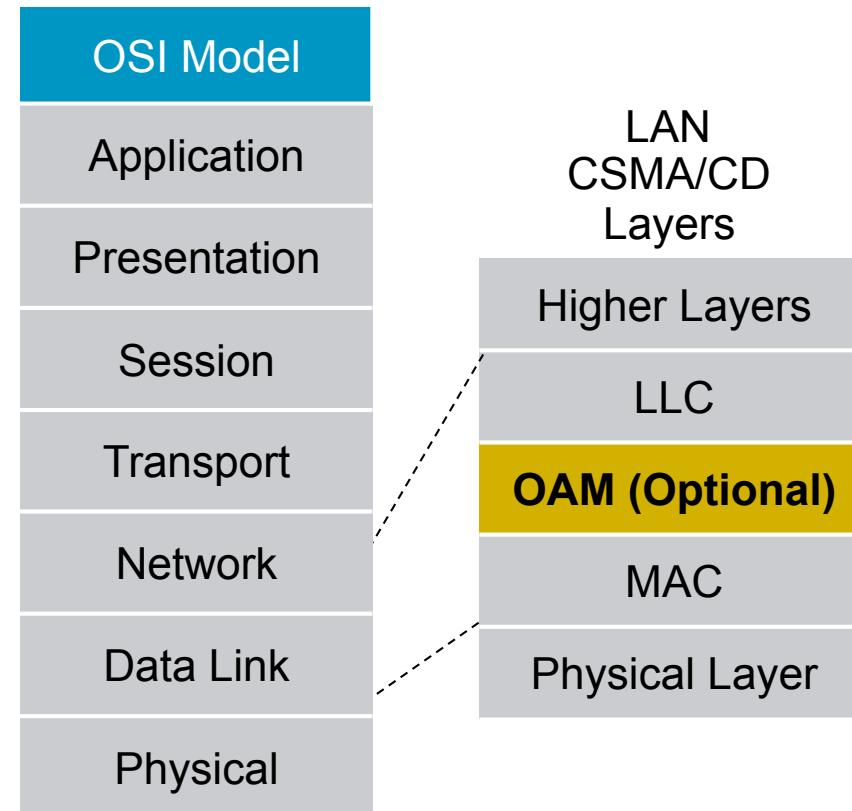
(1) No more than 10 frames transmitted in any one-second period

IEEE 802.3ah
Key Functions

- OAM discovery

  Discover OAM support and capabilities per device

- Link monitoring

  basic error definitions for Ethernet so entities can detect failed and degraded connections

- Fault signaling

  mechanisms for one entity to signal another that it has detected an error

- Remote MIB Variable Retrieval

  Ability to read one/more remote MIB variables from remote DTE

- Remote loopback

  used to troubleshoot networks, allows one station to put the other station into a state whereby all inbound traffic is immediately reflected back onto the link

IEEE 802.3ah
Remote Loopback

- Fault localization and link performance testing

- Loopback Control OAMPDU is used to control a remote OAM client

- Traffic sent from master loopback port is loopback by slave port, except Pause and OAMPDU

Master OAM

OAM
MAC
PHY

Slave OAM

OAM
MAC
PHY
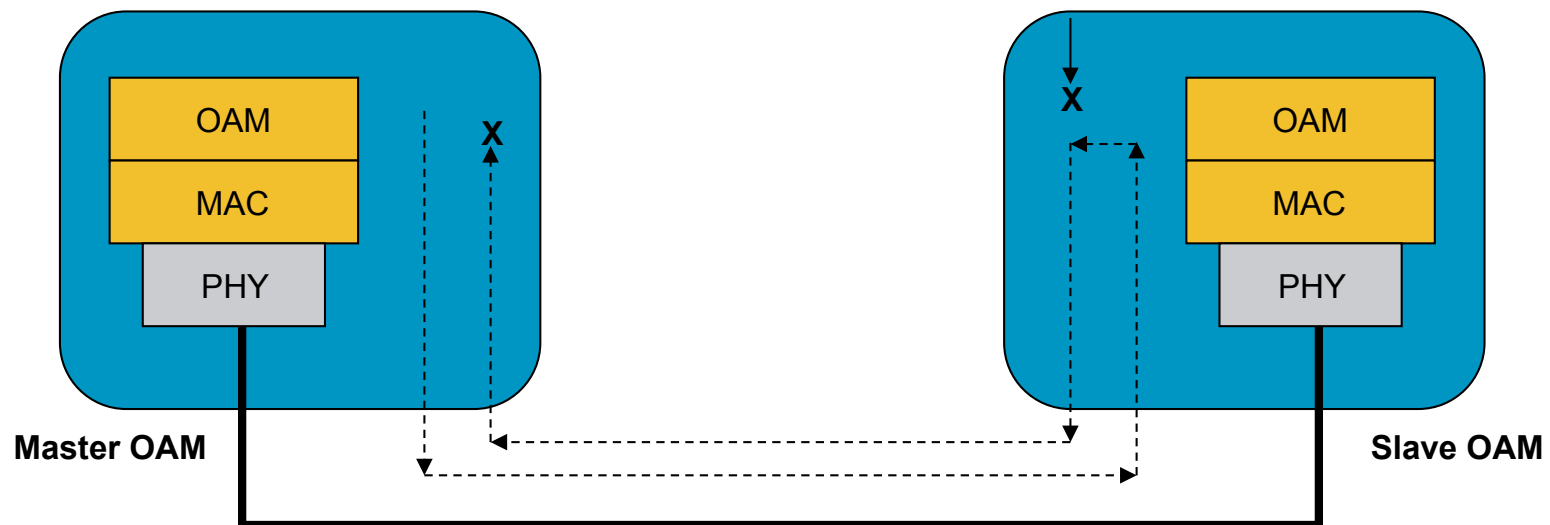
Ethernet Data-Plane Loopback
(Proprietary today)

- Ethernet data traffic can be looped back on a per port / per VLAN basis

- Use cases:

  Service turn-up

  Post service turn-up troubleshooting

  Out-of-service throughput testing

- Enabled via CLI configuration

- Configurable SRC and DST MAC Addresses swap

- Configurable direction:

  Facility Loopback (facing cloud)

  Terminal Loopback (facing bridge)

- Central Test Head allows for flexible and sophisticated test traffic patterns

- Complements CFM Loopback

- Available in Cisco ME-3400E

Central Test Head

Carrier Ethernet Network

Facility Loopback

NNI

ME 3400E

Terminal Loopback

UNI

Customer CPE
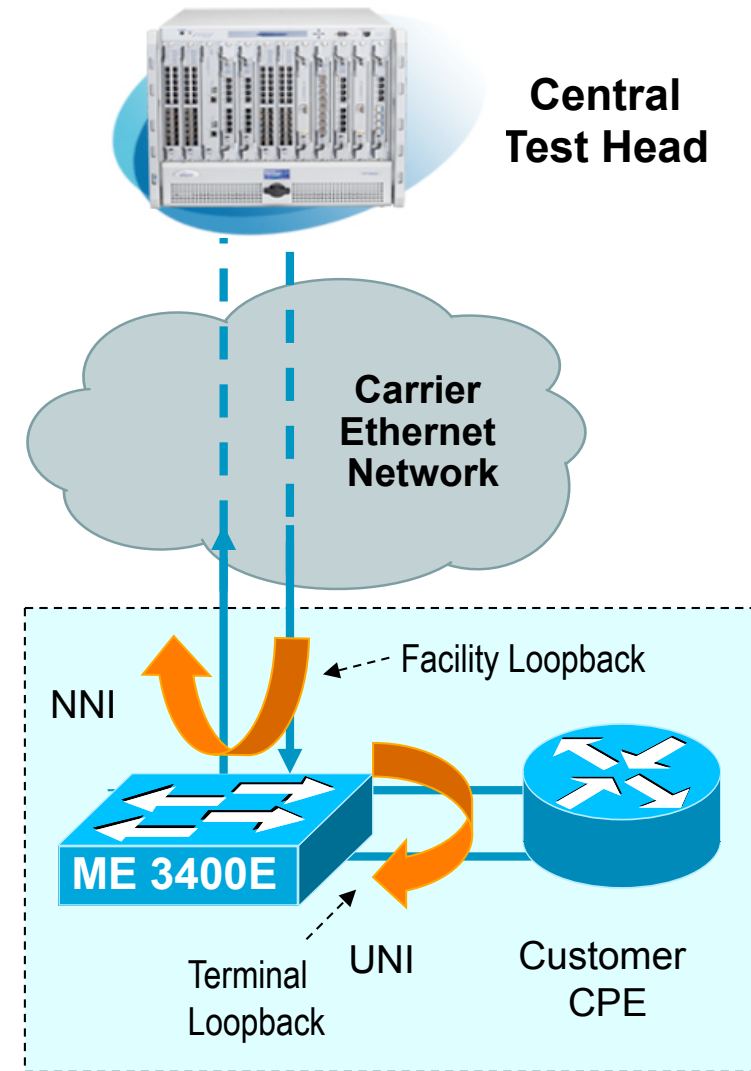
Ethernet Local Management Interface

MEF-16

Ethernet LMI
Overview

- Provides protocol and mechanisms used for:

    Notification of EVC addition, deletion or status (Active, Not Active, Partially Active) to CE

    Communication of UNI and EVC attributes to CE (e.g. CE-VLAN to EVC map)

    Cisco Enhancement — CE auto-configuration

    Notification of Remote UNI name and status to CE

- Asymmetric protocol based on Frame Relay LMI, mainly applicable to the UNI (UNI-C and UNI-N)

- Specification completed by MEF: http://www.metroethernetforum.org/PDFs/Standards/MEF16.doc
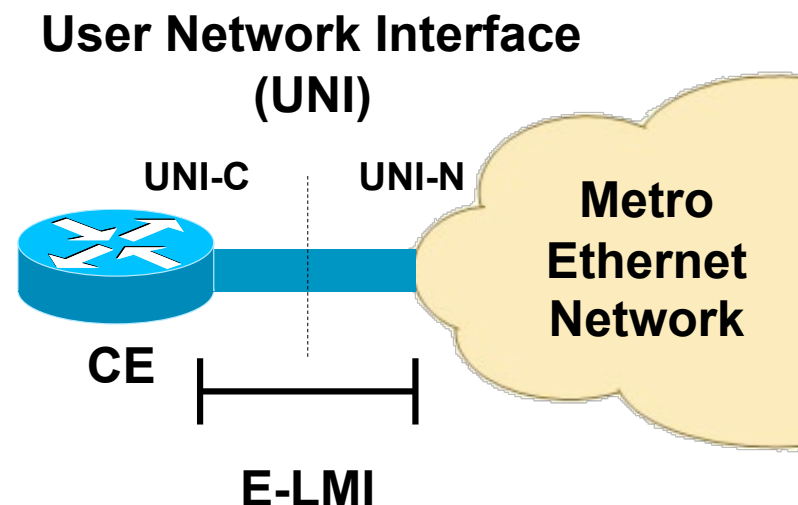
User Network Interface (UNI)

UNI-C   UNI-N

Metro Ethernet Network

CE

E-LMI

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE Notification

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

┅┅┅► ELMI Status Enquiry message (Full Status report)

◄─── ELMI Status message (Full Status report)

Example:

Local UNI ID	CE11_UNI
CE-VLAN/EVC Map type	Service_Multiplexing
EVC ID	EVC_P2P_100
EVC Type	Point_to_Point
CE-VLAN/EVC Map	vlan 100
EVC Status	New, Active
Remote UNI count – configured	1
Remote UNI count – active	1
Remote UNI ID	CE31_UNI
Remote UNI status	UP

Cisco enhancements to MEF ELMI

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE Notification

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

```
CE11#show ethernet lmi evc map interface gig0/0
UNI Id: CE11_UNI
St  Evc Id                CE-VLAN
--- --------------------- --------
 A EVC_MP_250             250
 A EVC_P2P_100            100
  Key: St=Status, A=Active, P=Partially Active,
I=Inactive,
      *=Default EVC, ?=Link Down
```

```
CE11#show ethernet lmi evc detail EVC_P2P_100
EVC Id: EVC_P2P_100
interface GigabitEthernet0/0
  Time since Last Full Report: 00:21:23
  Ether LMI Link Status: Up
  UNI Status: Up
  UNI Id: CE11_UNI
  CE-VLAN/EVC Map Type: Bundling
  VLAN: 100

  EVC Status: Active
  EVC Type: Point-to-Point
  Remote UNI Count: Configured = 1, Active = 1

UNI Id                   UNI Status    Port
------                   ----------    ----
CE31_UNI                 Up            Remote
```

```
CE11#show ethernet lmi evc detail EVC_MP_250
EVC Id: EVC_MP_250
interface GigabitEthernet0/0
  Time since Last Full Report: 00:25:54
  Ether LMI Link Status: Up
  UNI Status: Up
  UNI Id: CE11_UNI
  CE-VLAN/EVC Map Type: Bundling
  VLAN: 250

  EVC Status: Active
  EVC Type: Multipoint-to-Multipoint
  Remote UNI Count: Configured = 2, Active = 2

UNI Id                   UNI Status    Port
------                   ----------    ----
CE12_UNI                 Up            Remote
CE31_UNI                 Up            Remote
```

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE Notification—VLAN ID Missmatch

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

CE Configured with the incorrect C-VLAN (e.g. vid 1300)

```
CE11(config)#interface gig0/0.100
CE11(config-subif)#encapsulation dot1Q 1300

Jan 26 00:15:39.546: %ETHER_LMI-6-MISMATCHED_VLAN_NOT_CONFIGURED: VLAN 100 not
Configured but in VLAN mapping for UNI GigabitEthernet0/0

Jan 26 00:15:39.546: %ETHER_LMI-6-MISMATCHED_VLAN_CONFIGURED: VLAN 1300 configured
but not in VLAN mapping for UNI GigabitEthernet0/0 Interface

CE11#show ip interface brief
Interface                  IP-Address      OK? Method Status            Protocol
<snip>
GigabitEthernet0/0.100     100.100.100.11  YES NVRAM  down              down
```

Proactive ELMI Action
at CPE

Ethernet OAM Interworking

What Is OAM Interworking?

- Strict OAM layering should be honored: messages should not cross layers
- OAM Messages should not leak outside domain boundaries within a layer
- Interworking is event translations & not necessarily 1:1 message mapping
- Interworking may be inter-layer and intra-layer

Event Translation inter-domains intra-layer

Server Layers feed events into Client Layers

Service OAM

Network OAM

Network OAM

Transport OAM

Transport OAM

Transport OAM

Transport OAM
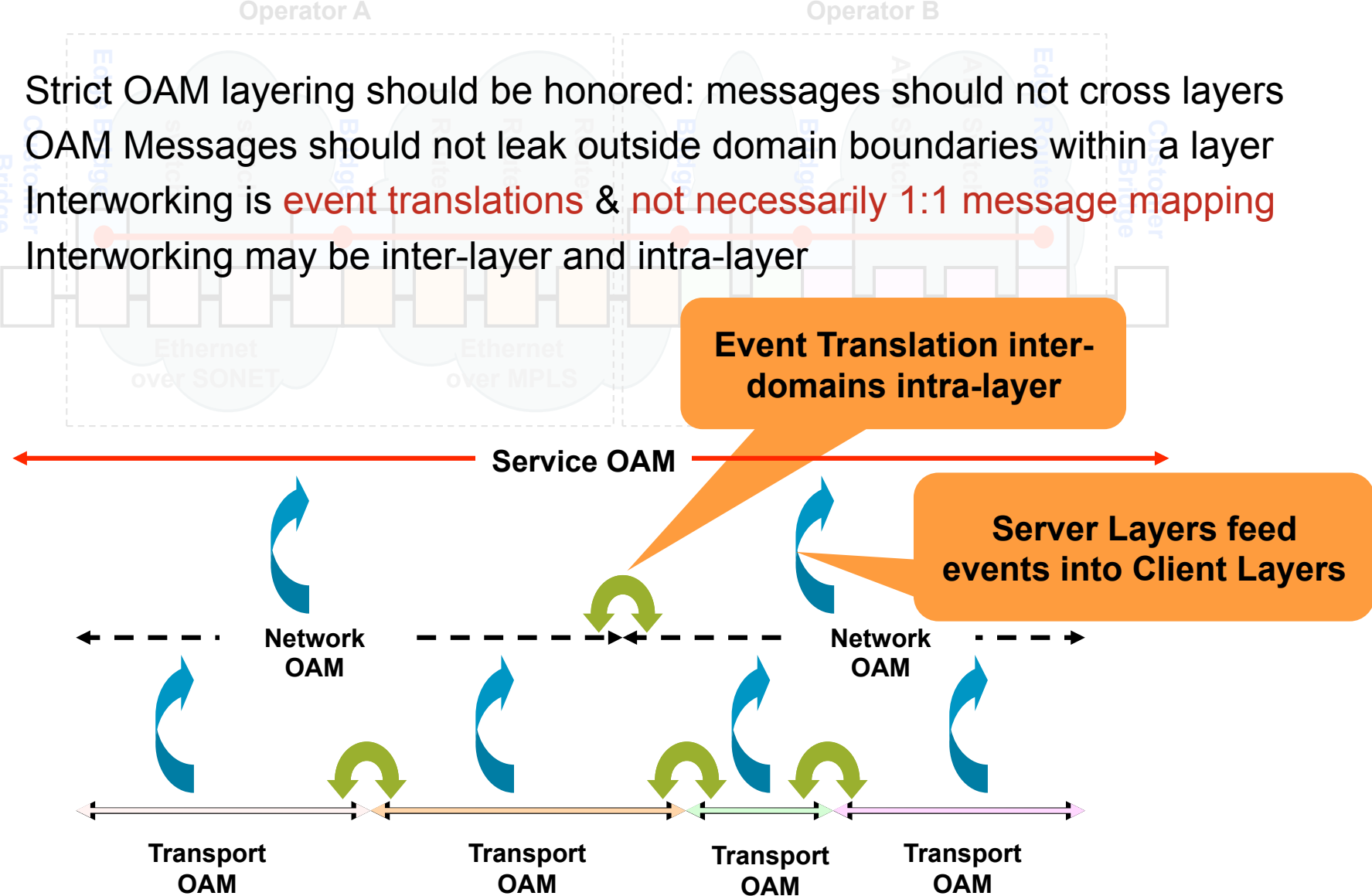
Interworking Scenarios

CFM ➤ **E-LMI**

Link OAM ➤ **CFM**

MPLS PW OAM ➤ **E-LMI**

Fault Management Scenarios

High Level Topology

Cisco 3800

Catalyst 3750-ME

MPLS Core

L3 VPN "A"

L3 VPN "B"

CFM IEEE 802.1ag

Ethernet access to MPLS VPN (EoMPLS)

L2VPN P2P / MP (EoMPLS / VPLS)

E-LMI

MPLS Aggregation

Cisco 7600

Access

Cisco ME-3400

Cisco 1800

Link OAM IEEE 802.3ah

Cisco 2800
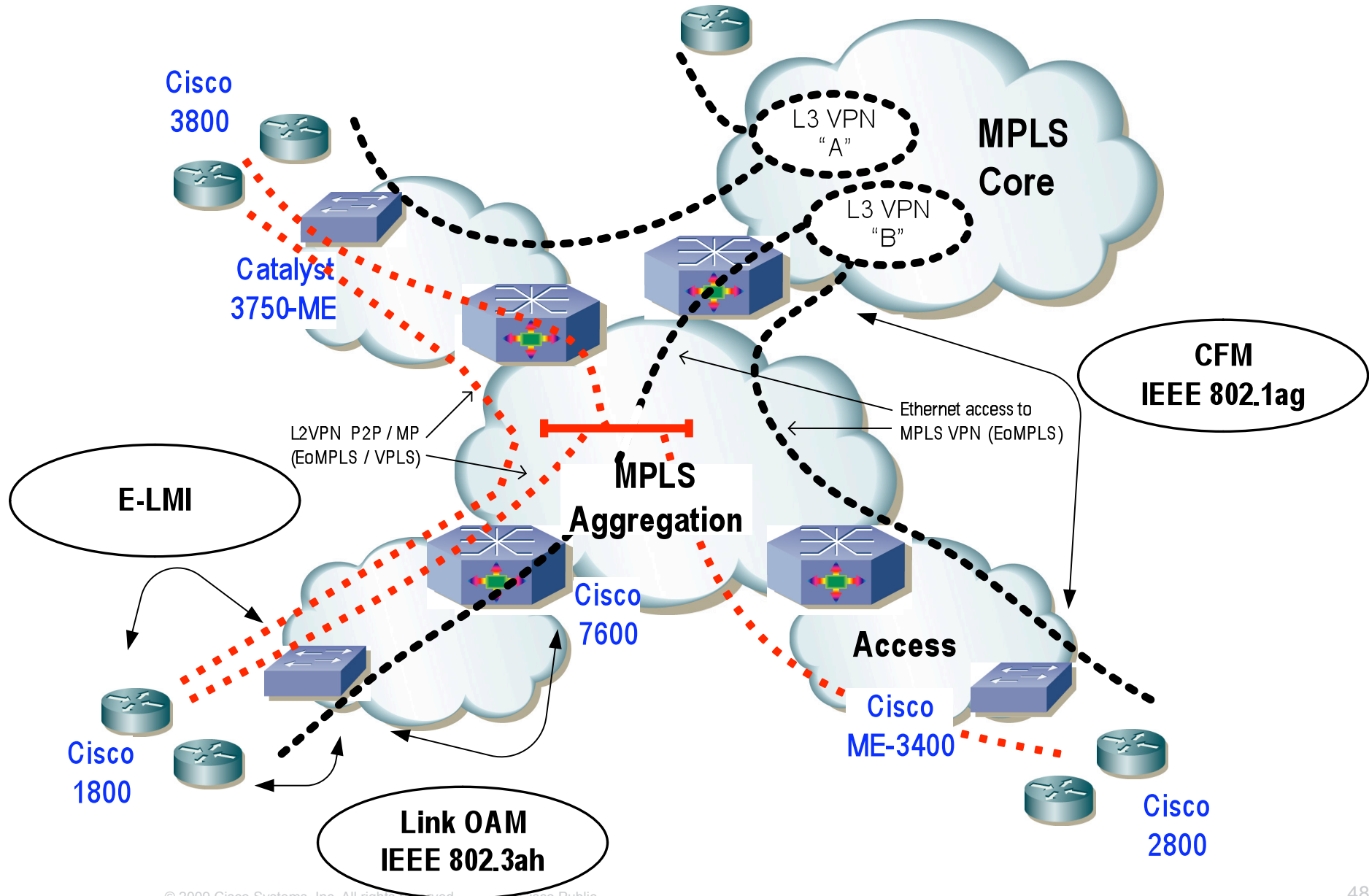
Fault Management Scenarios

Number	Description
1	End-to-End Service/Path Verification Fault Verification/Isolation
2	Using E-OAM for Ethernet Access to L3VPN
3	E2E CPE Fault Notification & CPE Corrective Action using Ethernet OAM Interworking
4	Ethernet OAM and MPLS OAM Interworking

Operational Scenario 1

- Problem Statement

  Fault Verification and Fault Isolation of ethernet connectivity issues

- Problem Solution

  IEEE 802.1ag (CFM) Ping and Traceroute utilities for reactive troubleshooting of service connectivity issues

Operational Scenario 1 (cont.)

- **Problem Statement**

  Fault Verification and Fault Isolation of ethernet connectivity issues

- **Problem Solution**

  IEEE 802.1ag (CFM) Ping and Traceroute utilities for reactive
  troubleshooting of service connectivity issues

Customer

Service Provider

uPE11

uPE31

```
uPE11#ping ethernet mpid 3100 level 4 vlan 100

Type escape sequence to abort.
Sending 5 Ethernet CFM loopback messages, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

Ethernet
Access

CE 11   uPE 11   PE-   31

Customer
Domain

Service Provider
Domain

Operator Domain

Operational Scenario 1 (cont.)

- Problem Statement

  Fault Verification and Fault Isolation of ethernet connectivity issues

- Problem Solution

  IEEE 802.1ag (CFM) Ping and Traceroute utilities for reactive
  troubleshooting of service connectivity issues

uPE11 **nPE11** **nPE31** **uPE31**

```
uPE11#traceroute ethernet 0012.017c.3d00 level 4 vlan 100
Type escape sequence to abort. TTL 255. Per-Hop Timeout is 10 seconds
Tracing the route to 0012.017c.3d00 on Domain PROVIDER_DOMAIN, Level 4, vlan 100
Traceroute sent via GigabitEthernet0/16


                              MAC      Ingress Ingress Action   Relay Action
      Hops    Host            Forwarded Egress  Egress Action    Next Hop
--------------------------------------------------------------------------------

B 1   nPE11                   0013.5f21.cec5 Gi3/1  IngOk         RlyCCDB
                              Forwarded
B 2   nPE31                   0007.8508.3485                      RlyFDB
                              Forwarded Gi3/1  EgrOK              uPE31
! 3   uPE31                   0012.017c.3d00 Gi1/1/1 IngOk        RlyNone
```

Operational Scenario 1 (cont.)

- Problem Statement

  Fault Verification and Fault Isolation of ethernet connectivity issues
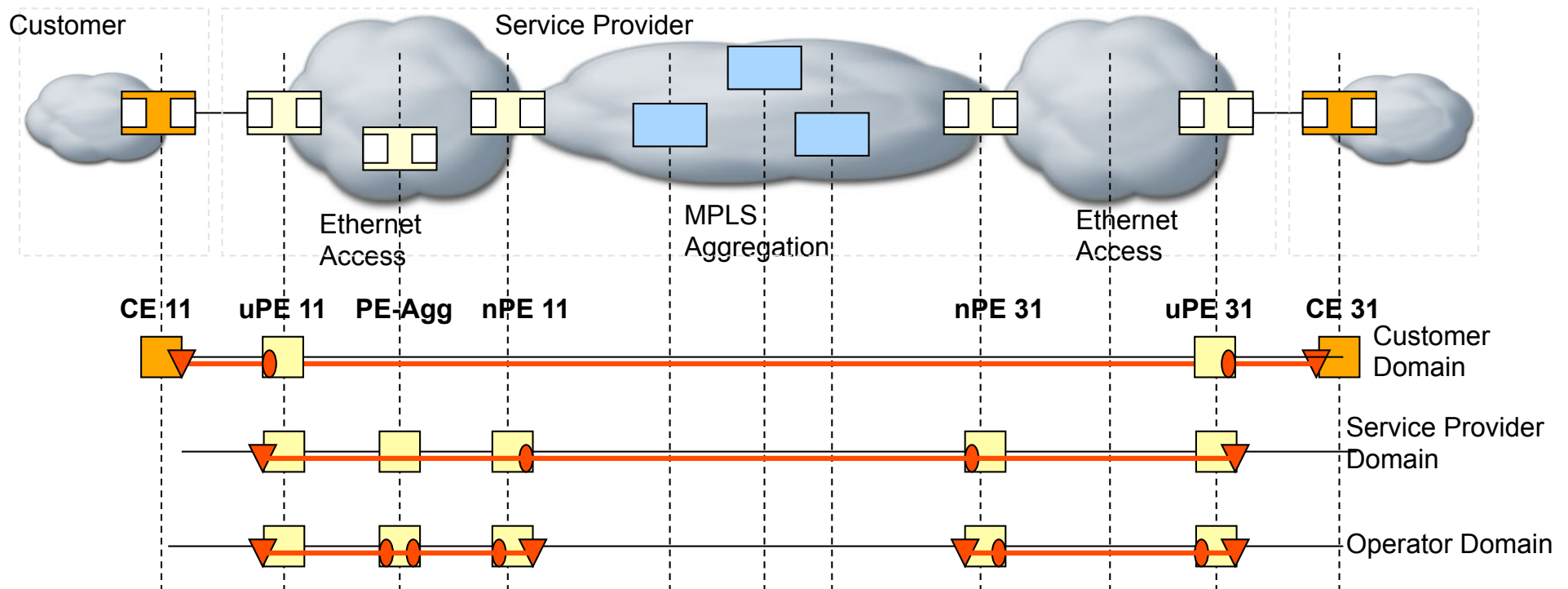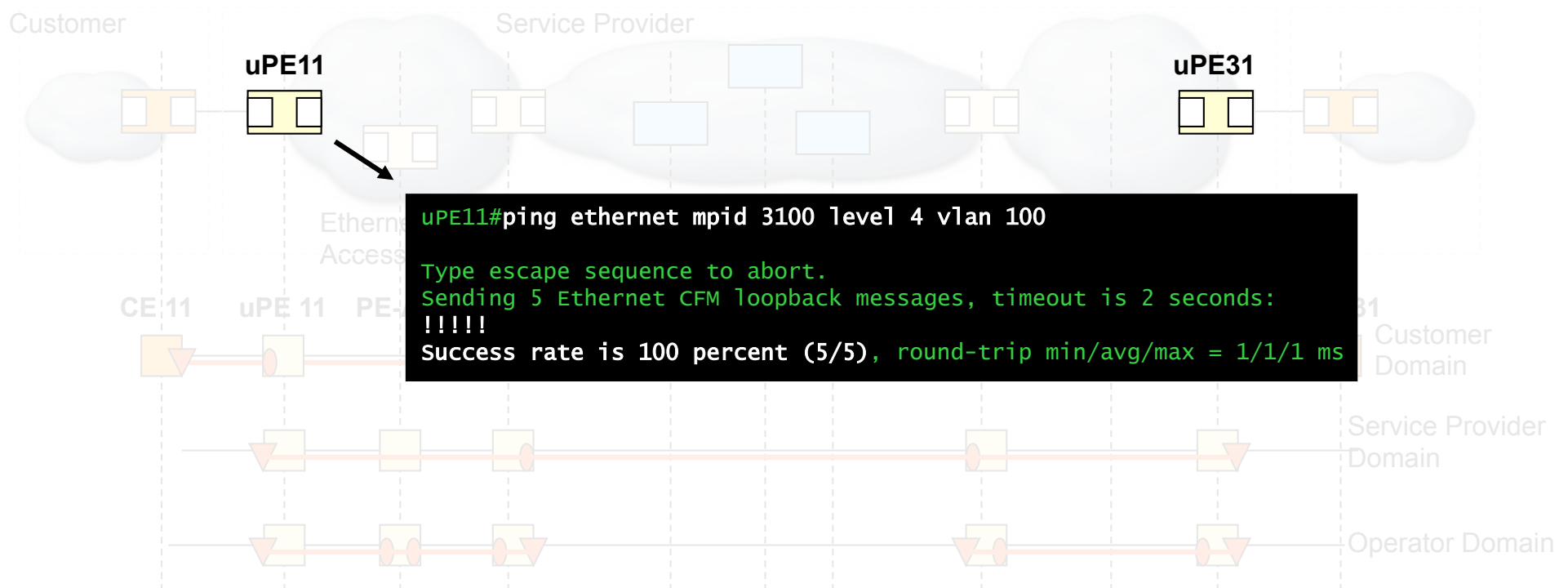
- Problem Solution

  IEEE 802.1ag (CFM) Ping and Traceroute utilities for reactive troubleshooting of service connectivity issues

```
nPE31(config)#int gig3/1
nPE31(config-if)#shutdown
```

Customer   Service Provider

uPE11   **nPE11**   **nPE31**   **uPE31**

Proactive
Fault Notification

Reactive
Fault Isolation

```
Jan 26 03:14:10.608: %ETHER_SERVICE-6-EVC_STATUS_CHANGED: status of EVC_P2P_100
changed to InActive

uPE11#traceroute ethernet 0012.017c.3d00 level 4 vlan 100
Type escape sequence to abort. TTL 255. Per-Hop Timeout is 10 seconds
Tracing the route to 0012.017c.3d00 on Domain PROVIDER_DOMAIN, Level 4, vlan 100
Traceroute sent via GigabitEthernet0/16


-------------------------------------------------------------------------------
                                  MAC        Ingress Ingress Action   Relay Action
   Hops    Host                   Forwarded  Egress  Egress Action    Next Hop
-------------------------------------------------------------------------------
B  1     nPE11                  0013.5f21.cec5 Gi3/1  IngOk            RlyCCDB
                                Forwarded
B  2     nPE31                  0007.8508.3485                         RlyCCDB
                                Not Forwarded  Gi3/1  EgrDown
```

Operational Scenario 2

- Problem Statement

  Troubleshooting Ethernet access connectivity problems by L3VPN PE

- Problem Solution

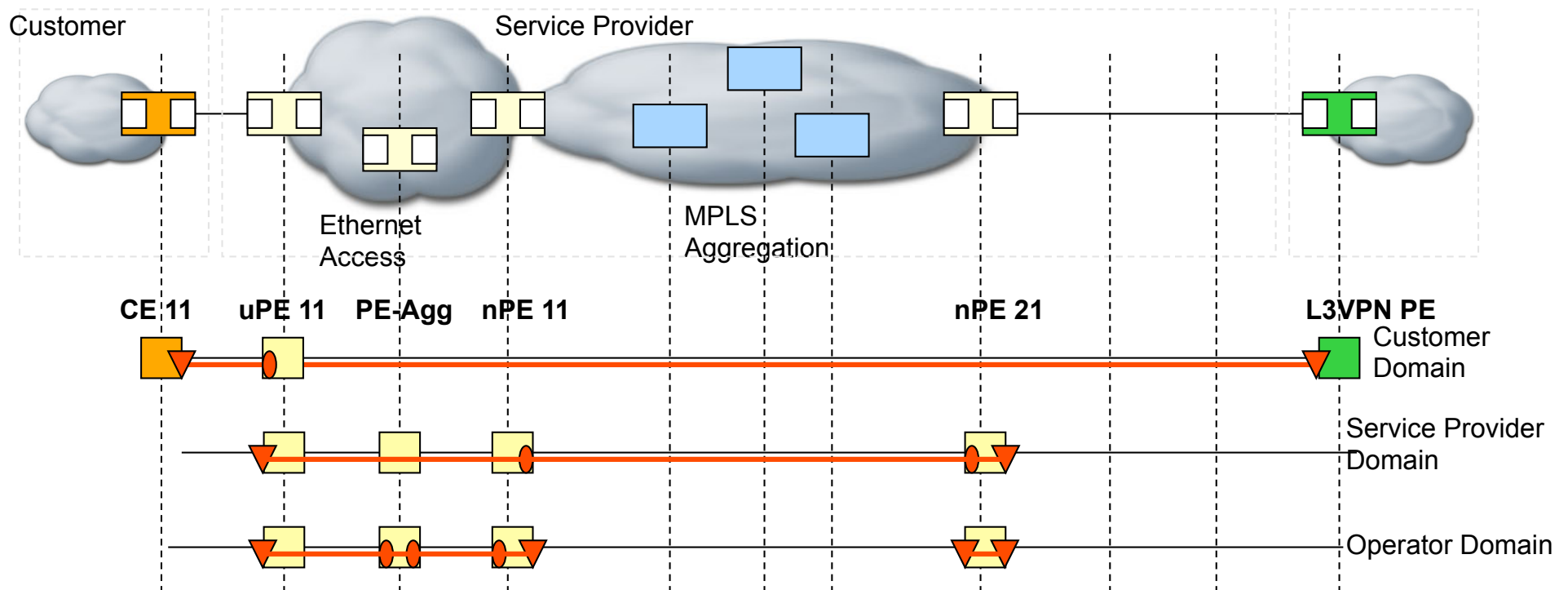 IEEE 802.1ag CFM with Outward-facing / Down MEPs at L3VPN PE

Operational Scenario 2 (cont.)

- Problem Statement

  Troubleshooting Ethernet access connectivity problems by L3VPN PE

- Problem Solution

  IEEE 802.1ag CFM with Outward-facing / Down MEPs at L3VPN PE

```
L3VPN-PE#show running-config | begin GigabitEthernet3/0/0
interface GigabitEthernet3/0/0
 description L3VPN PE to nPE21 gig3/3
 ethernet cfm mep level 4 outward domain PROVIDER_DOMAIN mpid 2450 vlan 450
 ethernet cfm mep level 4 outward domain PROVIDER_DOMAIN mpid 2350 vlan 350
!
interface GigabitEthernet3/0/0.350
 description To CE31
 encapsulation dot1Q 350
 ip vrf forwarding BLUE
 ip address 1.1.1.1 255.255.255.0
!
interface GigabitEthernet3/0/0.450
 description To CE21
 encapsulation dot1Q 450
 ip vrf forwarding RED
 ip address 1.1.1.1 255.255.255.0


L3VPN-PE#show ethernet cfm maintenance-points remote
Can only Ping/Traceroute to remote MEPs marked with *

MPID  Level Mac Address      Vlan PortState InGressPort     Age(sec)  Service ID
3350* 4     0012.017c.3d00 350  UP        Gi3/0/0.350     20        customer_350_provider
2451* 4     0019.552c.0b80 450  UP        Gi3/0/0.450     23        customer_450_provider
```

uPE 21   L3VPN PE
                      Customer
                      Domain

Service Provider
Domain

Operator Domain
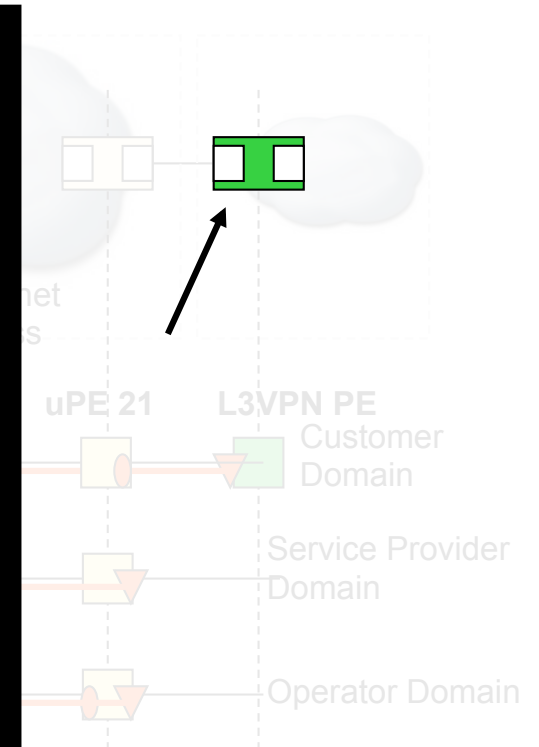
Operational Scenario 3

- Problem Statement

    End to End Fault Notification of service status to Customer Equipment

- Problem Solution

    IEEE 802.3ah to IEEE 802.1ag (CFM) Inter-Working (IW) for propagation of EVC status and CFM to E-LMI IW for notification to CE

Operational Scenario 3 (cont.)

- **Problem Statement**

  End to End Fault Notification of service status to Customer Equipment

- **Problem Solution**

  IEEE 802.3ah to IEEE 802.1ag (CFM) Inter-Working (IW) for propagation of EVC status and CFM to E-LMI IW for notification to CE

Operational Scenario 3 (cont.)

- Problem Statement

    End to End Fault Notification of service status to Customer Equipment

- Problem Solution

    IEEE 802.3ah to IEEE 802.1ag (CFM) Inter-Working (IW) for propagation of EVC status and CFM to E-LMI IW for notification to CE


```
CE31(config)#int fast 0/0
CE31(config-if)#shutdown

Jan 26 03:40:08.176: %ETHERNET_OAM-6-EXIT_SESSION: The client on interface Fa0/0
has left the OAM session.
Jan 26 03:40:10.180: %LINK-5-CHANGED: Interface FastEthernet0/0, changed state to
administratively down
Jan 26 03:40:11.180: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0,
changed state to down
```
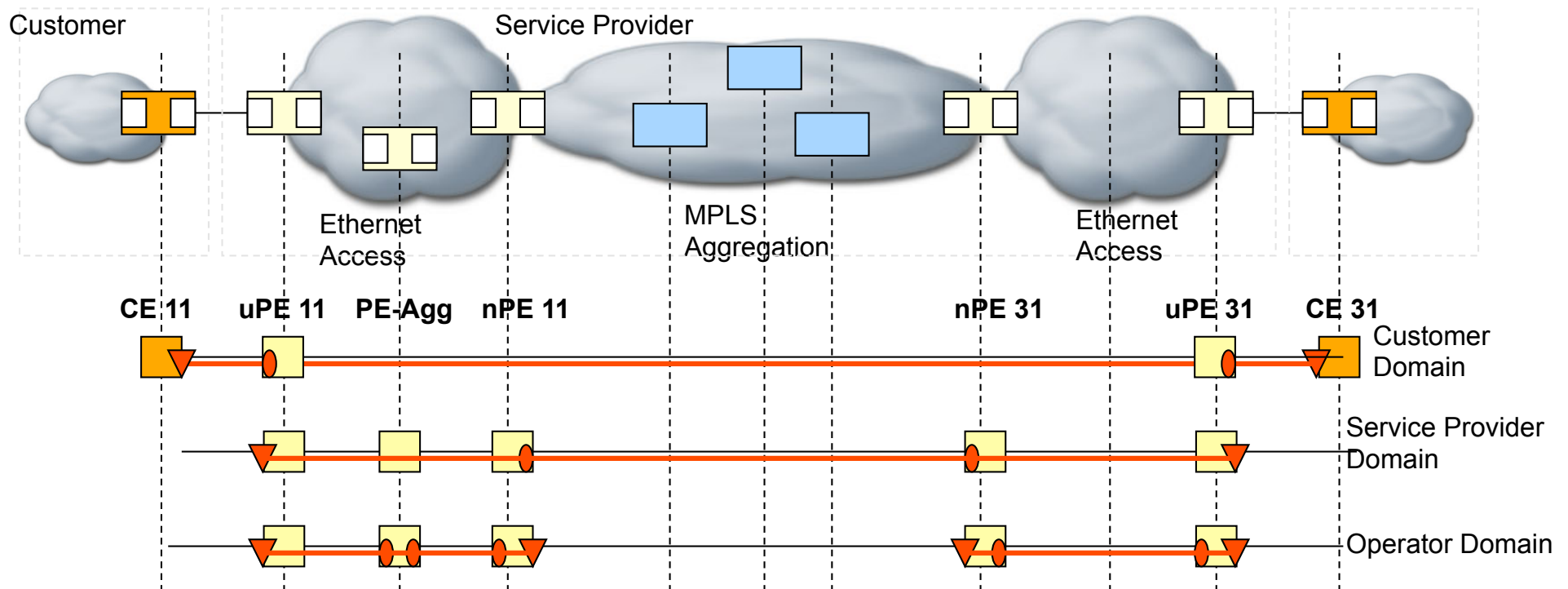
Operational Scenario 3 (cont.)

- Problem Statement

    End to End Fault Notification of service status to Customer Equipment

- Problem Solution

    IEEE 802.3ah to IEEE 802.1ag (CFM) Inter-Working (IW) for propagation of EVC status and CFM to E-LMI IW for notification to CE


```
Jan 26 03:40:08.176: %ETHERNET_OAM-6-RFI: The client on interface Fa1/0/1 has received a remote failure
Indication from its remote peer (failure reason = remote client administratively turned off)

Jan 26 03:40:08.184: %ETHER_SERVICE-6-EVC_STATUS_CHANGED: status of EVC_P2P_100 changed to InActive
Jan 26 03:40:09.191: %ETHERNET_OAM-6-EXIT_SESSION: The client on interface Fa1/0/1 has left the OAM session.

uPE31#show ethernet service evc
Identifier                      Type    Act-UNI-cnt Status
EVC_P2P_100                     P-P         1       InActive

uPE31#show ethernet lmi evc
UNI Id: CE31_UNI
St  Evc Id                                  CE-VLAN
--- ------------------------------------    ------------------------------------
 ?I EVC_P2P_100                             100

Key: St=Status, A=Active, P=Partially Active, I=Inactive, *=Default EVC, ?=Link Down
```
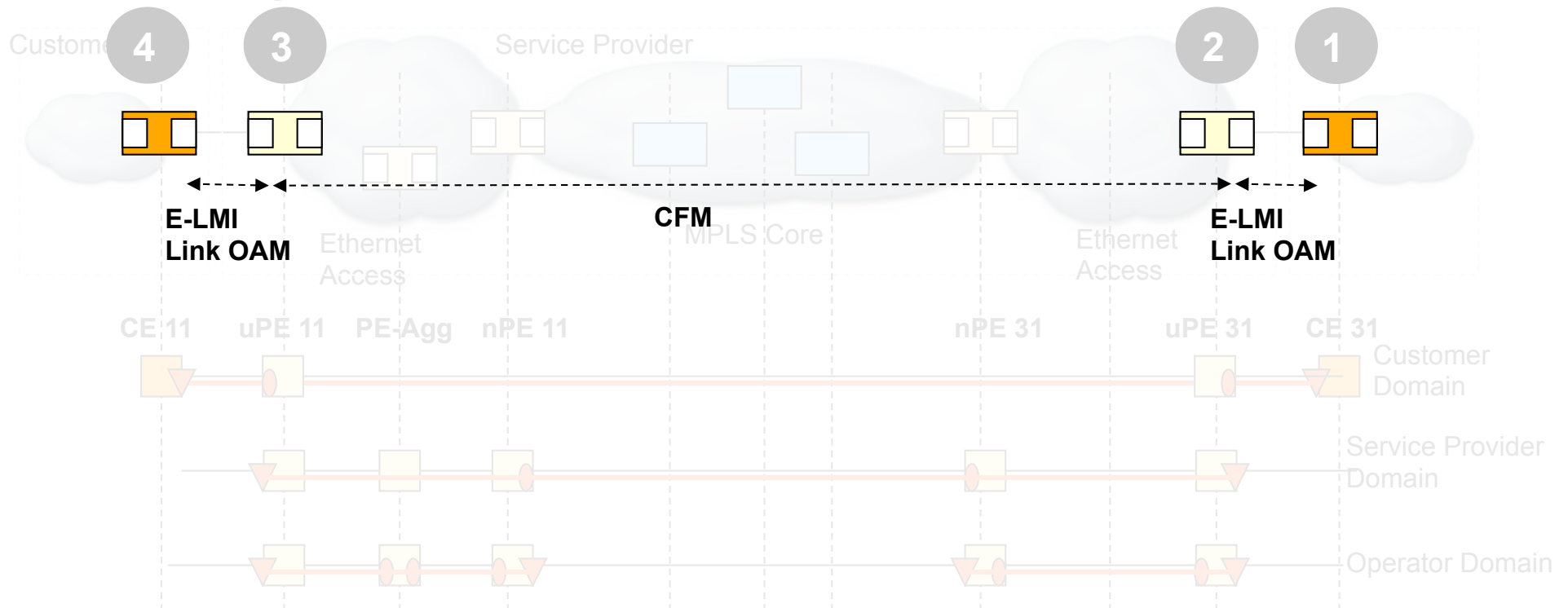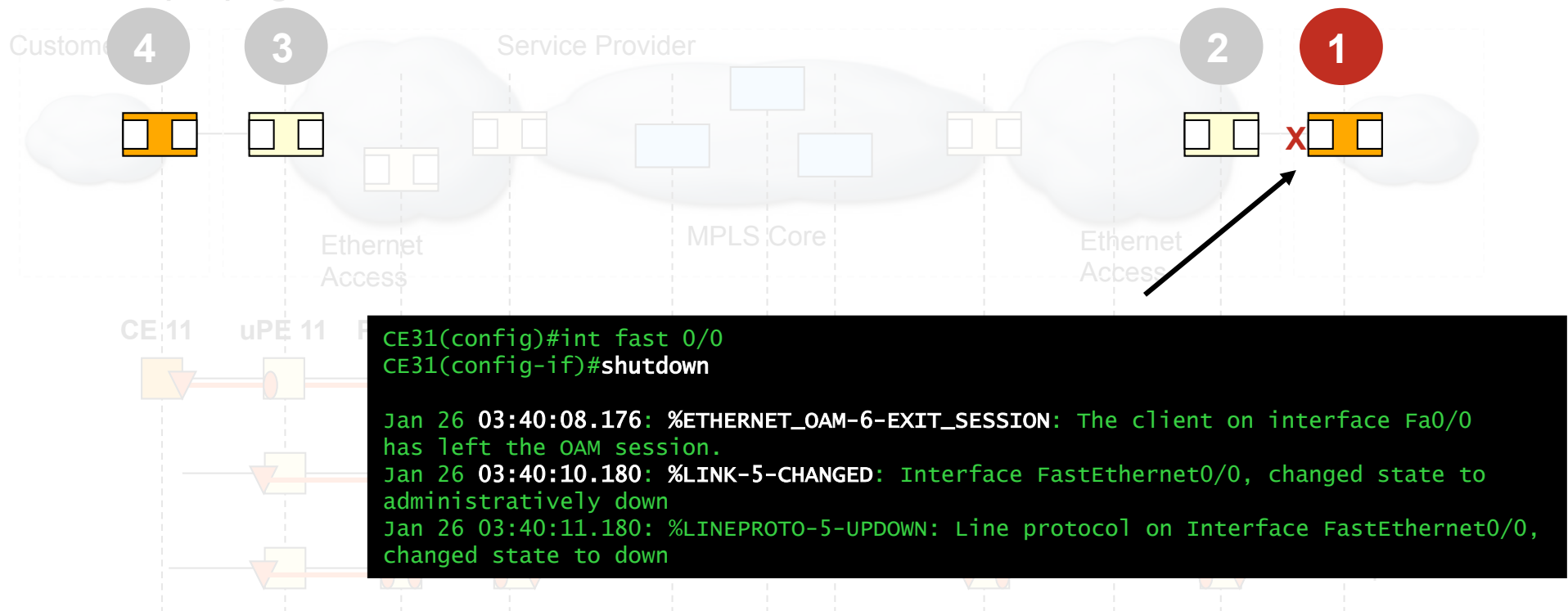
Operational Scenario 3 (cont.)

- Problem Statement

  End to End Fault Notification of service status to Customer Equipment

- Problem Solution

  IEEE 802.3ah to IEEE 802.1ag (CFM) Inter-Working (IW) for propagation of EVC status and CFM to E-LMI IW for notification to CE
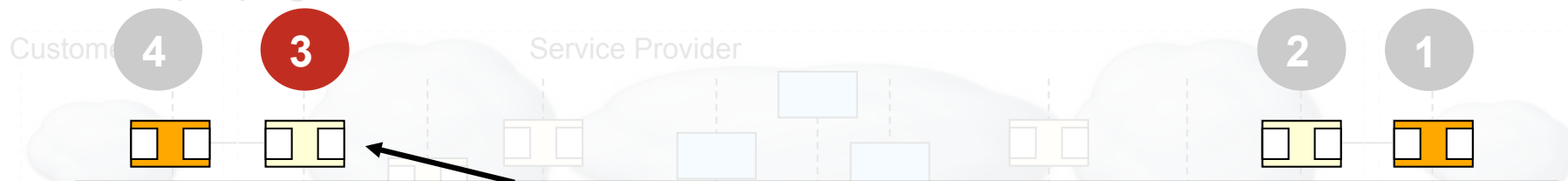

```
Jan 26 03:40:36.093: %ETHER_SERVICE-6-EVC_STATUS_CHANGED: status of EVC_P2P_100 changed to InActive

uPE11#show ethernet cfm maintenance-point remote
MPID Level Mac Address     Vlan PortState InGressPort     Age(sec) Service ID
3100 4     0012.017c.3d00 100  DOWN      Gi0/16          21       customer_100_provider

uPE11#show ethernet service evc
Identifier                      Type    Act-UNI-cnt Status
EVC_P2P_100                     P-P     1           InActive

uPE11#show ethernet lmi evc
UNI Id: CE11_UNI
St  Evc Id                                          CE-VLAN
--- ---------------------------------------         ---------------------------------
  I EVC_P2P_100                                     100

Key: St=Status, A=Active, P=Partially Active, I=Inactive, *=Default EVC, ?=Link Down
```
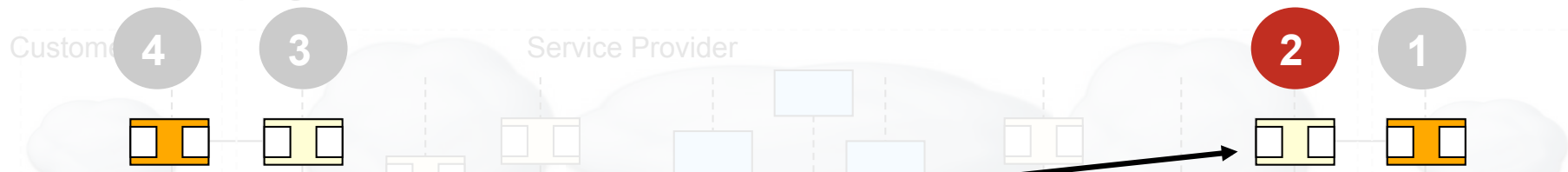
Operational Scenario 3 (cont.)

- Problem Statement

  End to End Fault Notification of service status to Customer Equipment

- Problem Solution

  IEEE 802.3ah to IEEE 802.1ag (CFM) Inter-Working (IW) for propagation of EVC status and CFM to E-LMI IW for notification to CE

Customer   **4**   **3**   Service Provider   **2**   **1**

Ethernet   MPLS Core   Ethernet

Proactive E2E
Fault Notification

Proactive CPE
Action

```
CE11#show ethernet lmi evc
UNI Id: CE11_UNI
St  Evc Id                                      CE-VLAN
--- ------------------------------------------  ---------------------------------
 I  EVC_P2P_100                                 100

Key: St=Status, A=Active, P=Partially Active, I=Inactive, *=Default EVC, ?=Link Down

CE11#show ip interface brief
Interface                   IP-Address      OK? Method Status              Protocol
<snip>
GigabitEthernet0/0.100      100.100.100.11  YES manual down                down
```
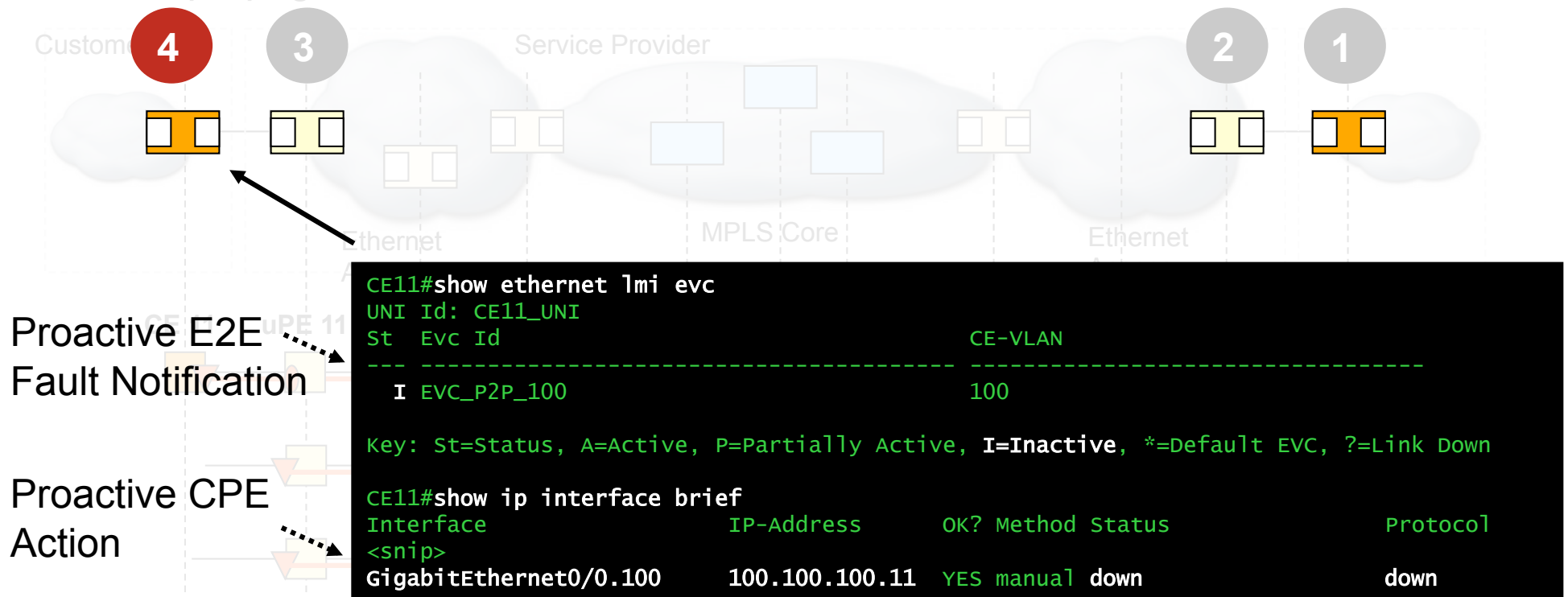
Operational Scenario 4
Ethernet and MPLS OAM

- ## Problem Statement

  Troubleshooting Ethernet services over MPLS

- ## Problem Solution

  CFM for detection, CFM and MPLS OAM for verification and isolation

MPLS domain

EoMPLS Pseudowire

Vlan 100

VCID 100

101.101.101.101

102.102.102.102

Vlan 100

Gi0/4
MPID 110

Gi0/3   Gi0/3   Gi0/14

Gi2/0/2

Gi2/0/2   Gi1/1/2   Gi1/0/2

Gi0/4

Gi0/1
MPID 112

34002C
S-1

3400G-1

7604-1

7604-2

3750-
ME-1

34002C
S-2

▶ MEP

● MIP
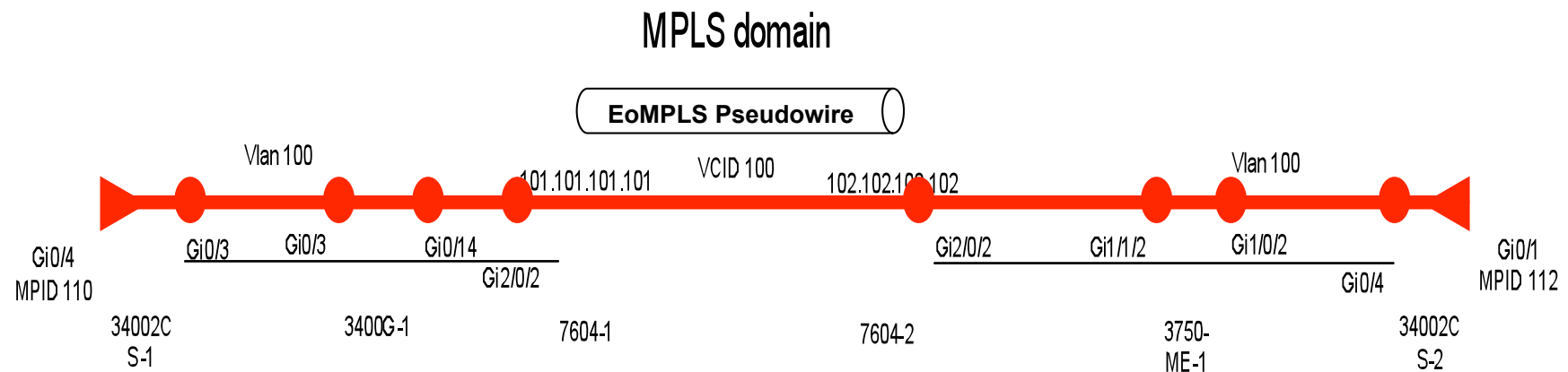
Operational Scenario 4 …Cont
Ethernet and MPLS OAM

```
Received SNMPv2c Trap:
Community: TEST
From: 127.0.0.1
sysUpTimeInstance = 668615
snmpTrapOID.0 = cEtherCfmCcMepDown
cEtherCfmEventServiceId.1.3.40 = john-p2p
cEtherCfmEventLclMacAddress.1.3.40 = 00 19 30 c0 bb 00
cEtherCfmEventLclMepCount.1.3.40 = 1
cEtherCfmEventLclIfCount.1.3.40 = 1
cEtherCfmEventRmtMepid.1.3.40 = 112
cEtherCfmEventRmtMacAddress.1.3.40 = 00 19 30 c0 ad 80
cEtherCfmEventCode.1.3.40 = 5
```
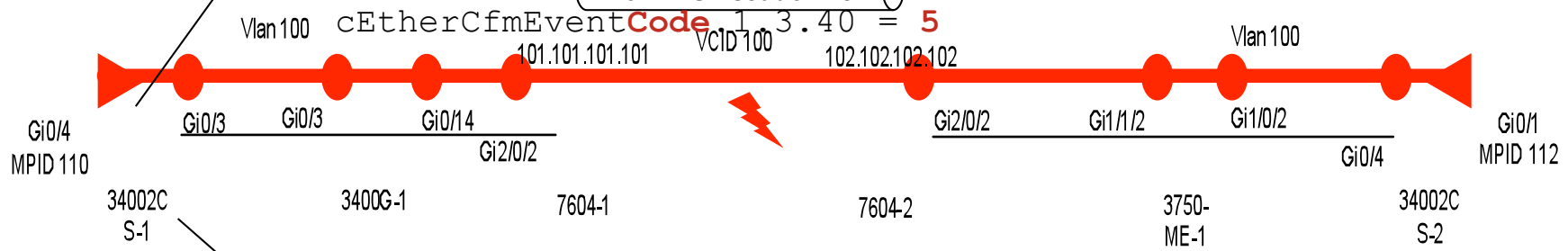

Vlan 100   101.101.101.101   VCID 100   102.102.102.102   Vlan 100

Gi0/4   Gi0/3   Gi0/3   Gi0/14   Gi2/0/2   Gi1/1/2   Gi1/0/2   Gi0/1
MPID 110   Gi2/0/2   Gi0/4   MPID 112

34002C   3400G-1   7604-1   7604-2   3750-   34002C
S-1   ME-1   S-2

```
ME3400G-2CS-1#show ethernet cfm errors
Level Vlan MPID Remote MAC      Reason                 Service ID
5     100  112  0019.30c0.ad80 Lifetime Timer Expir john-p2p
```

Operational Scenario 4 ...Cont
Ethernet and MPLS OAM

```
ME3400G-2CS-1#ping ethernet 0019.30c0.ad80 level 5 vlan 100

Type escape sequence to abort.
Sending 5 Ethernet CFM loopback messages, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
```

```
ME3400G-2CS-1#traceroute ethernet 0019.30c0.ad80 level 5 vlan 100
Type escape sequence to abort. TTL 255. Per-Hop Timeout is 10 seconds
Tracing the route to 0019.30c0.ad80 on Domain TEST-jose, Level 5, vlan 100
Traceroute sent via GigabitEthernet0/3


-----------------------------------------------------------------------------
-
                            MAC        Ingress Ingress Action    Relay Action
  Hops   Host               Forwarded  Egress  Egress Action     Next Hop
-----------------------------------------------------------------------------
-
B 1    ME3400G-1           0019.552b.df00 Gi0/3   IngOk             RlyFDB
                           Forwarded   Gi0/14  EgrOK             7604-1
B 2    7604-1              0016.9c6e.7985 Gi2/0/2 IngOk             RlyCCDB
                           Forwarded
*
*
*
```

12

64

MPLS OAM Summary

Testing the Pseudo-Wire

`R1#ping mpls pseudowire <IPv4 peer addr> <VC ID>`

Testing the Transport LSP

`R3#ping mpls ipv4 <IPv4 peer adr>`

Ethernet Performance Management

ITU-T Y.1731 Overview
OAM Functions for Performance Management

- ITU-T Y.1731 defines the PM functions and protocols to collect the performance data

- Frame Loss Measurement (ETH-LM)

  Based on in-profile service frame counters (for P2P services only)

  Dual-ended ETH-LM (using CCM PDU)

  Single-ended ETH-LM (using LMM and LMR PDUs)

- Frame Delay Measurement (ETH-DM)

  One-way ETH-DM (using 1DM PDU)

  Two-way ETH-DM (using DMM and DMR PDUs)

- Synthetic Frame Loss Measurement (ETH-SLM)

  Proposal under discussion at ITU-T

  Covers P2P and MP services using synthetic traffic frame loss

IP SLAs
Performance Management

Cisco IP SLAs

MPLS   CFM   IP

Echo Probe
Jitter Probe

Embedded Policy Management
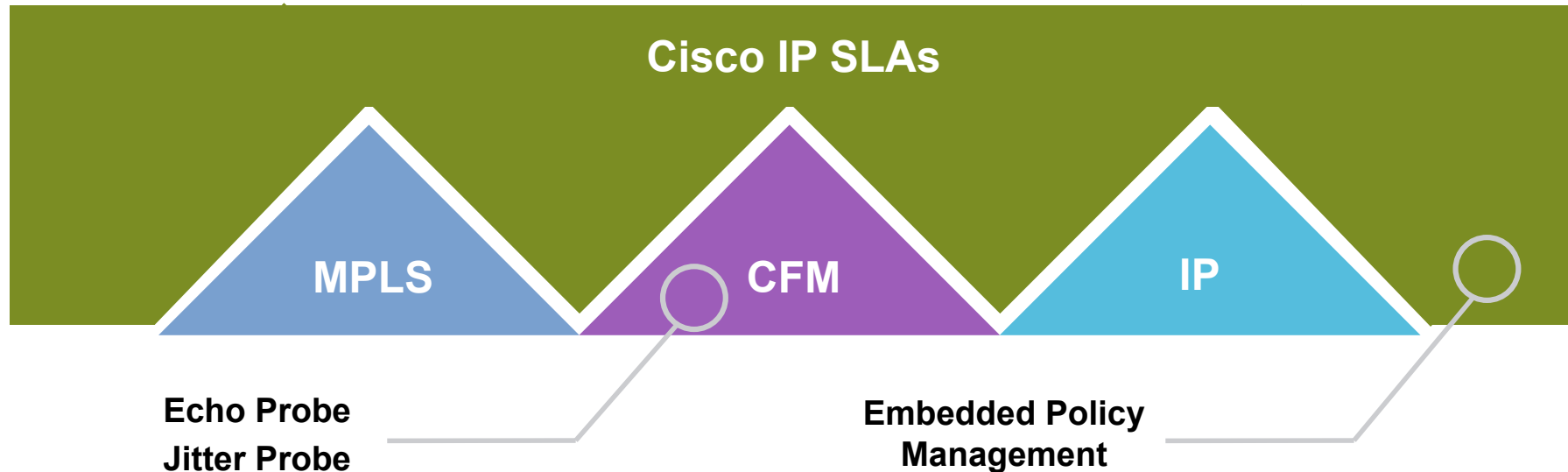
- IP SLAs Embedded Policy Management

  Scheduling Automation/Policy Alerts/Data Collection

- In-band Performance Management Tool for Ethernet

  Delay, Delay Variation and Packet Loss measurement

  Built in CFM principles

- Automatic Discovery of Probe Endpoints

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

End-to-end service performance management

| CE 11 | uPE 11 | AGG 11 | AGG 31 | uPE 31 | CE 31 |

IP SLA Ethernet "ECHO" probe
Round Trip Time

CFM LBM (with timestamps)

CFM LBR (with timestamps)
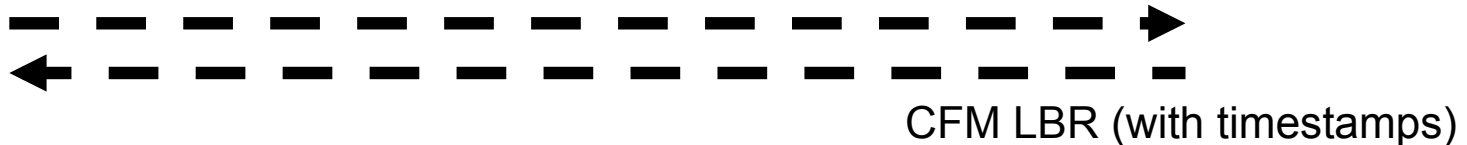
IP SLA Ethernet "JITTER" probe
One-way Delay
One-Way Delay Variation
One-way Packet Loss
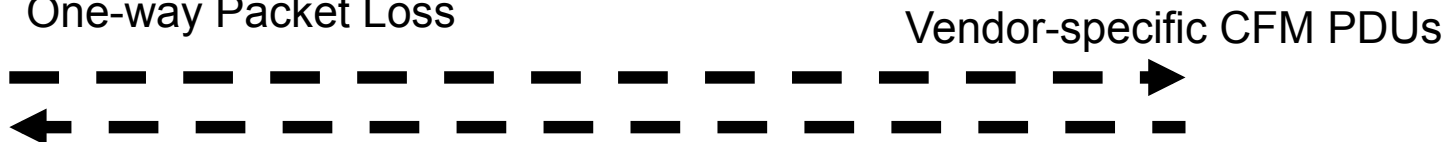
Vendor-specific CFM PDUs

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

End-to-end service performance management

CE 11 **uPE 11**   **AGG 11**   **AGG 31**   **uPE 31** **CE 31**

```
ip sla ethernet-monitor 1
 type echo domain PROVIDER_DOMAIN vlan 100
 tag Dynamic-Echo-vid-100
 owner Jose Liste

ip sla ethernet-monitor schedule 1 schedule-
period 90 frequency 30 start-time now
```

Time

Echo Probe parameters:
Vlan ID
MEP ID (optional)
Frequency

```
ip sla ethernet-monitor 2
 type jitter domain PROVIDER_DOMAIN vlan 100
num-frames 20 interval 10
 tag Dynamic-Jitter-vid-100
 owner Jose Liste

ip sla ethernet-monitor schedule 2 schedule-
period 90 frequency 30 start-time now
```

Time
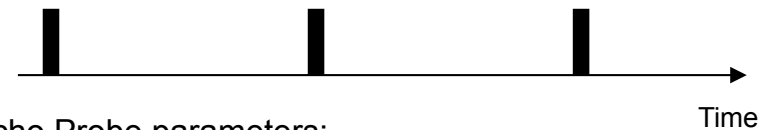
Jitter Probe parameters:
Vlan ID
MEP ID (optional)
Frequency
Number of packets
Inter-packet gap

Summary

 Cisco Public

Summary

- Ethernet OAM deliver equivalent function sets of legacy OAM and more to drive effective operations

- You can perform fault, performance and configuration management with E-OAM

- There are multiple suites of protocols from various standard bodies (& vendors) that work in different bucket

- And they do interwork to give you a comprehensive troubleshooting and maintenance platform.

Questions?
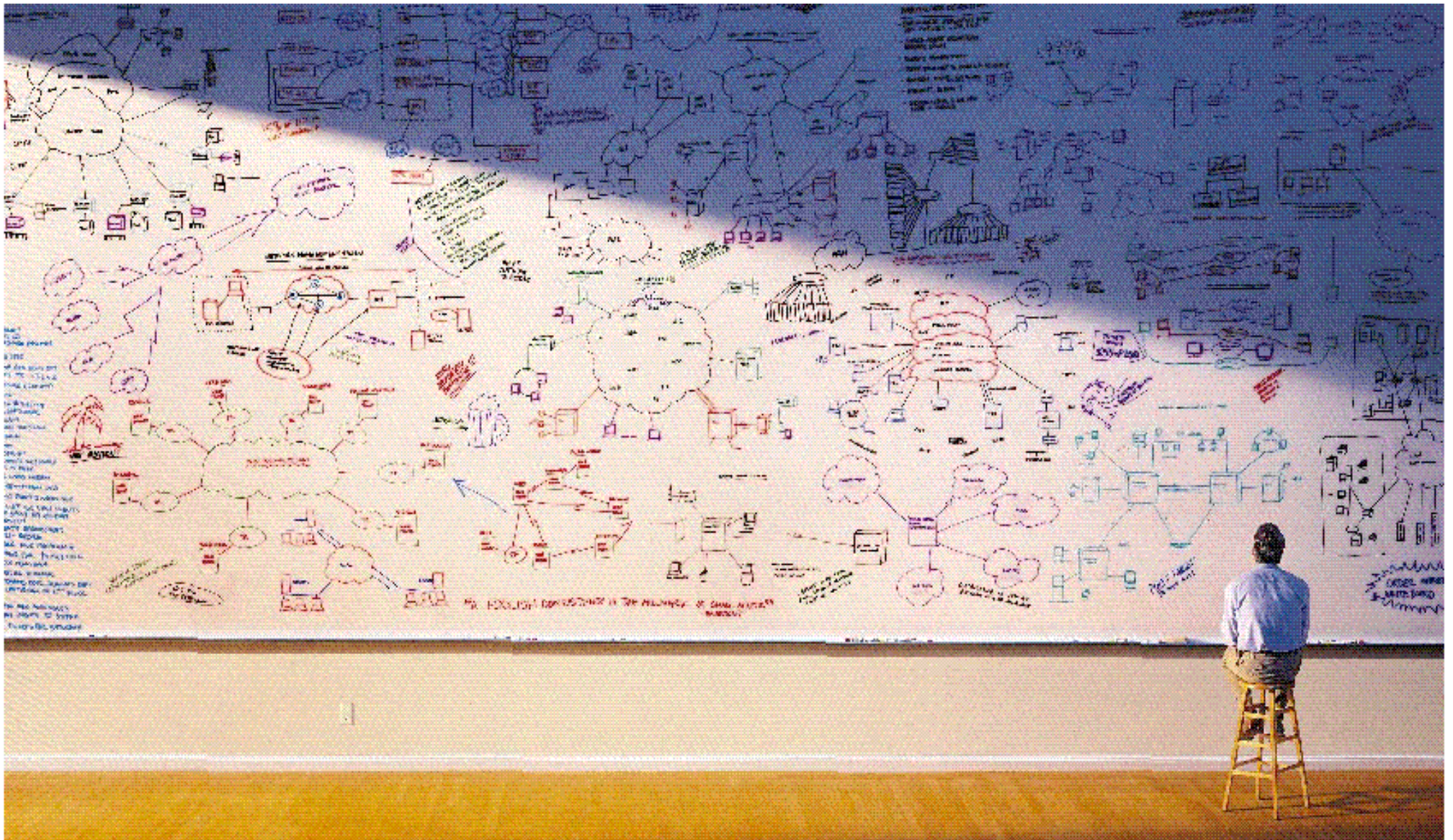
Acknowledgement

- Jose Liste, Technical Marketing Engineer at Cisco Systems

Cisco Public

Acronyms

Acronym	
AIS	Alarm Indication Signal
CCM	Continuity Check Message
CCMDB	CCM Data Base (see CCM)
CE	Customer Edge
CFM	Connectivity Fault Management
EFM	Ethernet in the First Mile
E-LMI	Ethernet LMI (see LMI)
E-OAM	Ethernet OAM (see OAM)
EVC	Ethernet Virtual Connection
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
LBM	Loopback Message
LBR	Loopback Reply
LMI	Local Management Interface
LTM	Linktrace Message
LTR	Linktrace Reply
MA	Maintenance Association
MAID	MA Identifier (see MA)
MD	Maintenance Domain

Acronym	
MEF	Metro Ethernet Forum
MEN	Metro Ethernet Network
MEP	Maintenance Association End Point
MEPID	MEP Identifier (see MEP)
MHF	MIP Half Function (see MIP)
MIB	Management Information Base
MIP	Maintenance Domain Intermediate Point
MP	Maintenance Point
OAM	Operations, Administration and Maintenance
PDU	Protocol Data Unit
PE	Provide Edge
RDI	Remote Defect Indicator
RFI	Remote Failure Indicator
TLV	Type, Length, Value
UNI	User to Network Interface
UNI-C	Customer side of UNI (see UNI)
UNI-N	Network side of UNI (see UNI)
VID	VLAN Identifier
VLAN	Virtual LAN

Ethernet OAM

- IEEE 802.1ag

  Connectivity Fault Management (**CFM**)

  Also referred as Service OAM

- IEEE 802.3ah (clause 57)

  Ethernet Link OAM

  Also referred as 802.3 OAM, **Link OAM** or Ethernet in the First Mile (EFM) OAM

- ITU-T **Y.1731**

  OAM functions and mechanisms for Ethernet-based networks

- MEF **E-LMI**

  Ethernet Local Management Interface

IEEE 802.3ah
OAM Events

- **Set of events that may impact link operation**

- **Critical Link events**

    Link fault—Fault in the Rx direction of local DTE

    Dying gasp—Unrecoverable local failure condition

    Critical event—Unspecified critical event

- **Link events**

    Errored Symbol Period Event

    Errored Frame Event

    Errored Frame Period Event

    Errored Frame Seconds Summary Event

Ethernet LMI
Periodic Polling and Asynchronous Update

- Based on polling procedure invoked by CE

- N391—Polling Counter, polling cycles between Full Status exchanges

- N393—Status Counter, number of consecutive errors

- T391—Polling Timer (PT), UNI-C transmits Status Enq.

- T392—Polling Verification Timer (PVT), timer by which UNI-N expects to be polled

ELMI-CE (UNI-C)　　　　　　　　　　**ELMI-PE (UNI-N)**

(A) (B) → STATUS ENQ (Ethernet LMI Check) →
← STATUS (Ethernet LMI Check) ← (C)

(A) → STATUS ENQ (Ethernet LMI Check) →
(B) ← STATUS (Ethernet LMI Check) ← (C)

(D)(A) → STATUS ENQ (Full Status Req) →
(B) ← STATUS (Full Status Resp) ← (C)

(A) → STATUS ENQ (Ethernet LMI Check) →
(B) ← STATUS (Ethernet LMI Check) ← (C)

← STATUS (EVC ASYNC Status) ← (E)

(A) T391 Expiry　　(B) Restart T391　　(E) MEN Update

(C) Restart T392　　(D) N391 polls sent
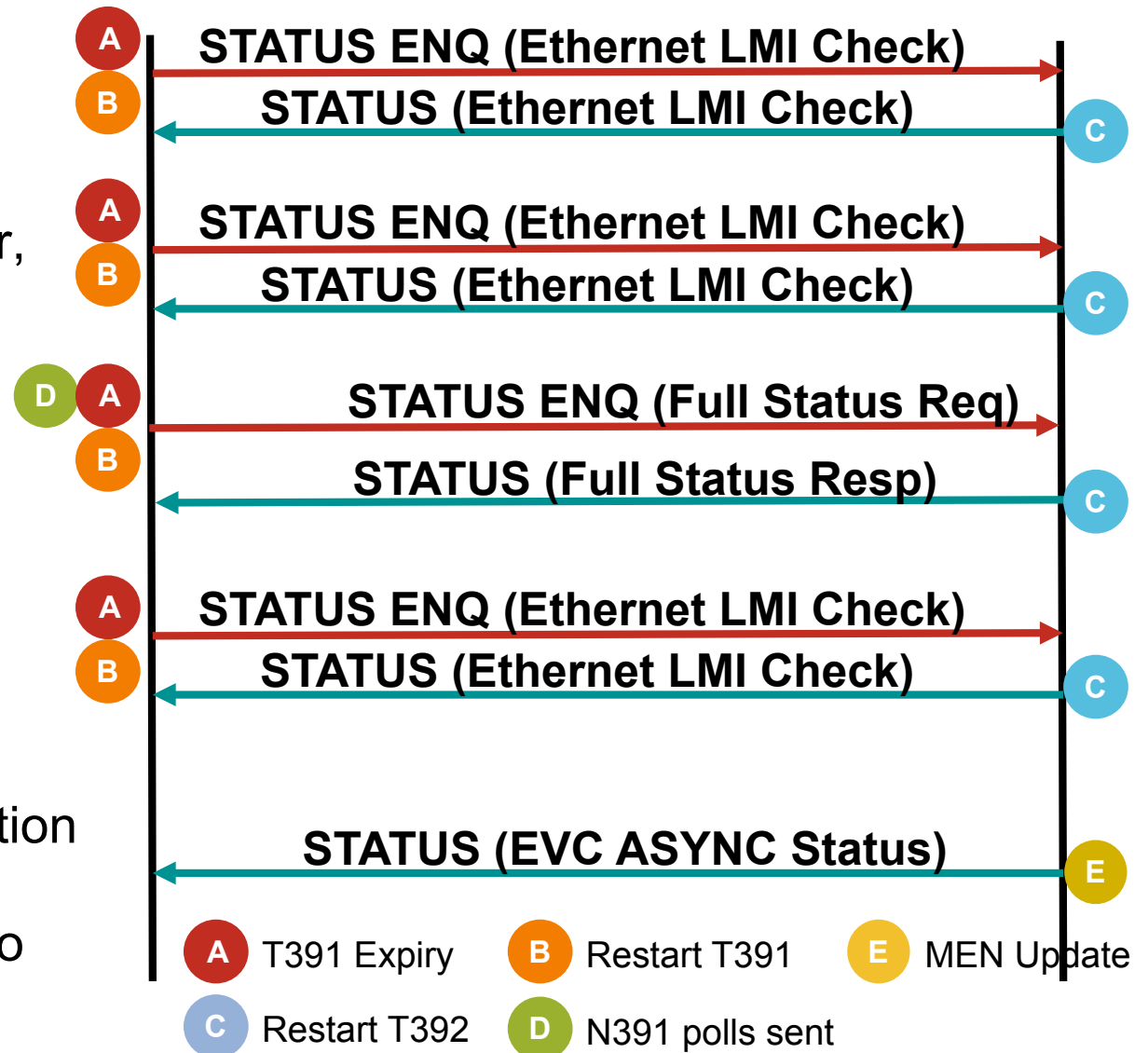
ITU-T Y.1731 Overview
Single-Ended (On-demand) ETH-LM
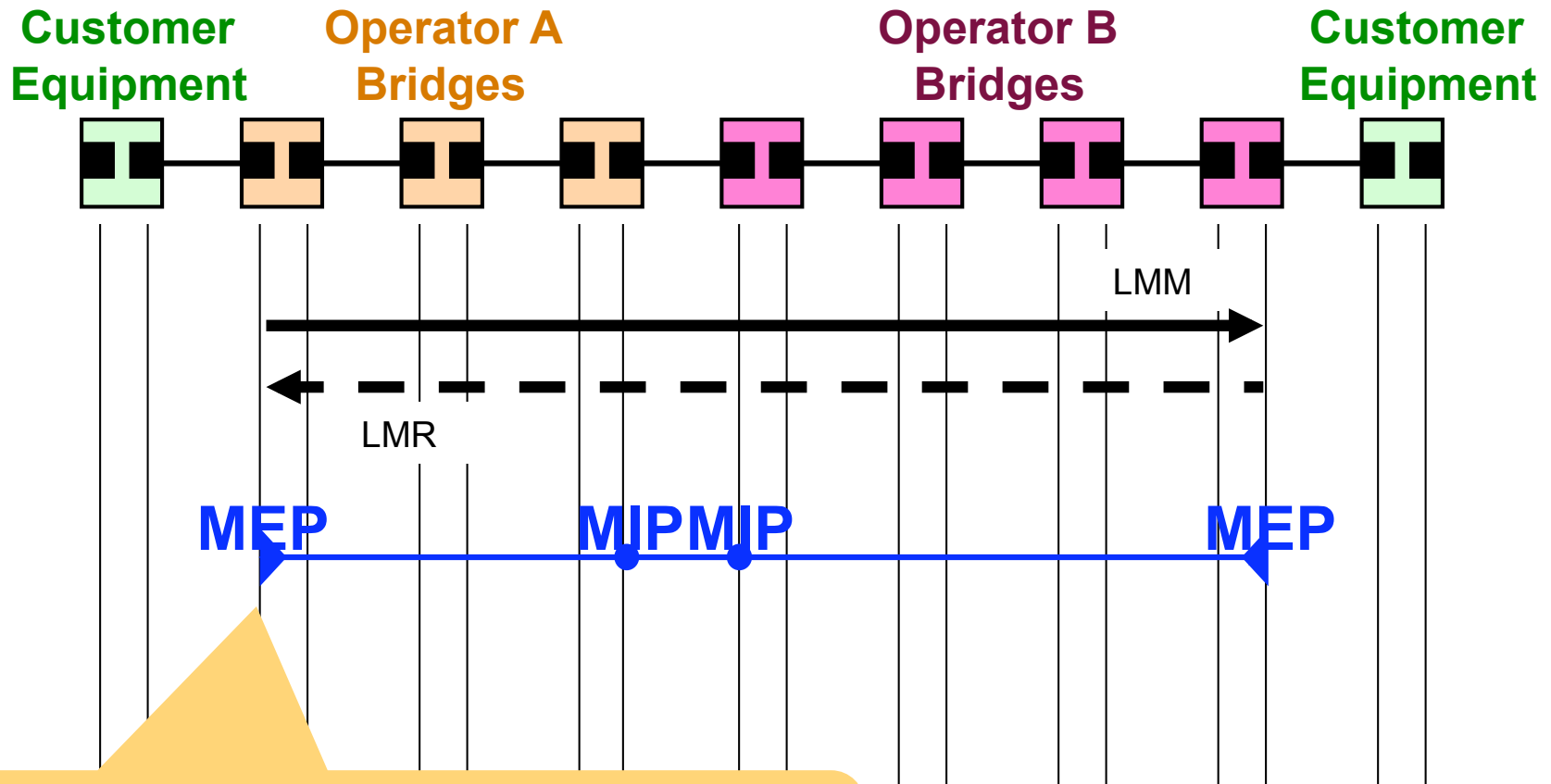
$$\text{Frame Loss}_{\text{far-end}} = |\text{TxFCf}[t_c] - \text{TxFCf}[t_p]| - |\text{RxFCf}[t_c] - \text{RxFCf}[t_p]|$$

$$\text{Frame Loss}_{\text{near-end}} = |\text{TxFCb}[t_c] - \text{TxFCb}[t_p]| - |\text{RxFCl}[t_c] - \text{RxFCl}[t_p]|$$

LMM – Loss Measurement Message
LMR – Loss Measurement Reply

ITU-T Y.1731 Overview
Two-Way ETH-DM

Customer Equipment **Operator A Bridges** **Operator B Bridges** **Customer Equipment**

DMM

DMR

MEP   MIPMIP   MEP

TxTimestamp

Frame Delay =
(RxTimeb – TxTimesampf) –
(TxTimestampb – RxTimesampf)

RxTimestampf
TxTimestampb

DMM – Delay Measurement Message
DMR – Delay Measurement Reply
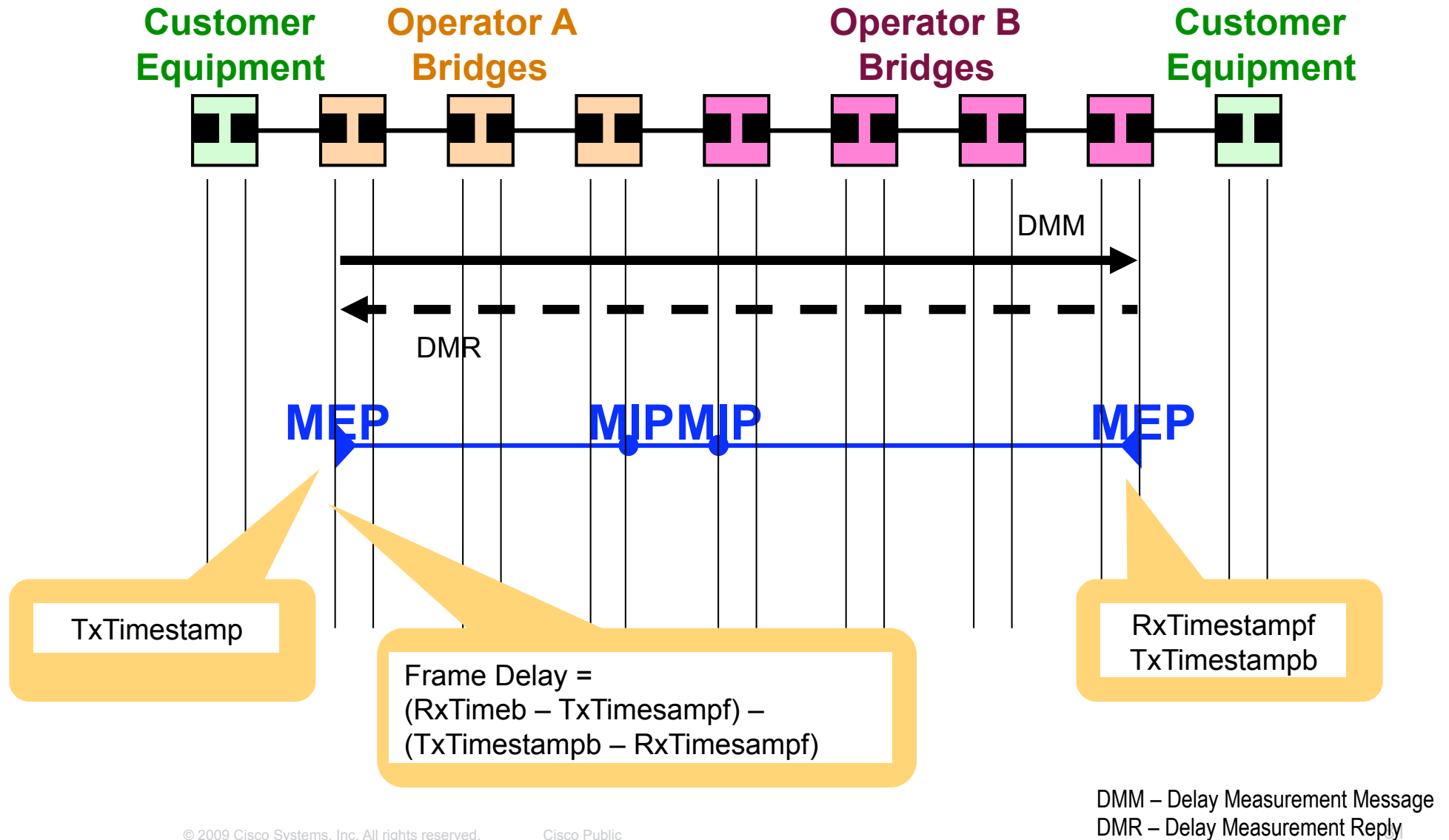
Interworking Scenarios
CFM to E-LMI
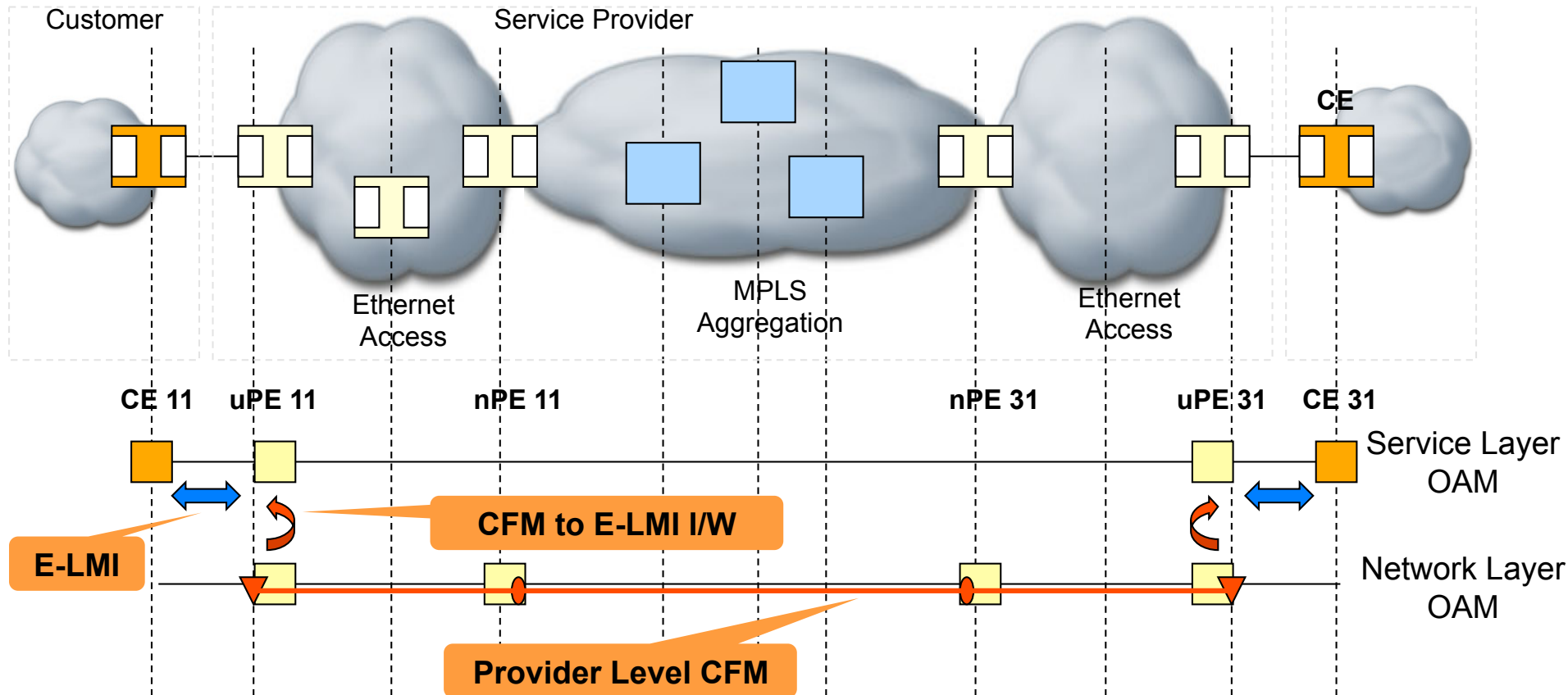
- CFM @ Provider Level acts as MEN OAM: provides EVC Status and Remote UNI Status/Name to E-LMI

  - Interface Status TLV of CC Messages carry remote UNI status

  - Cisco's Organization-specific TLV of CC Messages carry remote UNI name

  - Status of remote MEP in CCDB indicates EVC State

Interworking Scenarios
802.3ah to CFM (CC-based)
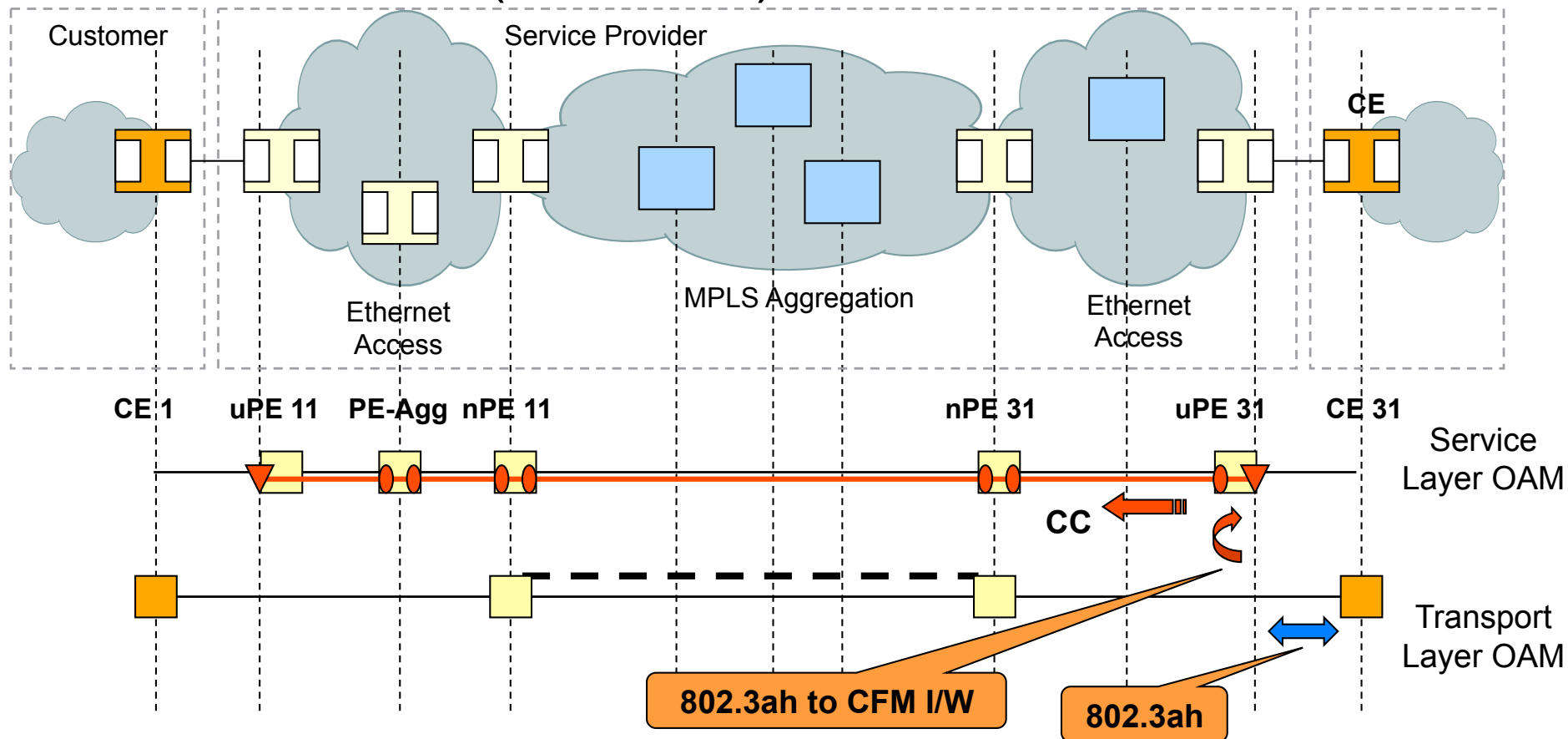
- Link Layer Defects detected by 802.3ah, relayed to CFM on same device
- CFM notifies remote devices of localized fault
- Two variants:
    CC based (802.3ah on edge of domain)
    AIS based (802.3ah within domain)

Interworking Scenarios
802.3ah to CFM (AIS-based)
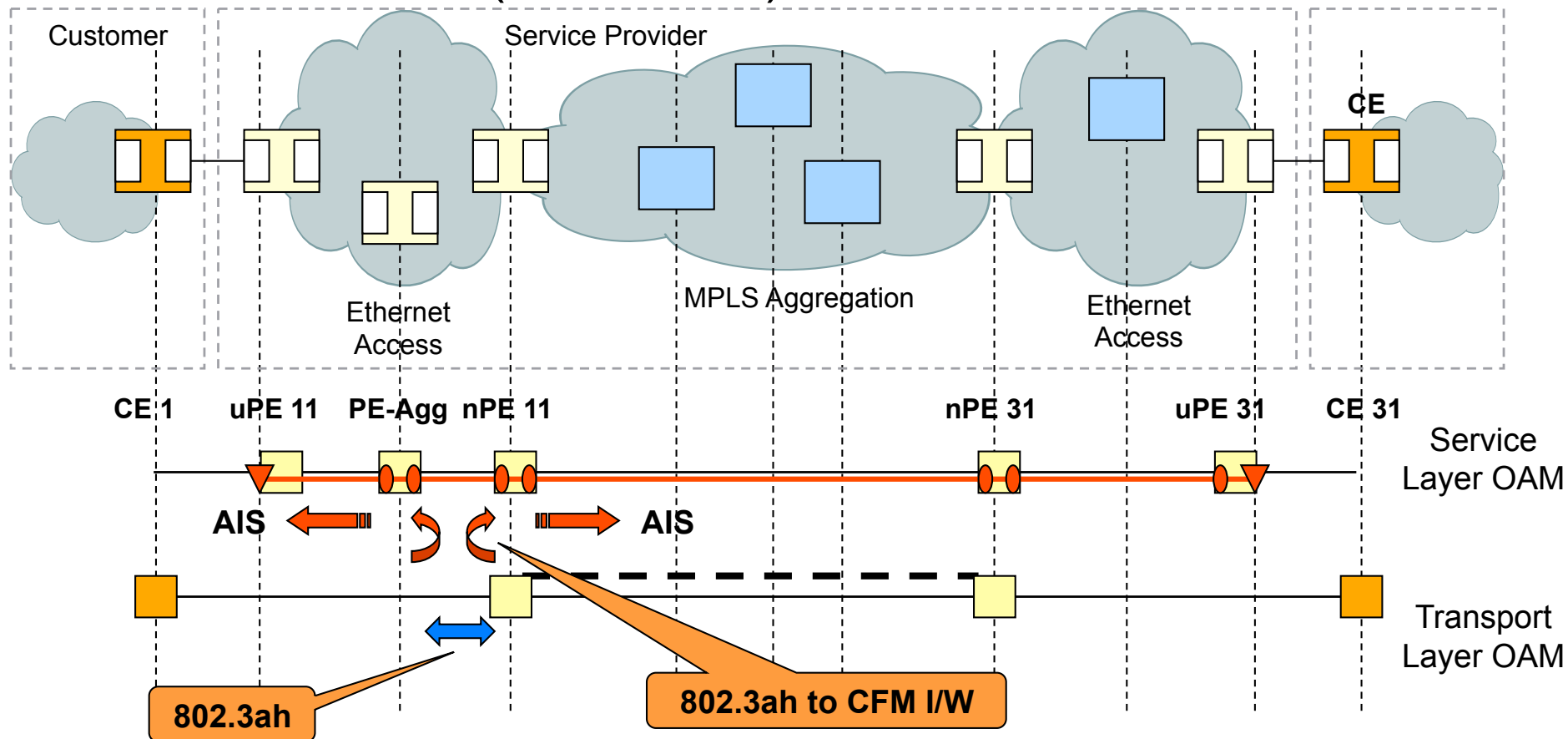
- Link Layer Defects detected by 802.3ah, relayed to CFM on same device
- CFM notifies remote devices of localized fault
- Two variants:
  - CC based (802.3ah on edge of domain)
  - AIS based (802.3ah within domain)

Interworking Scenarios
MPLS PW OAM to E-LMI
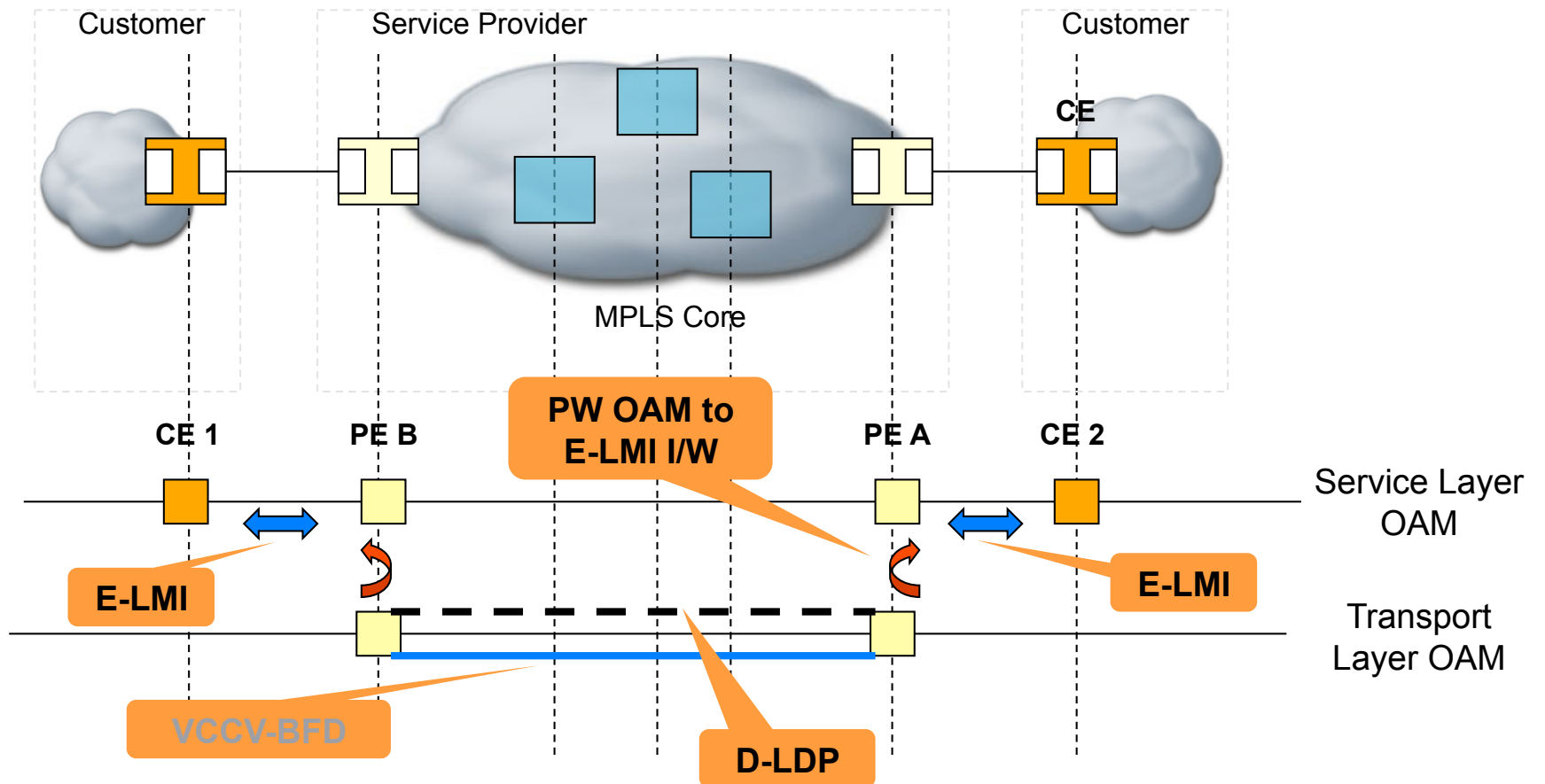
- Directed-LDP & VCCV (BFD mode) running between PEs
- D-LDP for defect notification, VCCV for defect detection
- Defects detected/communicated by PW OAM are relayed to E-LMI via I/W function on PE

CFM Deployment
Scenario A

| CE1 | Access 1 | Aggregation 1 | Aggregation 2 | Access 2 | CE2 |

Admin Domain "A"

- End to End service provided over a single Administrative Domain (e.g. Carrier A)

CFM Deployment
Scenario A (Cont.)

CE1 Access 1 Aggregation 1 Aggregation 2 Access 2 CE2

Customer Domain

End to End Customer service monitoring (optional)

SP Domain

End to End SP service monitoring

Link Domain

Port MEPs
First mile link monitoring

▷ MEP   ◯ MIP

CFM Deployment
Scenario B

CE1   Access 1   Aggregation 1   Aggregation 2   Access 2   CE2

Admin Domain "A"

Admin Domain "B"

- End to End service provided by a SP (e.g. Carrier A) who relies on another SP access network (e.g. Carrier B) to reach some customer sites

CFM Deployment
Scenario B (Cont.)

CE1 Access 1 Aggregation 1 Aggregation 2 Access 2 CE2

Customer Domain

End to End Customer service monitoring (optional)

Operator Domain

Independent Operator service monitoring

Link Domain

Port MEPs
E-NNI link monitoring

▷ MEP   ◯ MIP

Fault Management Scenarios

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services
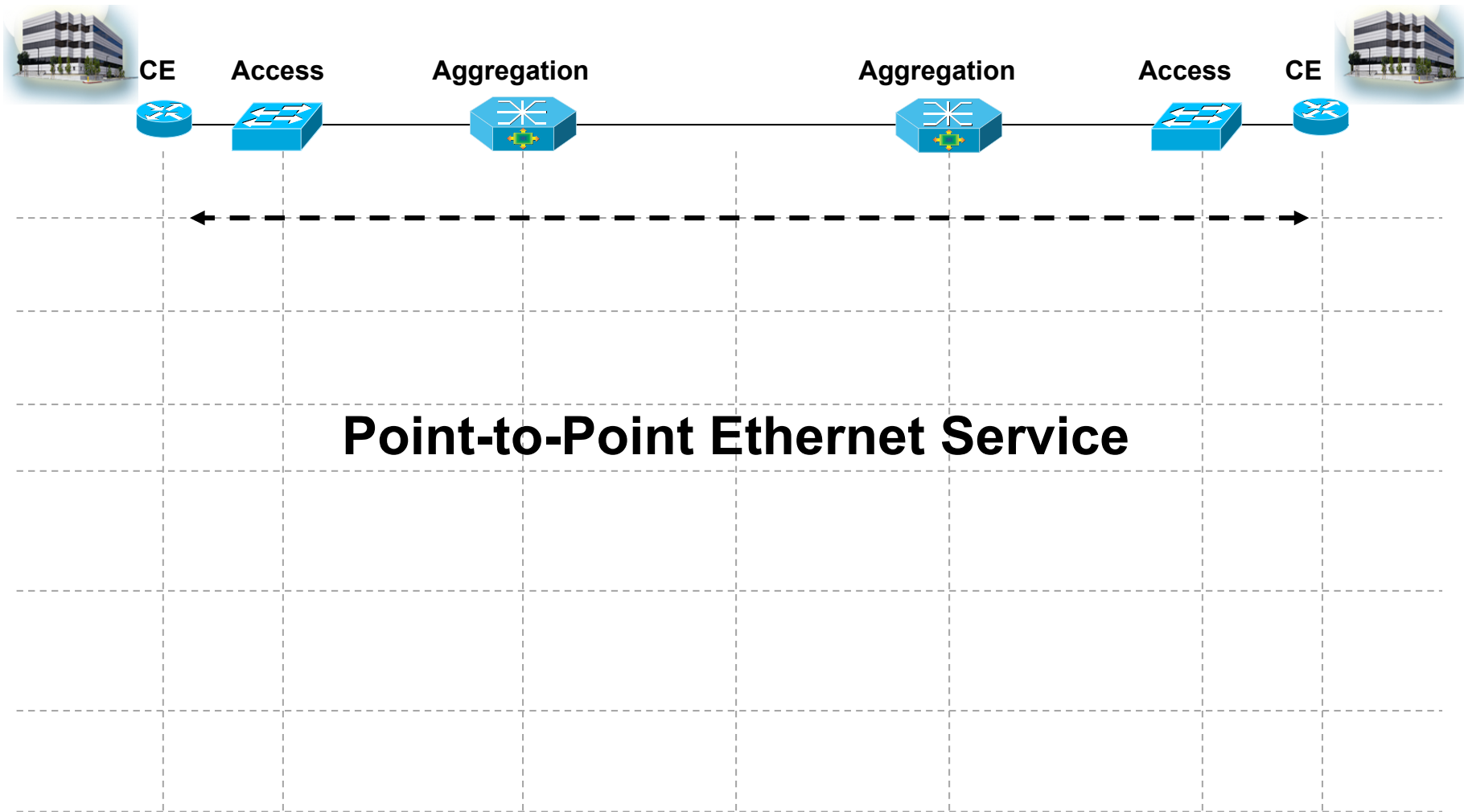
CE   Access   Aggregation   Aggregation   Access   CE

Point-to-Point Ethernet Service

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE · Access · Aggregation · Aggregation · Access · CE

E-LMI
Link OAM

CFM

E-LMI
Link OAM

CFM
to E-LMI IW

CFM
to E-LMI IW

Link OAM
to CFM IW

Link OAM
to CFM IW

OAM protocol positioning
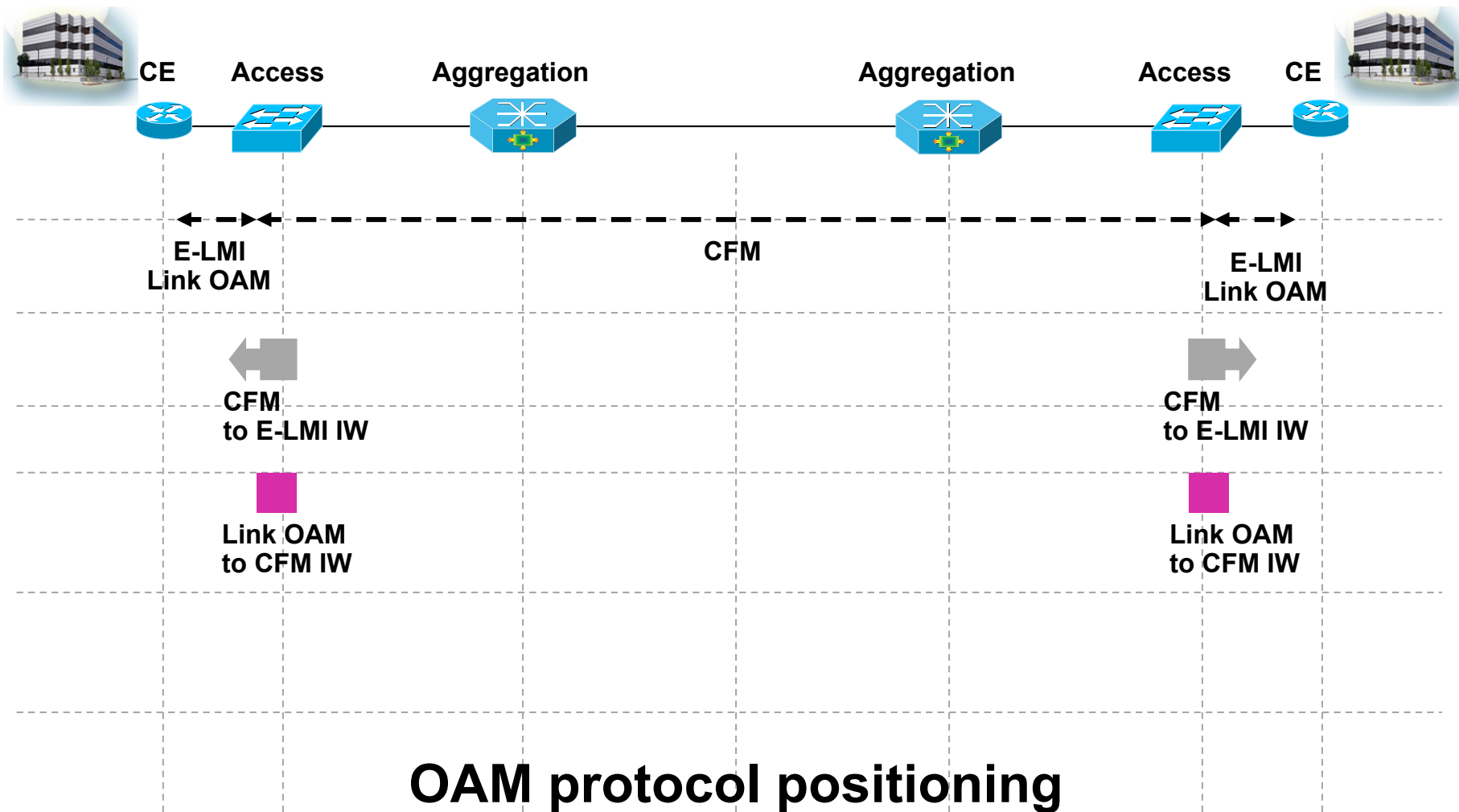
Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Proactive End-to-End Service Monitoring

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

CFM Continuity Check Messages (CCM)

t_0

t_1

t_2
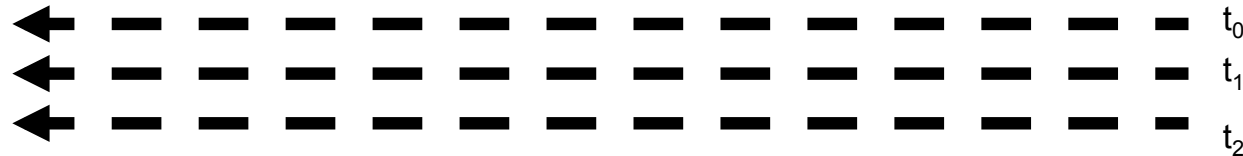
CCM
Database

```
UPE11#show ethernet cfm maintenance-points remote
-------------------------------------------------------------------------
MPID  Domain Name                           MacAddress      IfSt  PtSt
 Lvl  Domain ID                             Ingress
 RDI  MA Name                               Type Id         SrvcInst
      EVC Name                                              Age
-------------------------------------------------------------------------
3100  PROVIDER_DOMAIN                       aabb.cc00.0599  Up    Up
 4    PROVIDER_DOMAIN                       Et0/1.100
 -    customer_100_provider                 Vlan 100        N/A
      N/A                                                   0s

Total Remote MEPs: 1
```

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

End-to-end Service/Failure Verification

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

uPE11# ping ethernet

CFM Loopback Message (LBM)

CFM Loopback Reply (LBR)

```
UPE11#ping ethernet mpid 3100 domain PROVIDER_DOMAIN vlan 100

Type escape sequence to abort.
Sending 5 Ethernet CFM loopback messages to aabb.cc00.0599, timeout is 5 seconds
:!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/5/12 ms
```

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Service Path Discovery/Failure Isolation

CE 11	uPE 11	AGG 11	AGG 31	uPE 31	CE 31

uPE11# traceroute ethernet
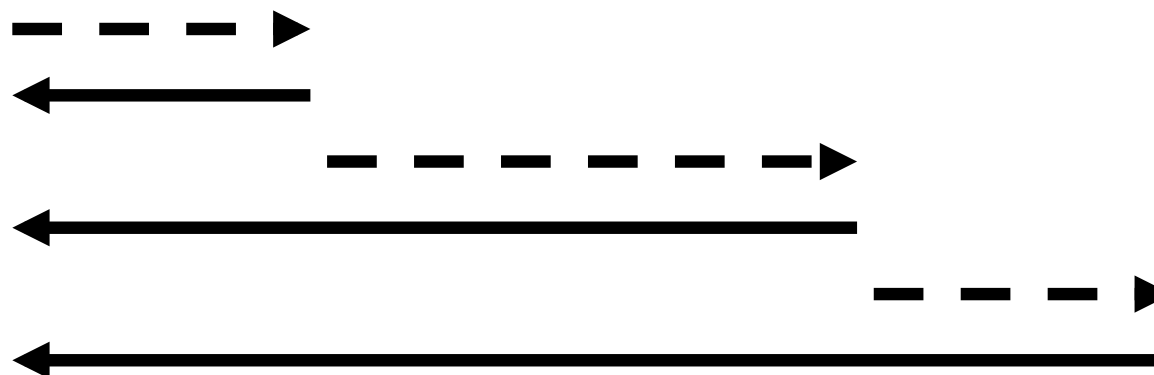
CFM Linktrace Message (LTM)
CFM Linktrace Reply (LTR)

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Service Path Discovery/Failure Isolation

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31
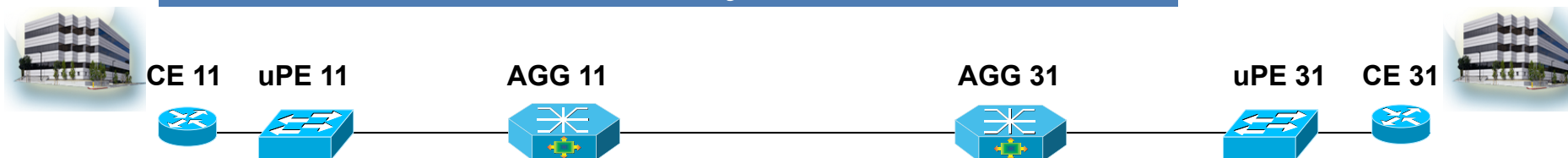
uPE11# traceroute ethernet

```
UPE11#traceroute ethernet mpid 3100 domain PROVIDER_DOMAIN vlan 100
Type escape sequence to abort. TTL 64. Linktrace Timeout is 5 seconds
Tracing the route to aabb.cc00.0599 on Domain PROVIDER_DOMAIN, Level 4, vlan 100
Traceroute sent via Ethernet0/1.100, path found via MPDB

B = Intermediary Bridge
! = Target Destination
* = Per hop Timeout
---------------------------------------------------------------------------
                            MAC         Ingress      Ingr Action  Relay
Action
  Hops    Host            Forwarded   Egress       Egr Action   Previous
Hop
---------------------------------------------------------------------------
B 1    AGG11             aabb.cc00.0399 Et0/0.100    IngOk        RlyMPDB
                         Forwarded     Et0/1.100    EgrOK        aabb.cc00.0299
B 2    AGG31             aabb.cc00.0499 Et0/0.100    IngOk        RlyMPDB
                         Forwarded     Et0/1.100    EgrOK        aabb.cc00.0399
! 3    UPE31             aabb.cc00.0599 Et0/0.100    IngOk        RlyHit:MEP
                         Not Forwarded                           aabb.cc00.0499
```

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE Notification

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

▪▪▪▪▶ ELMI Status Enquiry message (Full Status report)

◀━━━ ELMI Status message (Full Status report)

Example:

Local UNI ID	CE11_UNI
CE-VLAN/EVC Map type	Service_Multiplexing
EVC ID	EVC_P2P_100
EVC Type	Point_to_Point
CE-VLAN/EVC Map	vlan 100
EVC Status	New, Active
Remote UNI count – configured	1
Remote UNI count – active	1
Remote UNI ID	CE31_UNI
Remote UNI status	UP

Cisco enhancements
to ELMI

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE Notification

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

┈┈▶   ELMI Status Enquiry message (Full Status report)

◀━━   ELMI Status message (Full Status report)

```
CE11#show ethernet lmi evc detail EVC_P2P_100
EVC Id: EVC_P2P_100
interface Ethernet0/0
  Time since Last Full Report: 00:49:01
  Ether LMI Link Status: Up
  UNI Status: Up
  UNI Id: CE11_UNI
  CE-VLAN/EVC Map Type: Service Multiplexing with no bundling
  VLAN: 100

  EVC Status: Active
  EVC Type: Point-to-Point
  Remote UNI Count: Configured = 1, Active = 1

  UNI Id                              UNI Status    Port
  ------                              ----------    ----
  CE31_UNI                            Up            Remote
```

Network Stable:
Remote UNI shows
UP

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE Notification—VLAN ID Missmatch

CE 11   **uPE 11**   **AGG 11**   **AGG 31**   **uPE 31**   **CE 31**

CE Configured with the correct C-VLAN (e.g. vid 100)
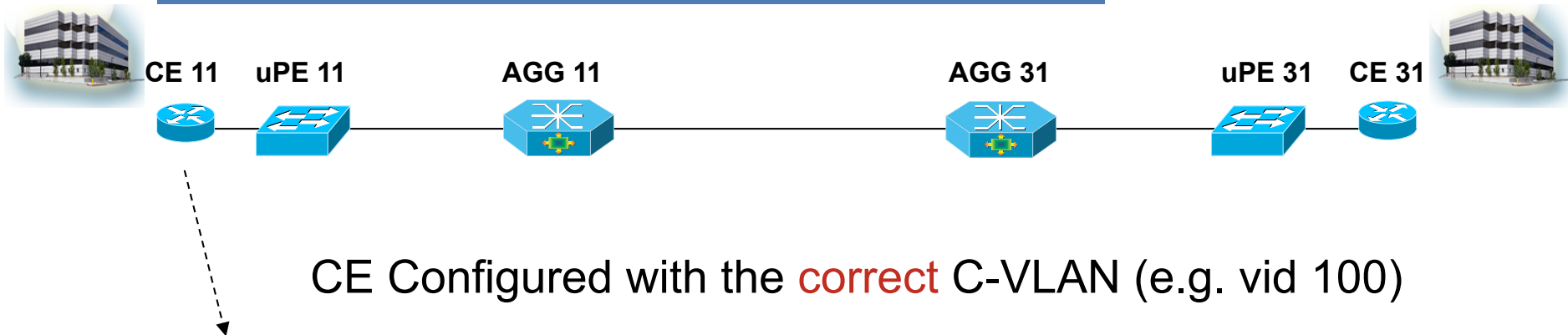
```
CE11(config)#interface gig0/0.100
CE11(config-subif)#encapsulation dot1Q 100

CE11#show ip interface brief
Interface                 IP-Address      OK? Method Status              Protocol
<snip>
GigabitEthernet0/0.100    100.100.100.11  YES NVRAM  up                  up
```

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE Notification—VLAN ID Missmatch

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

CE Configured with the incorrect C-VLAN (e.g. vid 1300)

```
CE11(config)#interface gig0/0.100
CE11(config-subif)#encapsulation dot1Q 1300

Jan 26 00:15:39.546: %ETHER_LMI-6-MISMATCHED_VLAN_NOT_CONFIGURED: VLAN 100 not
Configured but in VLAN mapping for UNI GigabitEthernet0/0

Jan 26 00:15:39.546: %ETHER_LMI-6-MISMATCHED_VLAN_CONFIGURED: VLAN 1300 configured
but not in VLAN mapping for UNI GigabitEthernet0/0 Interface

CE11#show ip interface brief
Interface                    IP-Address      OK? Method Status               Protocol
<snip>
GigabitEthernet0/0.100       100.100.100.11  YES NVRAM  down                 down
```

Proactive ELMI Action
at CPE

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Failure Scenario: Network Failure

CE   Access   Aggregation   Aggregation   Access   CE

CFM remote MEP timeout   CFM remote MEP timeout

MEP Down (timeout) alarm   MEP Down (timeout) alarm
DefRemoteCCM IEEE alarm   DefRemoteCCM IEEE alarm
EVC declared Inactive   EVC declared Inactive
CFM to ELMI Interworking   **CFM to ELMI Interworking**

ELMI Status message   ELMI Status message
Async EVC report   Async EVC report

ELMI action: ELMI action:
CE brings down   CE brings down
(sub)interface   (sub)interface

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

X

```
UPE11#

*Apr  8 04:33:44.911: %E_CFM-3-REMOTE_MEP_DOWN: Remote MEP mpid 3100 vlan
100 MA name customer_100_provider in domain PROVIDER_DOMAIN changed state
to down with event code TimeOut.

*Apr  8 04:33:44.911: %ETHER_SERVICE-6-EVC_STATUS_CHANGED: status of
EVC_P2P_100 changed to InActive

*Apr  8 04:33:47.587: %E_CFM-3-FAULT_ALARM: A fault has occurred in the
network for the local MEP having mpid 1100 vlan 100 for service MA name
customer_100_provider with the event code DefRemoteCCM.


UPE11#show ethernt cfm errors
----------------------------------------------------------------------
MPID Domain Id                                   Mac Address    Type   Id  Lvl
     MAName                                      Reason                Age
----------------------------------------------------------------------
3100 PROVIDER_DOMAIN                             aabb.cc00.0599 Vlan   100 4
     customer_100_provider                       Lifetime Timer Expired 119s
```

Cisco-defined
alarm

IEEE-defined
alarm

Error DB

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31

X
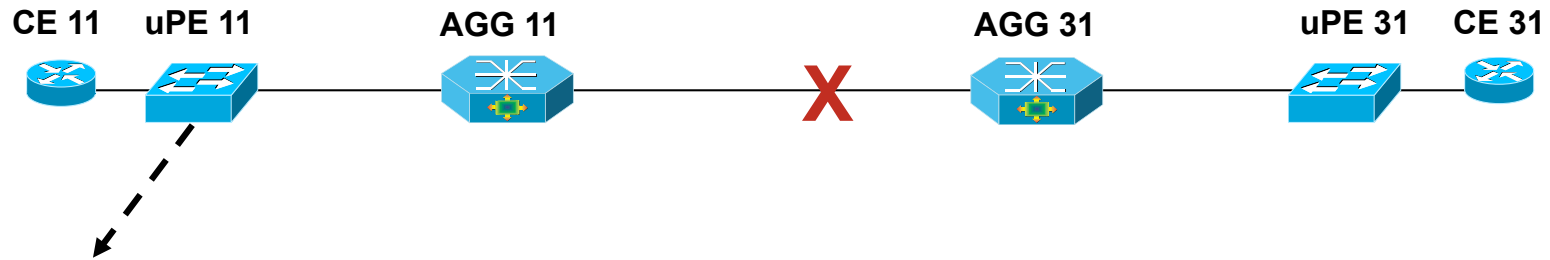
```
UPE11#ping ethernet aabb.cc00.0599 domain PROVIDER_DOMAIN vlan 100

Type escape sequence to abort.
Sending 5 Ethernet CFM loopback messages to aabb.cc00.0599, timeout is 5 seconds
:.....
Success rate is 0 percent (0/5)


UPE11#traceroute ethernet aabb.cc00.0599 domain PROVIDER_DOMAIN vlan 100
Type escape sequence to abort. TTL 64. Linktrace Timeout is 5 seconds
Tracing the route to aabb.cc00.0599 on Domain PROVIDER_DOMAIN, Level 4, vlan 100
Traceroute sent via Ethernet0/1.100, path found via MPDB

B = Intermediary Bridge
! = Target Destination
* = Per hop Timeout
---------------------------------------------------------------------------
                                MAC        Ingress      Ingr Action  Relay Action
   Hops    Host                 Forwarded  Egress       Egr Action   Previous Hop
---------------------------------------------------------------------------
B 1    AGG11                    aabb.cc00.0399 Et0/0.100  IngOk       RlyMPDB
                                Forwarded      Et0/1.100  EgrOK       aabb.cc00.0299
*
*
*
*
```

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE 11   uPE 11   AGG 11   AGG 31   uPE 31   CE 31
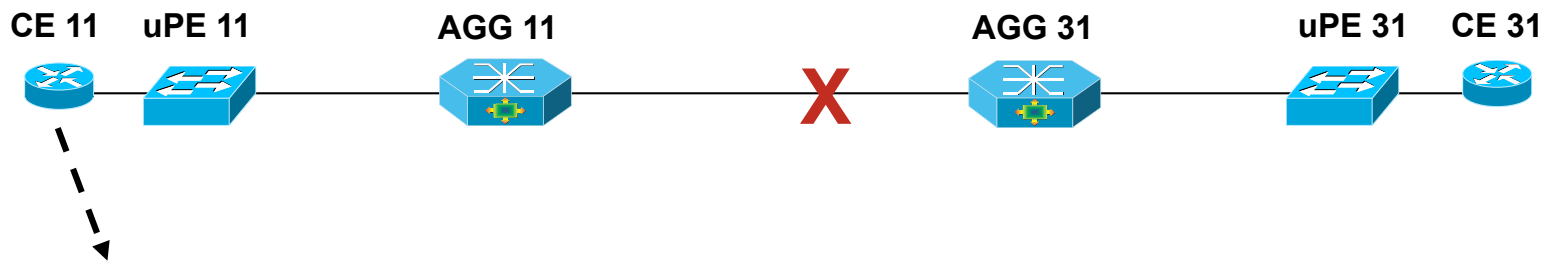
```
CE11#

*Apr  8 04:33:44.991: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/0.100,
changed state to down


CE11#show ethernet lmi evc detail EVC_P2P_100
EVC Id: EVC_P2P_100
interface Ethernet0/0
  Time since Last Full Report: 00:01:13
  Ether LMI Link Status: Up
  UNI Status: Up
  UNI Id: CE11_UNI
  CE-VLAN/EVC Map Type: Service Multiplexing with no bundling
  VLAN: 100

  EVC Status: Inactive
  EVC Type: Point-to-Point
  Remote UNI Count: Configured = 1, Active = 0

  UNI Id                            UNI Status      Port
  ------                            ----------      ----
  CE31_UNI                          Unreachable     Remote
```

Network Failure:
Remote UNI shows
UNREACHABLE

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Failure Scenario: UNI Link Down

CE   Access   Aggregation   Aggregation   Access   CE

UNI Link Down

EVC declared Inactive

CFM CCM Interface Status TLV "isDown"

CFM MEP Up (port state Down) alarm
DefMACstatus IEEE alarm
EVC declared Inactive
CFM to ELMI InterWorking

ELMI Status message
Async EVC report

ELMI action:
CE brings down
(sub)interface

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE 11　　**uPE 11**　　　　　**AGG 11**　　　　　　　　　　**AGG 31**　　　　**uPE 31**　**CE 31**
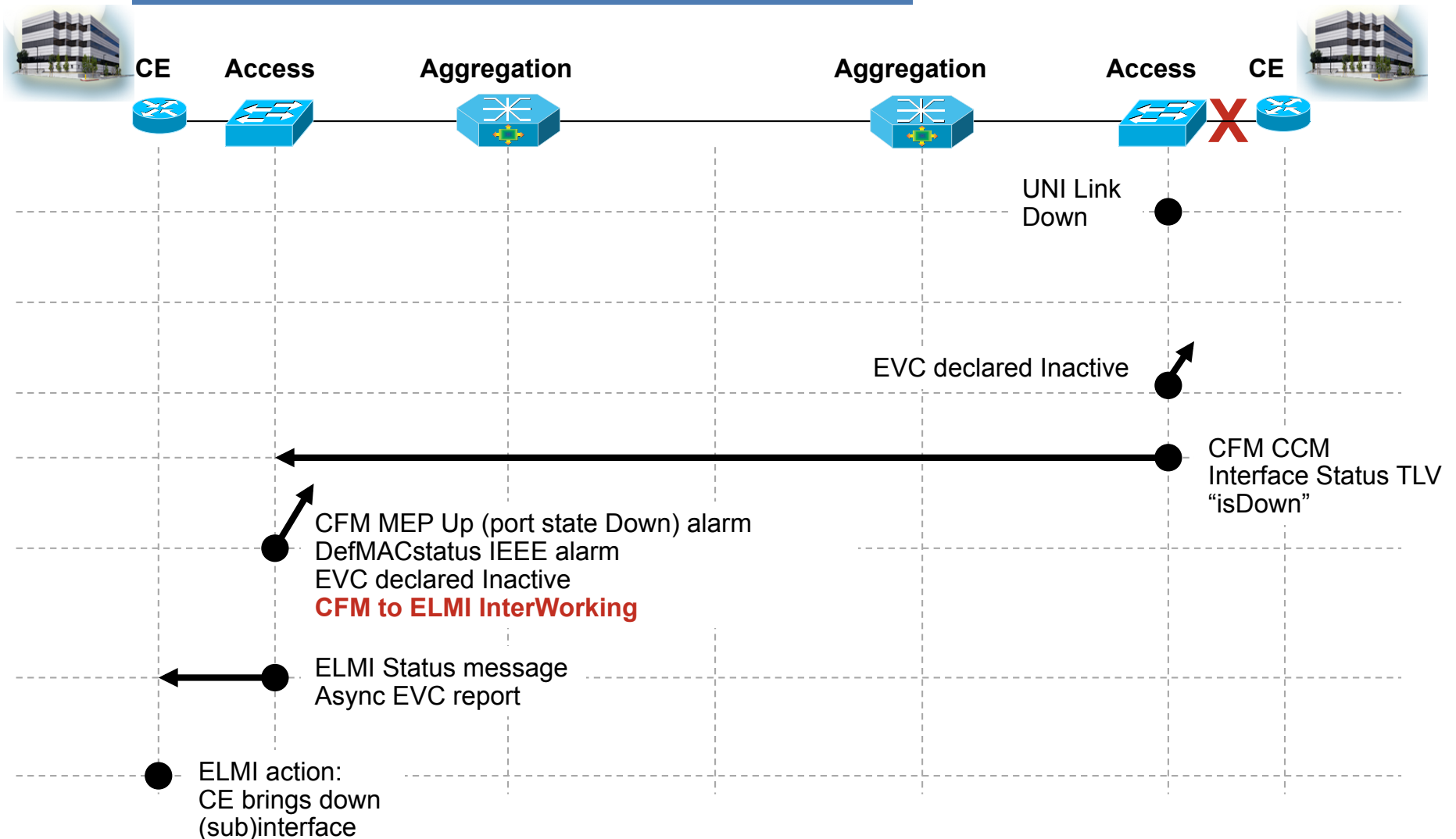
```
UPE11#

*Apr  8 04:41:54.823: %E_CFM-6-REMOTE_MEP_UP: Continuity Check message is
received from a remote MEP with mpid 3100 vlan 100 MA name
customer_100_provider domain PROVIDER_DOMAIN interface status Down event
code PortState.

*Apr  8 04:41:54.823: %ETHER_SERVICE-6-EVC_STATUS_CHANGED: status of
EVC_P2P_100 changed to InActive

*Apr  8 04:41:57.451: %E_CFM-3-FAULT_ALARM: A fault has occurred in the
network for the local MEP having mpid 1100 vlan 100 for service MA name
customer_100_provider with the event code DefMACstatus.


UPE11#show ethernet cfm maintenance-point remote
--------------------------------------------------------------------------
MPID  Domain Name                              MacAddress        IfSt  PtSt
 Lvl  Domain ID                                Ingress
 RDI  MA Name                                  Type Id           SrvcInst
      EVC Name                                                   Age
--------------------------------------------------------------------------
3100  PROVIDER_DOMAIN                          aabb.cc00.0599    Down  Up
 4    PROVIDER_DOMAIN                          Et0/1.100
 -    customer_100_provider                    Vlan 100          N/A
      N/A                                                        0s

Total Remote MEPs: 1
```

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE 11   **uPE 11**   **AGG 11**   **AGG 31**   **uPE 31**   **CE 31**

```
CE11#

*Apr  8 04:41:54.907: %LINEPROTO-5-UPDOWN: Line protocol on Interface Ethernet0/0.100,
changed state to down

CE11#show ethernet lmi evc detail EVC_P2P_100
EVC Id: EVC_P2P_100
interface Ethernet0/0
  Time since Last Full Report: 00:01:07
  Ether LMI Link Status: Up
  UNI Status: Up
  UNI Id: CE11_UNI
  CE-VLAN/EVC Map Type: Service Multiplexing with no bundling
  VLAN: 100

  EVC Status: Inactive
  EVC Type: Point-to-Point
  Remote UNI Count: Configured = 1, Active = 0

  UNI Id                                  UNI Status     Port
  ------                                  ----------     ----
  CE31_UNI                                Down           Remote
```

UNI Failure:
Remote UNI shows DOWN

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Failure Scenario: UNI Admin Shutdown

CE   Access   Aggregation   Aggregation   Access   CE

UNI admin
Shutdown at CE

CE transmits
802.3ah Dying Gasp

802.3ah alarm
EVC declared Inactive
802.3ah to CFM InterWorking

CFM CCM
Organization-specific TLV
AdminDown

CFM MEP Up (port state AdminDown) alarm
DefMACstatus IEEE alarm
EVC declared Inactive
CFM to ELMI InterWorking

Cisco enhancement
to CFM

ELMI Status message
Async EVC report

ELMI action:
CE brings down
(sub)interface

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Failure Scenario: Power Failure at CE

CE   Access   Aggregation   Aggregation   Access   CE

Power lost
at CE site

CE transmits Power Failure
802.3ah Dying Gasp

802.3ah alarm
EVC declared Inactive
802.3ah to CFM InterWorking

CFM CCM
Interface Status TLV
"isDown"

CFM MEP Up (port state Down) alarm
DefMACstatus IEEE alarm
EVC declared Inactive
CFM to ELMI InterWorking

ELMI Status message
Async EVC report

ELMI action:
CE brings down
(sub)interface

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Failure Scenario: UNI Errors (Detected by CE)

Receive Errors detected by CE

CE   Access   Aggregation   Aggregation   Access   CE

X

CE exceeds 802.3ah
HIGH error threshold

CE sends 802.3ah
Event OAM PDUs

802.3ah to CFM InterWorking
EVC declared Inactive

CFM CCM
Organization-specific TLV
remoteExcessiveErrors

CFM MEP Up (port state remoteExcessiveErrors) alarm
EVC declared Inactive
CFM to ELMI InterWorking

Cisco enhancement
to CFM

ELMI Status message
Async EVC report

ELMI action:
CE brings down
(sub)interface

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

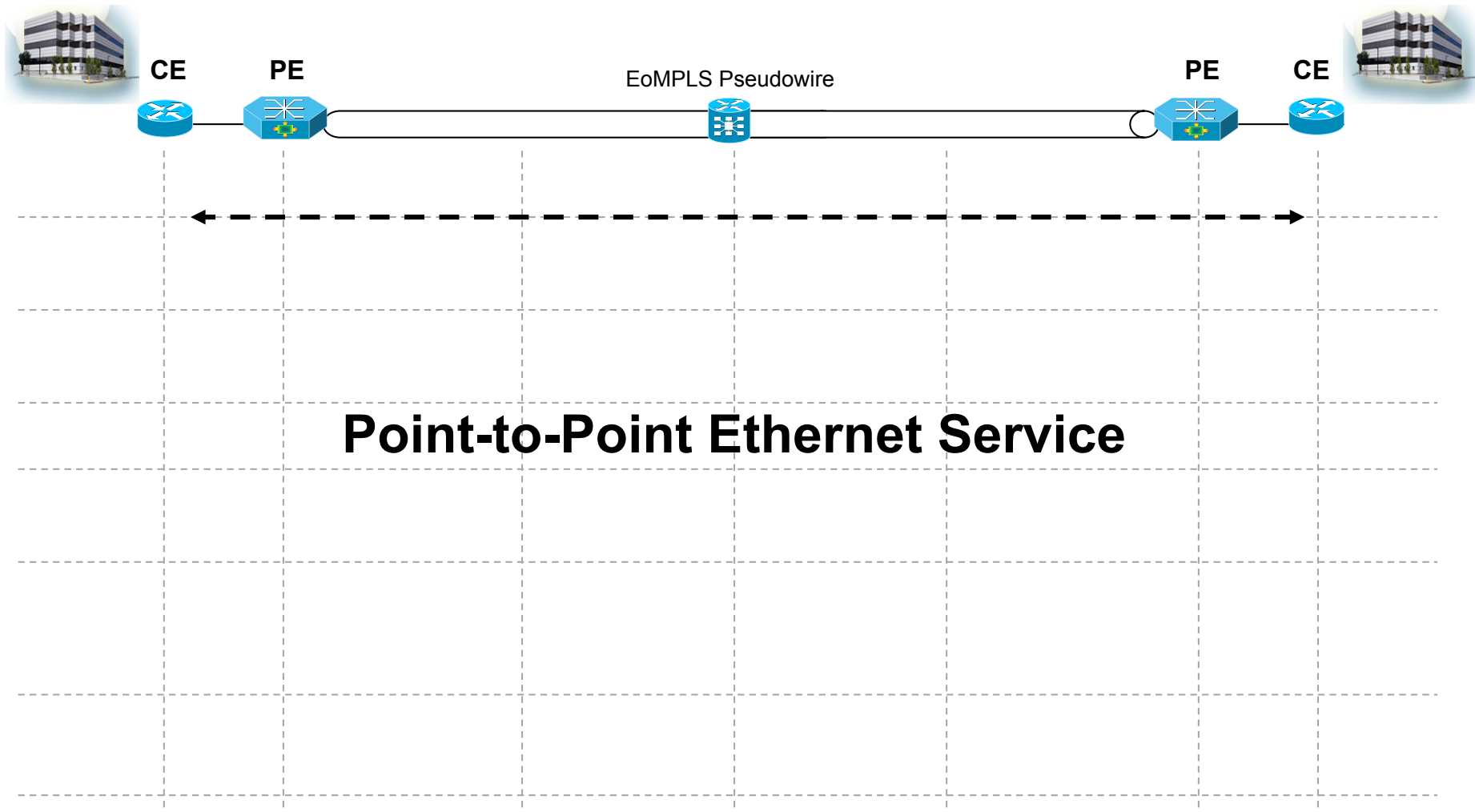**Failure Scenario: UNI Errors** (detected by SP)

Receive Errors detected by SP

CE   Access   Aggregation   Aggregation   Access   CE

X ←

SP exceeds 802.3ah
HIGH error threshold

SP sends 802.3ah
Event OAM PDUs

802.3ah to CFM InterWorking
EVC declared Inactive

CFM CCM
Organization-specific TLV
localExcessiveErrors

CFM MEP Up (port state localExcessiveErrors) alarm
EVC declared Inactive
CFM to ELMI InterWorking

Cisco enhancement
to CFM

ELMI Status message
Async EVC report

ELMI action:
CE brings down
(sub)interface

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE   PE   EoMPLS Pseudowire   PE   CE

Point-to-Point Ethernet Service

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

CE   PE   EoMPLS Pseudowire   PE   CE

E-LMI   **Directed LDP session**   **E-LMI**

**PW OAM
To E-LMI IW**   **PW OAM
To E-LMI IW**

OAM Protocol Positioning

Deploying Carrier Ethernet OAM
Ethernet Layer 2 VPN Services

Failure Scenario: UNI Failure

CE   PE   EoMPLS Pseudowire   PE   CE

CE UNI failure:
Admin "shutdown"

EVC declared Inactive
PW declared DOWN (syslog)

Tx LDP TLV Status
(PW status: AC DOWN)

PW declared DOWN (syslog)
EVC declared Inactive (syslog)
PW OAM to ELMI InterWorking

ELMI Status message
Async EVC report

ELMI action:
CE brings down
(sub)interface
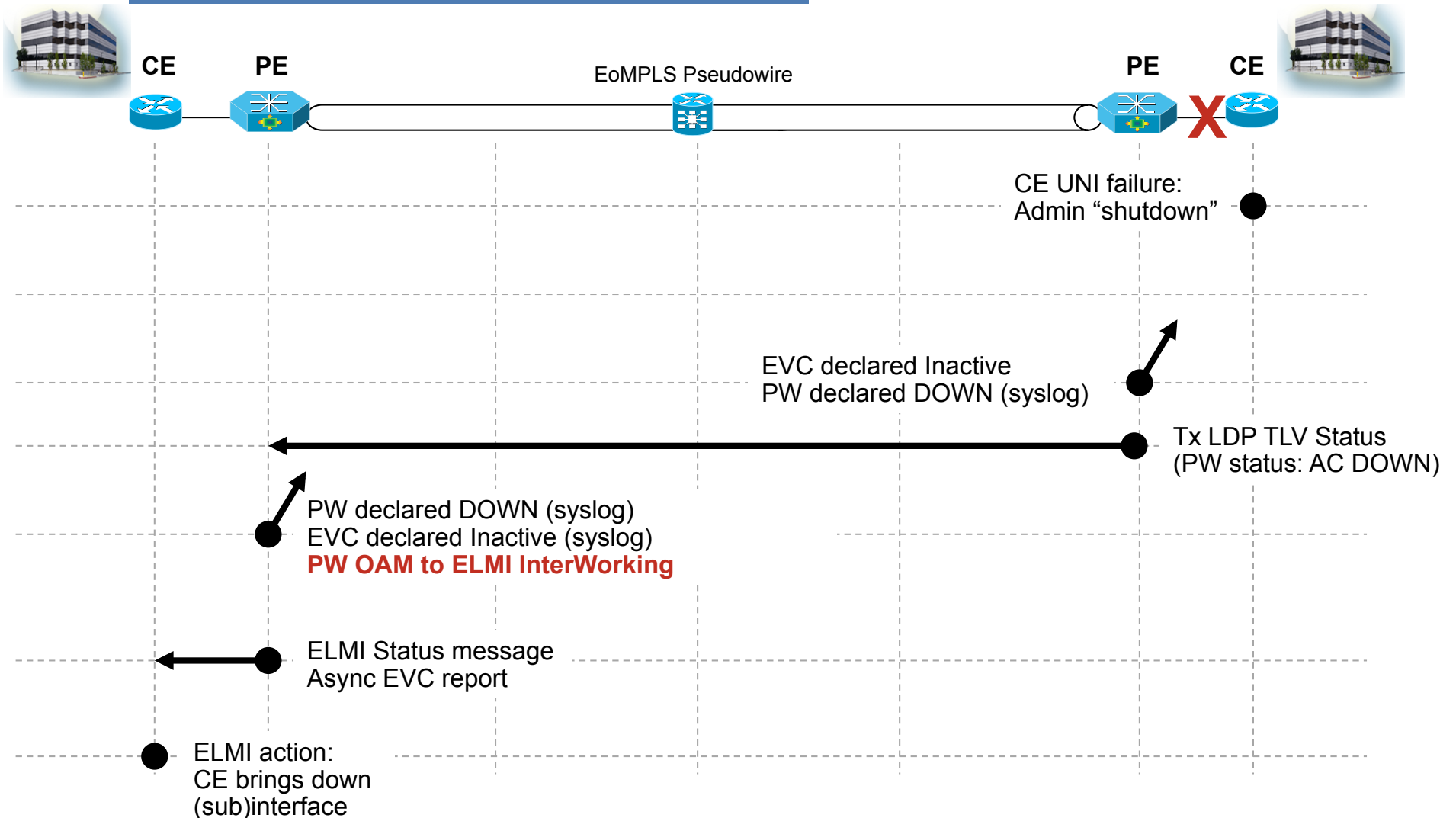
ITU-T Y.1731 Terminology
Comparison with IEEE 802.1ag

IEEE 802.1ag		ITU-T Y.1731	
ME	Maintenance Entity	**ME**	Maintenance Entity
MA	Maintenance Association	**MEG**	ME Group
MAID	MA Identifier	**MEGID**	MEG Identifier
MD	Maintenance Domain	**---**	No such construct available
MD Level	MD Level	**MEG Level**	MEG Level
MEP	MA End Point	**MEP**	MEG End Point
MIP	MD Intermediate Point	**MIP**	MEG Intermediate Point
---	No such construct available	**Server MEP**	Server MEP