



Ethernet OAM Tutorial



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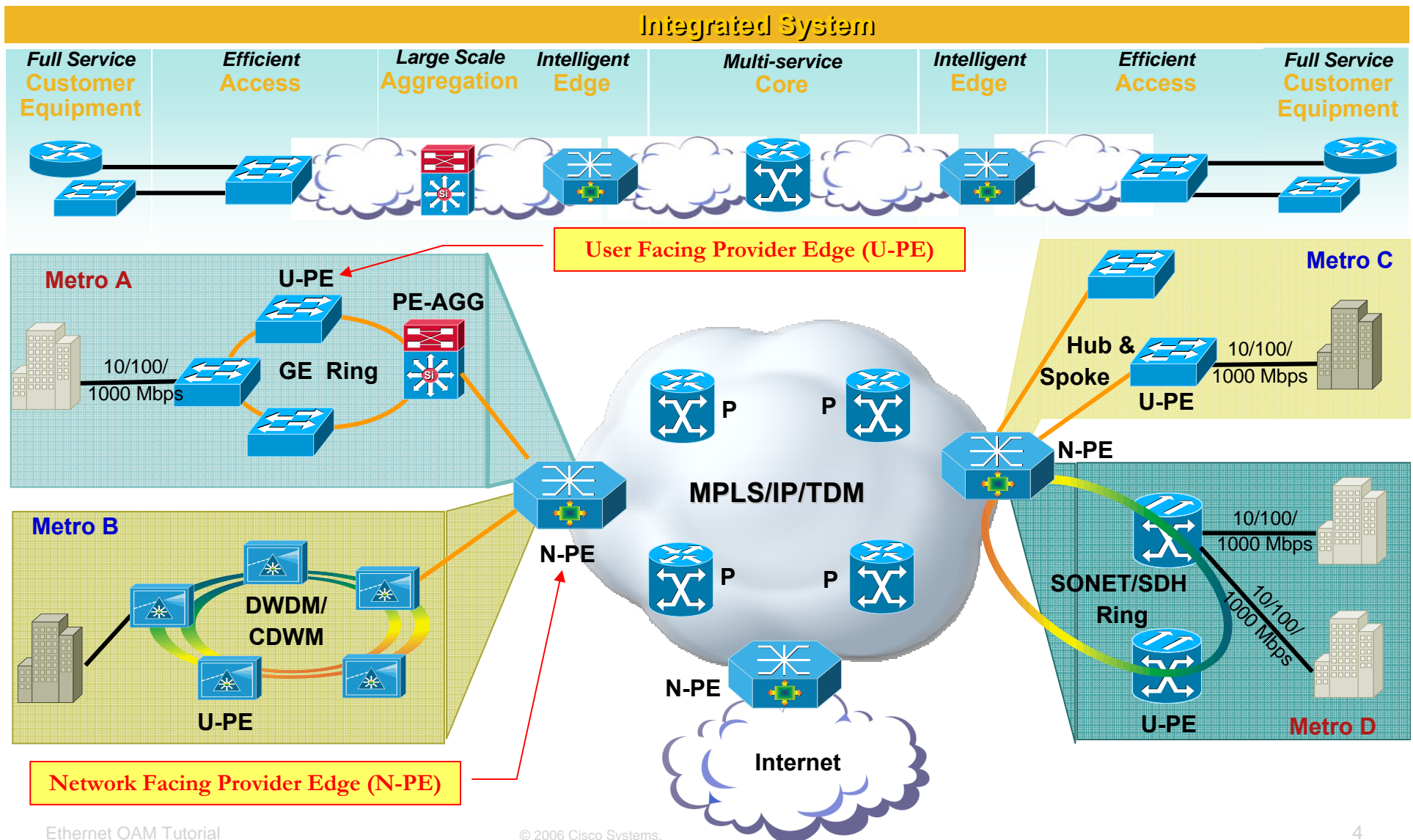
HOUSEKEEPING

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Please don't forget to complete your online session evaluations after each session
Please don't forget to complete the Overall Conference Evaluation which will be available online
- **Please switch off your mobile phones!**

Agenda

- Review of Metro Ethernet technologies & Ethernet OAM
- Manageability to the Customer Premises
- Ethernet OAM Overview
- Ethernet OAM Deployment Overview
- 802.1ag Connectivity Fault Management for Services Management
- 802.3ah for Ethernet in the First Mile for Connectivity Verification
- Metro Ethernet Forum MEF-16 E-LMI for Rapid Service Deployment
- Ethernet OAM Interworking
- Summary

Metro Ethernet – Deployment scenarios

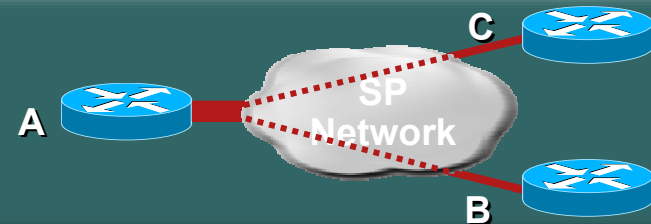


Metro Ethernet—Service Descriptions

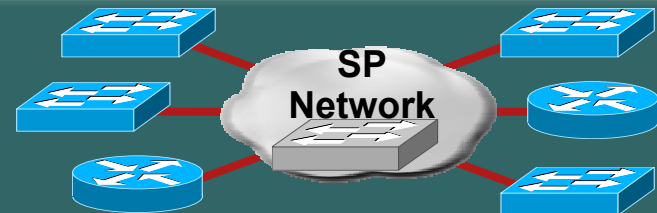
Ethernet Wire Service—EWS
(Like a Leased Line)



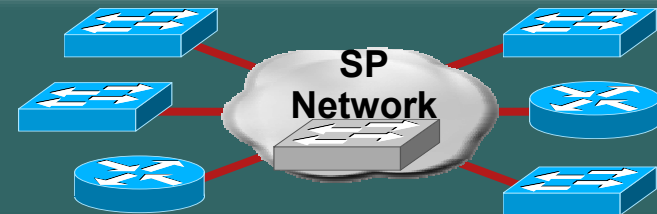
Ethernet Relay Service—ERS
(Like Frame Relay)



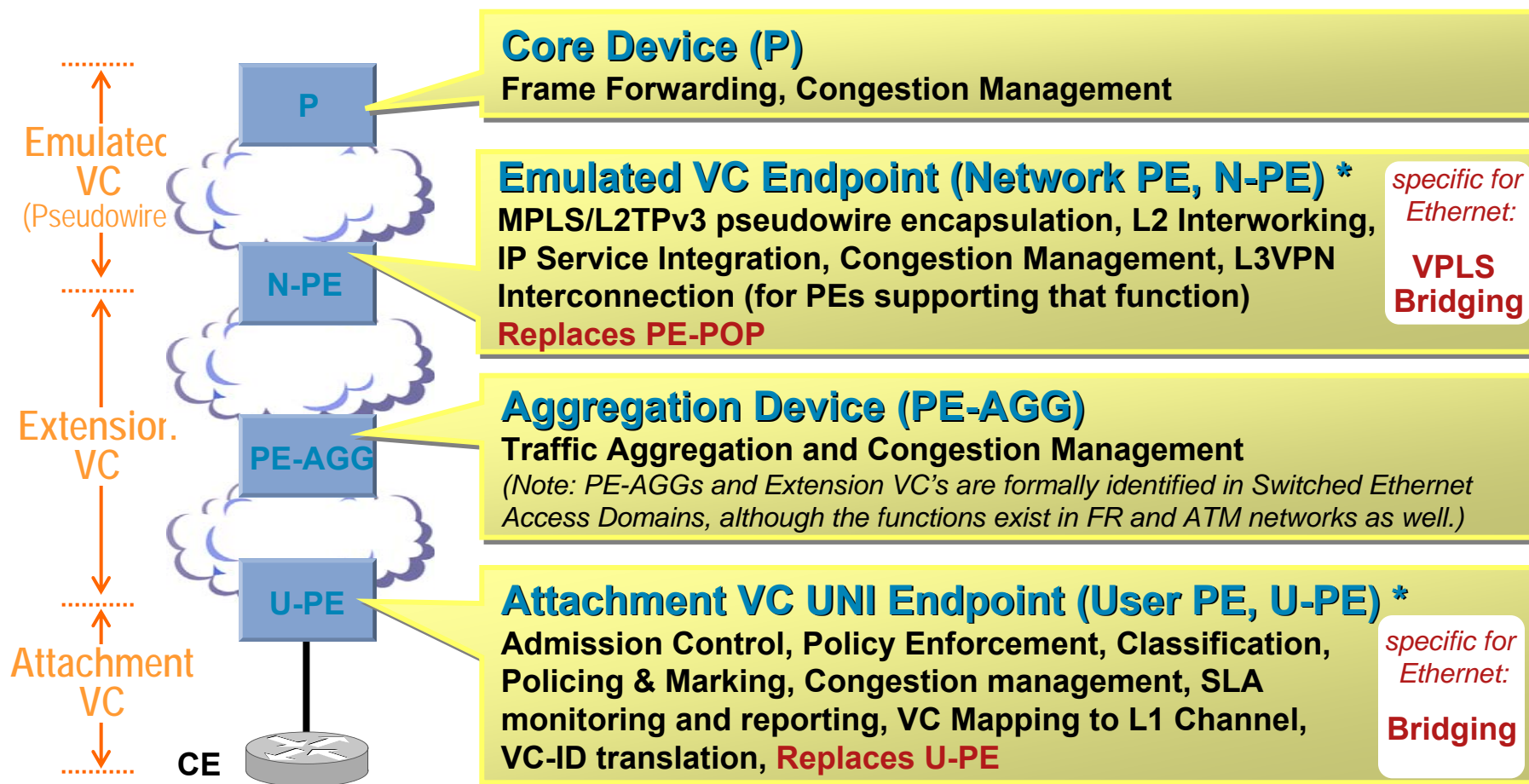
Ethernet Multipoint Service—EMS
(Enhanced with VPLS, Port Mapping)



Ethernet Relay Multipoint Service—ERMS
(New service where the SP cloud acts like a LAN, VLAN Mapping)



IETF Terminology for Metro Ethernet



Note: These different roles can be collapsed within a single box

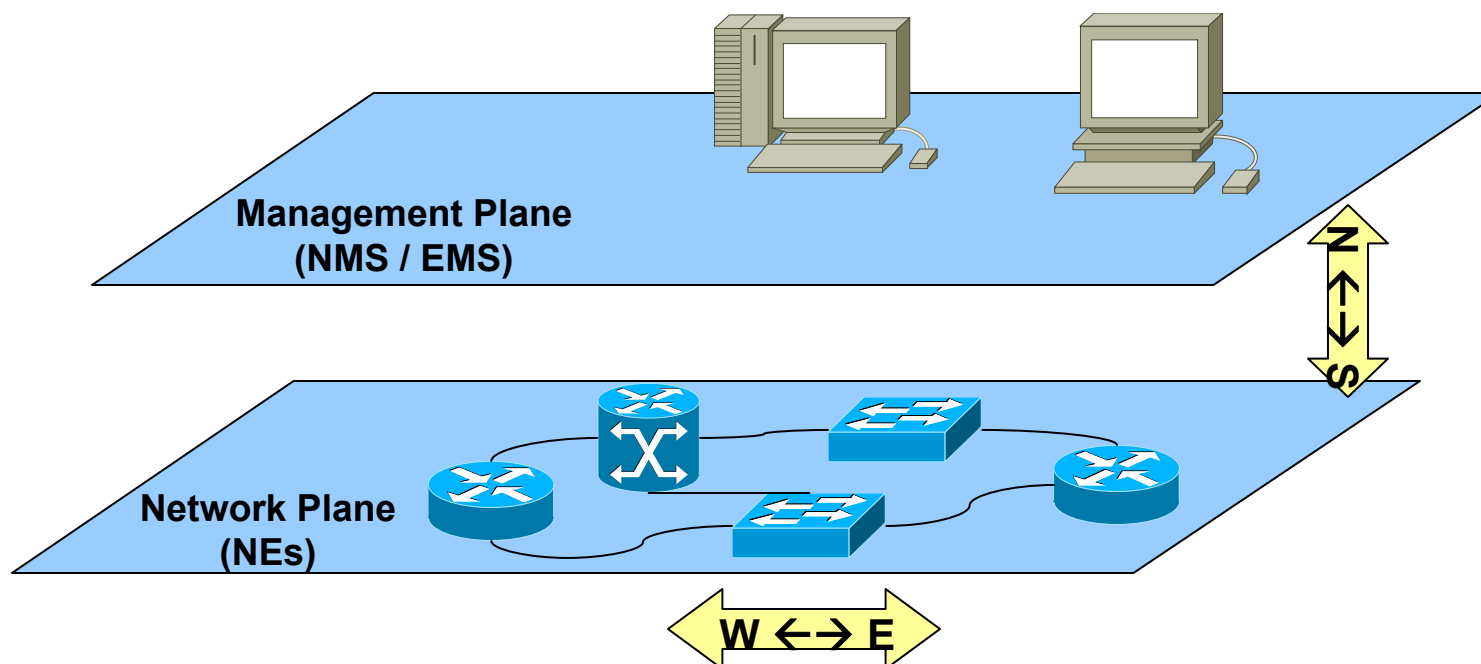
* For More Information refer to <http://www.ietf.org/internet-drafts/draft-ietf-ppvpn-l2-framework-03.txt>

Review of OAM



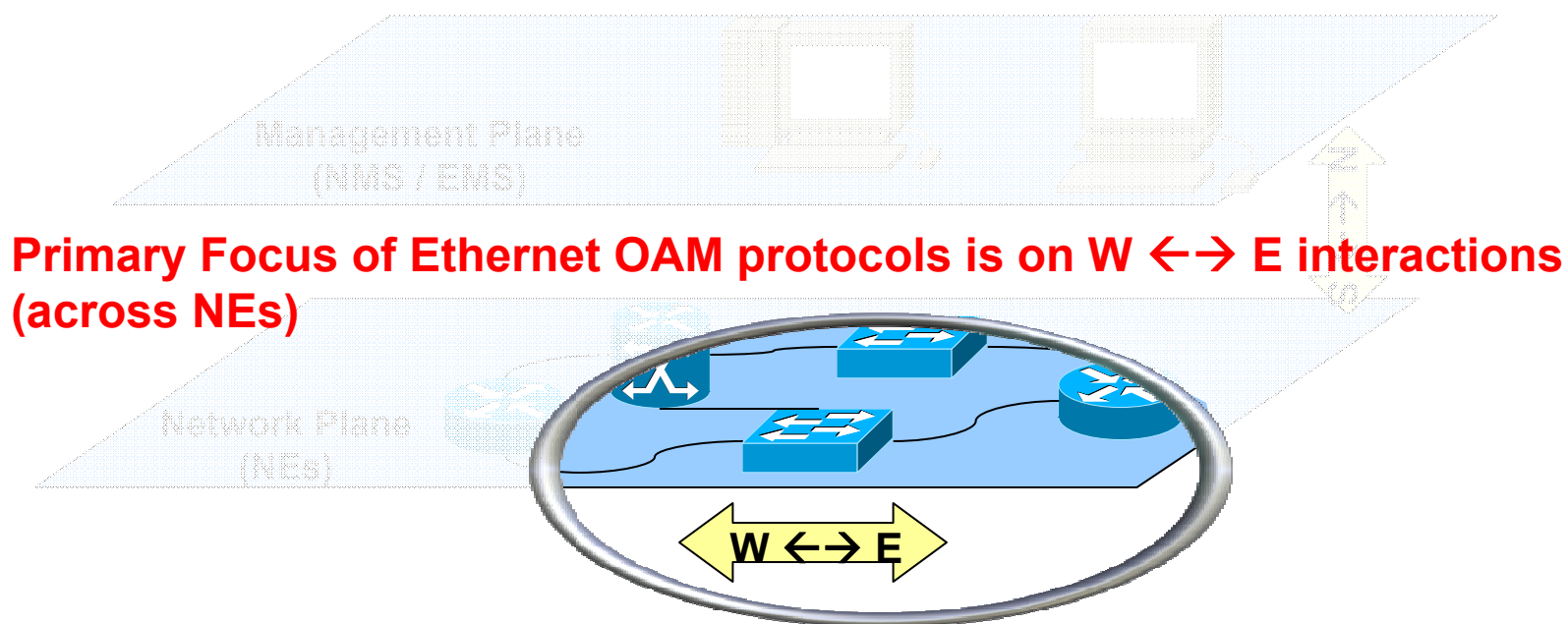
OAM &P: The Concept

- **O**perations, **A**dministration, **M**aintenance & **P**rovisioning:
 - fault indication
 - security management
 - configuration & service provisioning
 - performance monitoring
 - diagnostic functions
- OAM covers both $N \leftrightarrow S$ and $W \leftrightarrow E$ interfaces

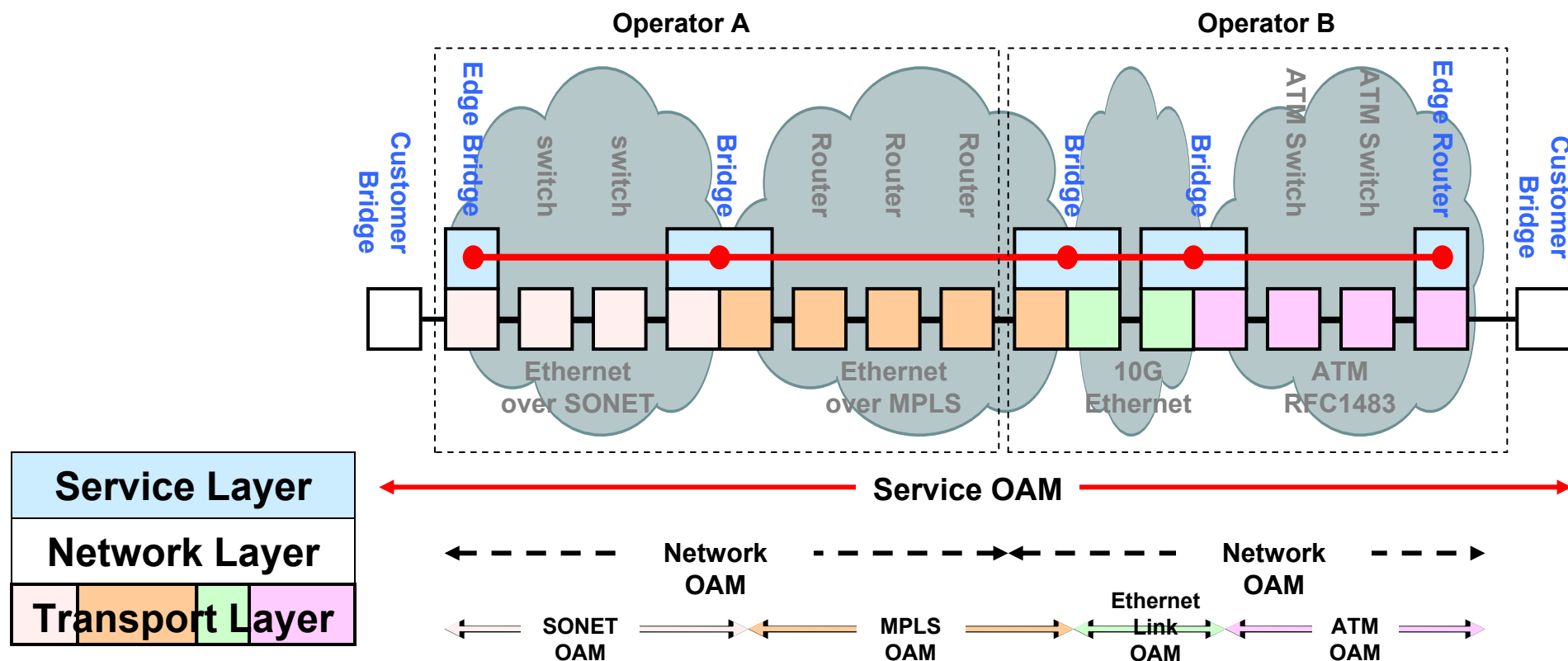


OAM &P: The Concept

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OAM Layering



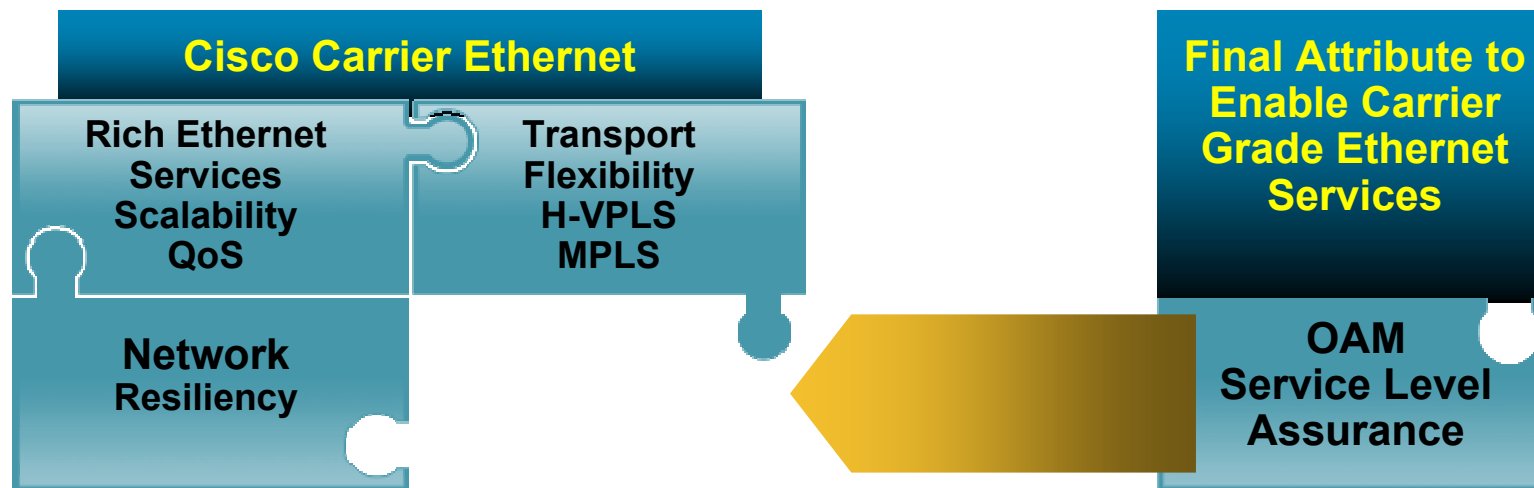
- Model is iterative (layer stacking) & relative (service layer for Operator is transport layer for SP)
- Each Layer supports its own OAM mechanisms
- Inter-working across and within OAM layers is possible

Manageability to the Customer Premise



Carrier Ethernet Attributes

Platform and Technology Convergence



Accelerate Migration to Carrier Ethernet

Ethernet OAM Provides Manageability to Customer Premise
Increased Business Confidence in Ethernet Service Level Agreements
Granular Bandwidth, Increased Transport Efficiency, Lower Costs

What Is Service Assurance?



Detection

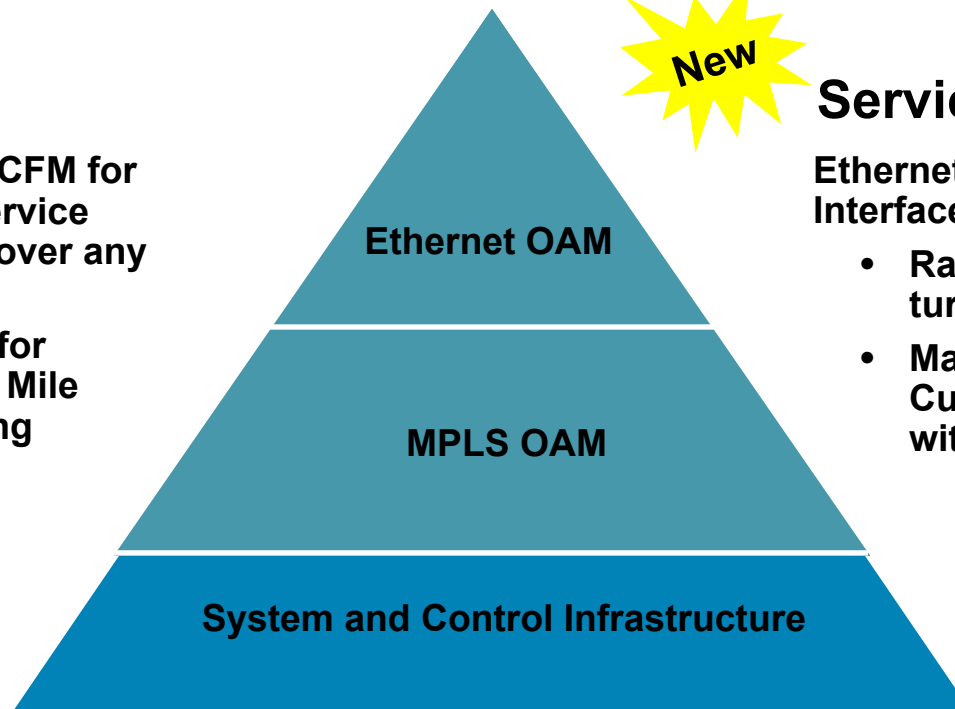
- IEEE 802.1ag CFM for End-to-end service management over any infrastructure
- IEEE 802.3ah for Ethernet First Mile Link Monitoring



Service Availability

Ethernet Local Management Interface (E-LMI)

- Rapid Start service turn-up
- Manageability to Customer Premise with CPE



Resiliency

- Non-Stop Forwarding (NSF)
- Stateful Switchover (SSO)
- Control Plane Failure with Zero Packet Loss
- Pseudowire Redundancy for L2 Failover
- MPLS Link Protection

Ethernet OAM: Service Availability

Rapid Start Service Turn Up—Reduce Truck Rolls

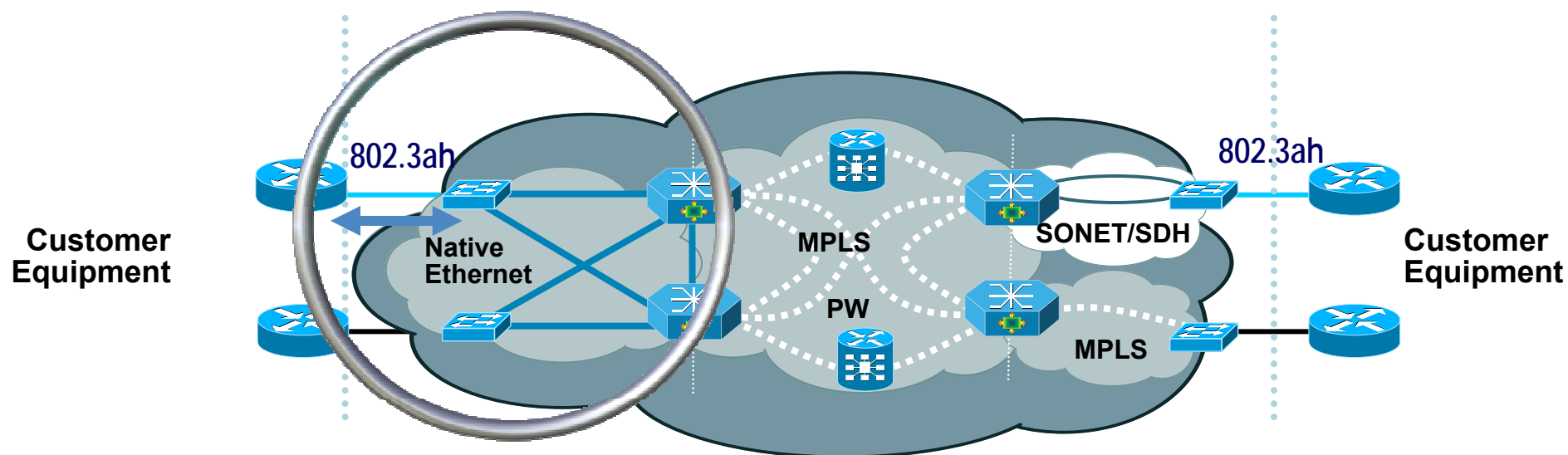
Rapid Start -- Service Turn-Up

- Technician installs CPE Router
- CPE communicates to UPE “I’m Alive”
- UPE responds with available Ethernet connection services (EVCs)
- CPE confirms connection to available EVCs
- Dramatic time-to-install reduction



Service Assurance Detection

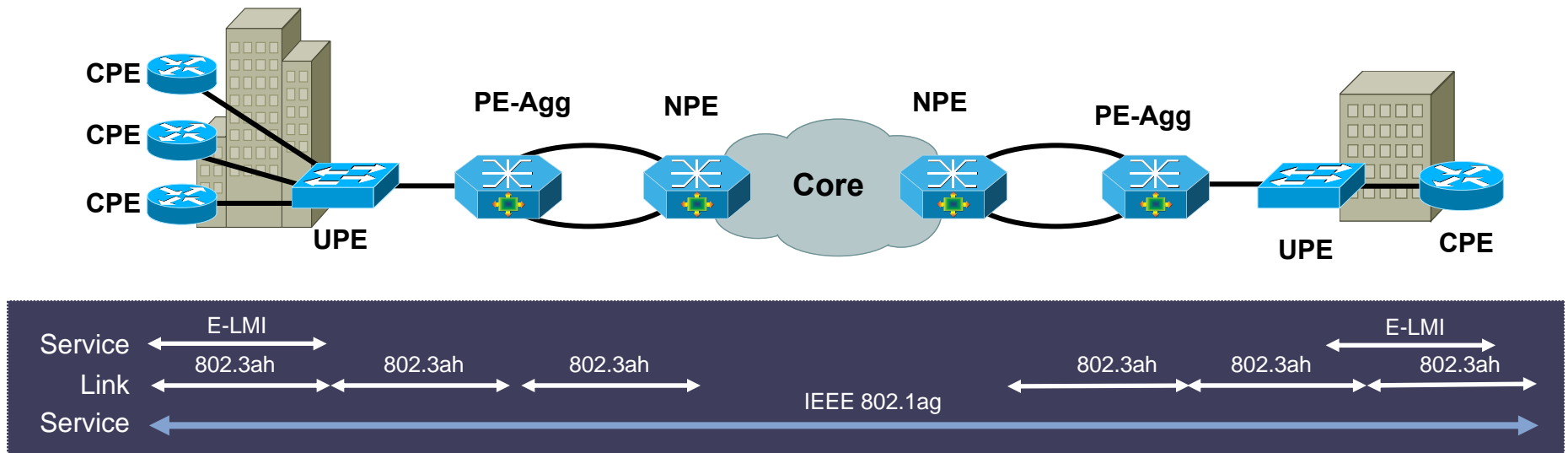
IEEE 802.3ah Link Layer OAM



- Standardized as IEEE 802.3ah Ethernet in the First Mile (EFM)
- Maintain consistency of an Ethernet transport connection (per link, or “physical” OAM)
- Addresses three key operational issues when deploying Ethernet across geographically disparate locations
 - Link monitoring, fault signaling, remote loopback, and OAM discovery
- Operates on a single point-to-point link between two devices
- Slow protocol using packets called OAMPDUs which are never forwarded

Service Assurance: Detection

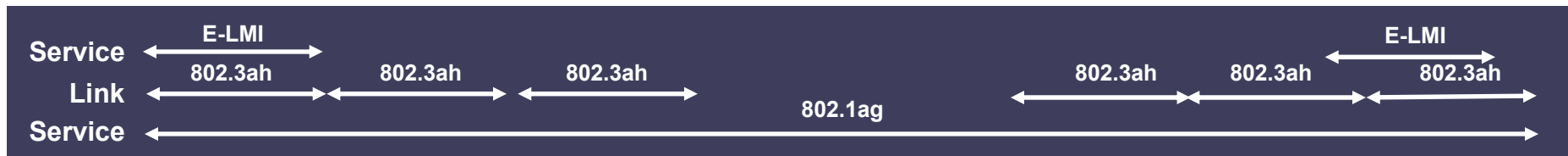
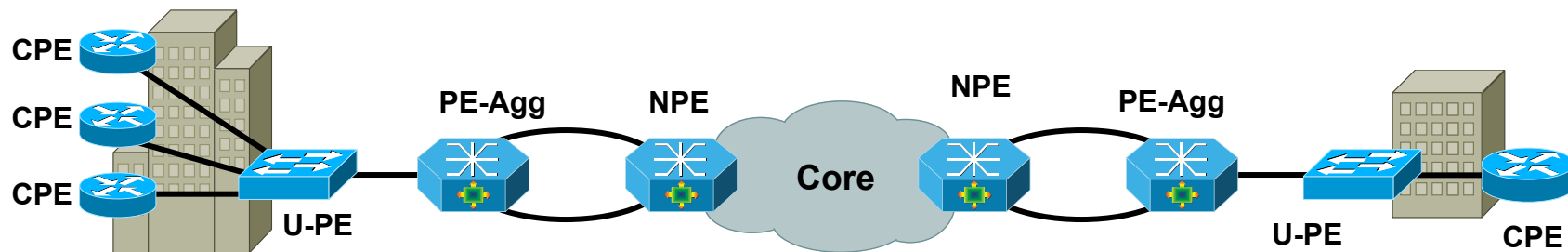
IEEE 802.1ag Connectivity Fault Management (CFM)



- IEEE 802.1ag (CFM) uses Ethernet frames, not MPLS, ATM, or SONET frames, cells, or sub-Ethernet control information
- All devices must support these Ethernet frames to allow service provider to verify end-to-end service connectivity over any IP, MPLS, or VPLS infrastructure

End-to-End Manageability

Customer Loyalty: Service Level Assurance






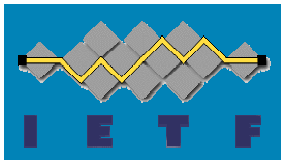
Carrier Ethernet Capabilities

- IEEE 802.1ag: Fault Management per Service/VLAN
- IEEE 802.3ah Link Protection and Monitoring
- MEF 16 E-LMI for Customer Premise Equipment

Benefits





- End-to-end Service Manageability
- First Mile Physical Connectivity Verification
- Pro-active Service Status and Availability

Standards Landscape

Standard Organization	Ethernet OAM [W \leftrightarrow E, N \leftarrow \rightarrow S]
	Link OAM [E\leftrightarrowW] IEEE 802.3ah Fault Mgmt [E\leftrightarrowW] IEEE 802.1ag MIBS IEEE 802.3 + 802.1
	EMS/NMS [N\leftrightarrowS] EMS-NMS Info Model Service OAM [E\leftrightarrowW] Performance Mgmt
	Ethernet OAM [E\leftrightarrowW] Y.1731 Ethernet Protection G.8031 FCAPS SG4
	L2VPN OAM Req. & Framework [E\leftrightarrowW] L2VPN WG

Carrier Ethernet

Ethernet OAM Standards Summary

Standards Body	Ethernet Services	Architecture/Control	Ethernet OAM*	Ethernet
IEEE  		<ul style="list-style-type: none"> 802.3: MAC 802.3ar: Congestion Management 802.1D/Q: Bridges/VLAN 802.17: RPR 802.1ad: Provider Bridges .1ah: Provider Backbone Bridges .1ak: Multiple Registration Protocol .1aj: Two Port MAC Relay .1AE/af: MAC/Key Security .1aq: Shortest Path Bridging 	<ul style="list-style-type: none"> 802.3ah: EFM 802.1ag: CFM 802.1AB: Discovery 802.1ap: VLAN MIB 	<ul style="list-style-type: none"> 802.3: PHYs 802.3as: Frame Expansion
MEF 	<ul style="list-style-type: none"> MEF 10: Service Attributes MEF 3: Circuit Emulation MEF 6: Service Definition MEF 8: PDH Emulation MEF 9: Service Certification MEF 14: Traffic Profiles 	<ul style="list-style-type: none"> MEF 4: Generic Architecture MEF 2: Protection Req and Framework MEF 11: UNI Req and Framework MEF 12: Layer Architecture 	<ul style="list-style-type: none"> MEF 16: E-LMI 	<ul style="list-style-type: none"> MEF 13: UNI Type 1 E-NNI
ITU 	<ul style="list-style-type: none"> G.8011: Services Framework G.8011.1: EPL Service G.8011.2: EVPL Service G.asm: Service Mgmt Arch G.smc: Service Mgmt Chnl 	<ul style="list-style-type: none"> G.8010: Layer Architecture G.8021: Equipment Model G.8010v2: Layer Architecture G.8021v2: Equipment Model Y.17ethmpls: ETH-MPLS Interwork 	<ul style="list-style-type: none"> Y.1730: Ethernet OAM Req Y.1731: OAM Mechanisms G.8031: Protection Y.17ethqos: QoS Y.ethperf: Performance 	<ul style="list-style-type: none"> G.8012: UNI/NNI G.8012v2: UNI/NNI

Overview of Ethernet OAM



Drivers for Ethernet OAM

- **Management Complexity**

 - Large Span Networks**

 - Multiple constituent networks belong to disparate organizations/companies**

 - IP overlay or plug-n-play no longer valid options!**

- **Operational Efficiency**

 - Reduce Opex, avoid truck-roll**

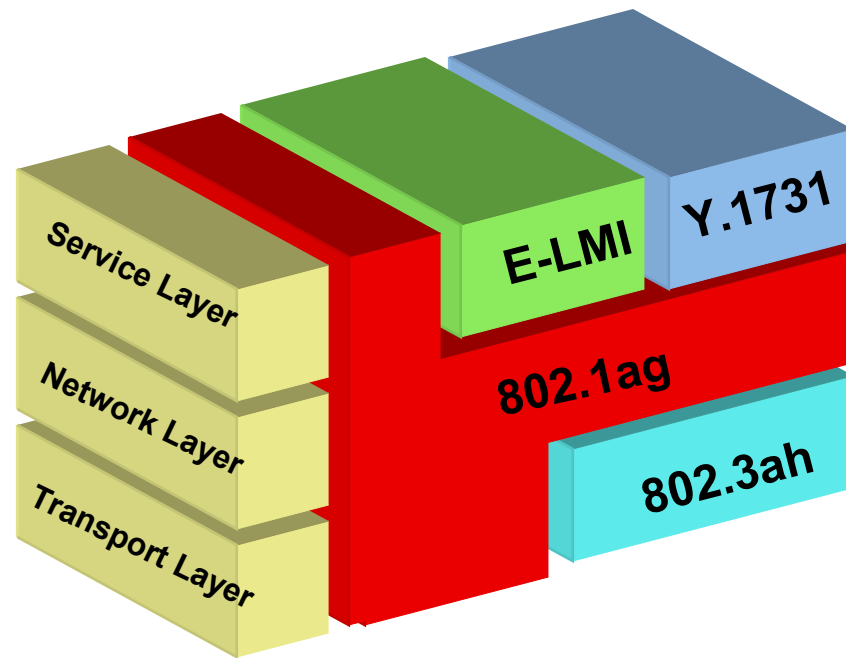
 - Downtime cost**

- **OAM benchmarks set by TDM and existing WAN technologies**

The Promise of Ethernet OAM

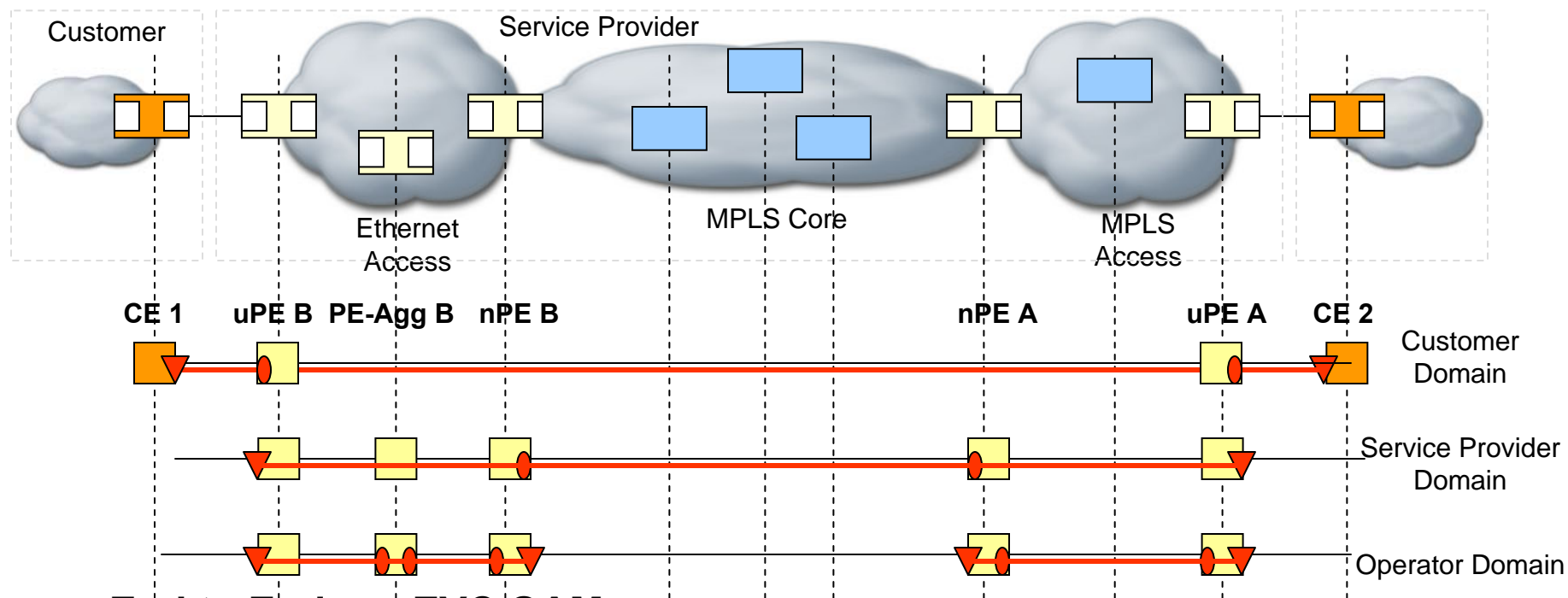
- **Simplify deployment of Ethernet WAN services**
particularly important as Ethernet moves to a volume market with less technically sophisticated customers
- **Enable monitoring & verification of SLAs**
Not all customers and all services are equal.
SLAs will be a key differentiator for carriers and service providers.
- **Provide End-to-End OAM**
Not only within the franchise of a single carrier
Eliminate finger-pointing between carriers
- **Facilitate deployment of Ethernet services over multiple access technologies**
Service independence from access and transport
- **Deliver SP's customers packaged plug and play solutions**

Ethernet OAM: the Protocol Building Blocks



- **IEEE 802.1ag: Connectivity Fault Management (CFM)**
- **ITU-T Y.1731: OAM functions and mechanisms for Ethernet based networks**
- **IEEE 802.3ah: Ethernet Link OAM (EFM OAM)**
- **MEF E-LMI: Ethernet Local Management Interface**

802.1ag Connectivity Fault Management (CFM)



- End to End per EVC OAM
- Hierarchical Maintenance Domains
 - MEPs/MIPs
- Standard Ethernet Frames (in-band)
 - Continuity Check
 - Loopback
 - Link Trace

Y.1731

- **CFM plus...**

ETH-LCK (out of service diagnostics)

Multicast Loopback

AIS

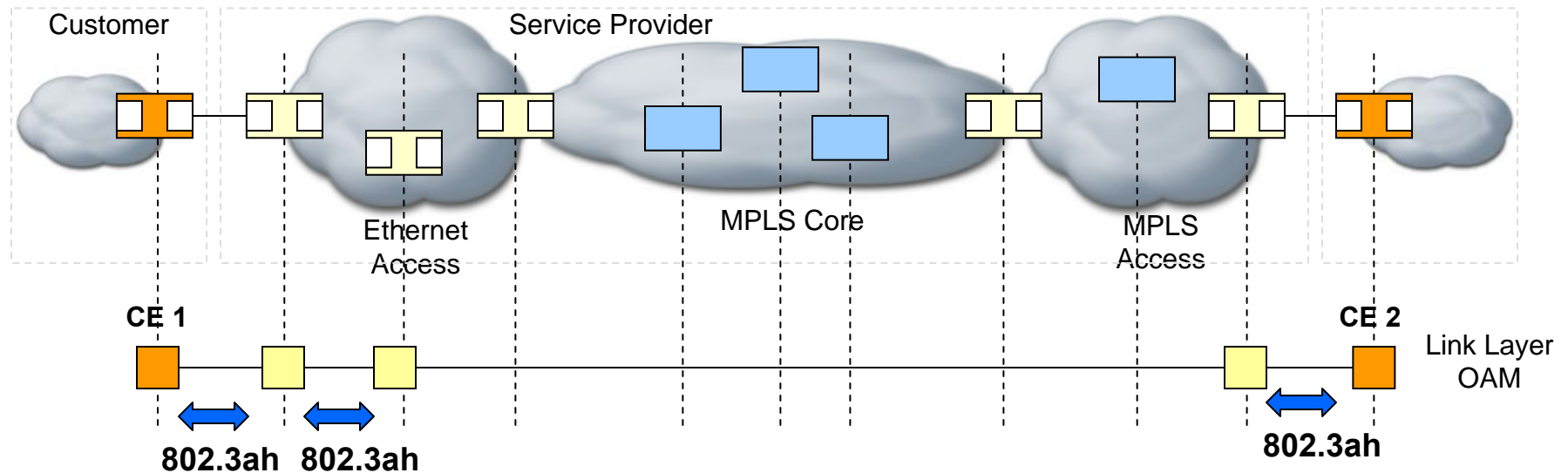
TEST

Maintenance Communication Channel

Experimental OAM

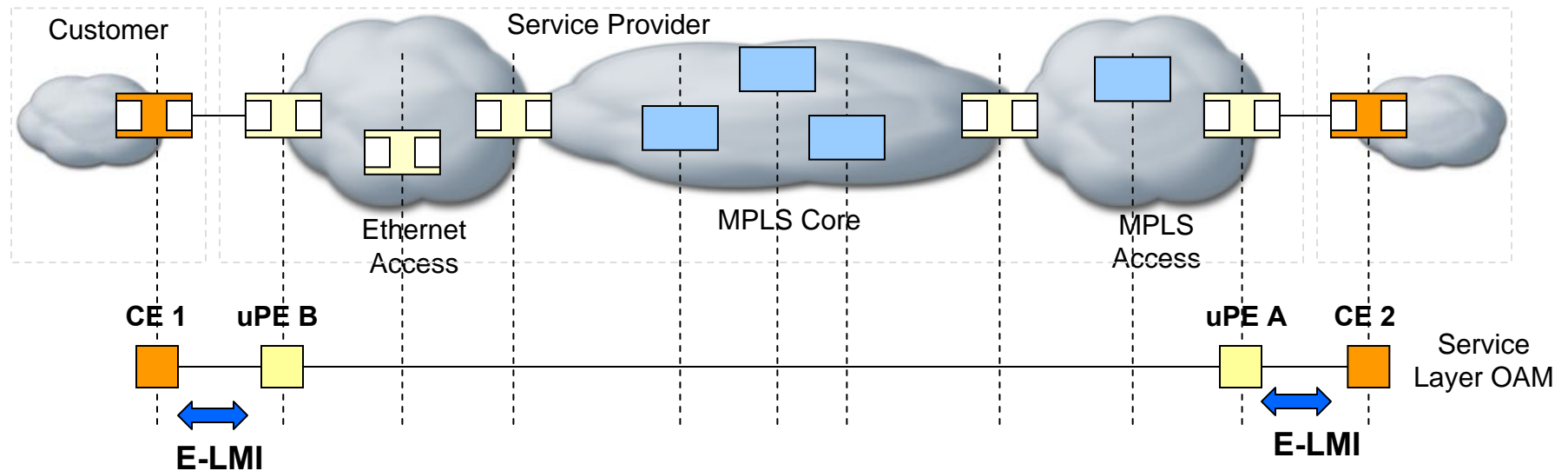
Performance Measurement (Delay, Packet loss ...)

802.3ah



- **Link Level OAM**
- **Operates on point-to-point link, not propagated beyond a single hop.**
- **Slow Protocol (Max rate of 10 frames per second)**
- **Functions:**
 - OAM discovery** – Discover OAM capabilities on peer device
 - Link monitoring** – Event notification when error thresholds exceeded
 - Remote MIB Variable Retrieval** – Polling and response (but not writing) of 802.3ah MIB
 - Remote Failure indication** – Inform peer that receive path is down.
 - Remote Loopback** – Puts peer in (near-end) intrusive loopback state. Statistics can be collected while testing link.

E-LMI



- Asymmetric protocol, applicable on UNI only (uPE to CE)
- Specifies procedures & message formats exchanged and NOT how uPE collects OAM data – relies on Service/Network OAM running uPE to uPE
- Allows uPE to communicate to CE:
 - EVC Status
 - Remote UNI Status
 - CE-VLAN to EVC Map
 - BW Profiles

802.1ag

Connectivity Fault Management



Why do Service Providers want Connectivity Fault Management?

- Debugging Layer 2 networks is not easy in the Enterprise space.
- Debugging networks of Layer 2 networks promises to be even harder.
- Especially when the component networks belong to different organizations and/or different companies.
- Experience in providing circuit-based services provides a very useful model for managing and debugging nets of nets.

What is Ethernet Connectivity Fault Management?

- **Connectivity Fault Management (CFM)** is an important part of “End-to-End OAM”.
- CFM is **Ethernet** frames, **not** MPLS, ATM, or SONET frames, cells, or sub-Ethernet control information.
- **Only bridges** see CFM because bridges are the only active relay functions that exist.
- MPLS, ATM, and SONET OAM are important for debugging Ethernet “wires”, but are **not always** end-to-end.

(Terminology issue) There is no such thing as a “Metro Ethernet Edge Router”

- If interoperability is to be achieved among the various technologies used for Metro Ethernet, the **IEEE 802 LAN architecture** must be observed.
- There are only two kinds of active relay elements in IEEE 802: **Bridges** and **Hubs** (Repeaters).
- A “Metro Ethernet Edge Router” is a **Bridge** that does not need to run spanning tree, has only two ports per VLAN enabled (one trunk and one local Ethernet), and uses Pseudowires for trunks.
- (This notion saves a lot of verbiage in this document. Whether a box is a router or a bridge depends on which function you are looking at.)

Maintenance and other OAM issues **not** discussed

- Minimal discussion of Provider-to-Customer (single-link) IEEE 802.3ah OAM.
- No explanation of MPLS, ATM, or other OAM.
- No explanation of other techniques such as periodic confirmation of network topology and configuration, SNMP-based “traceroute”, or Layer 3 functions such as Ping.
- No explanation of other protocols such as Ethernet Line Management Interface, BPDUs, etc.

Two standards bodies are defining CFM or End-to-End OAM

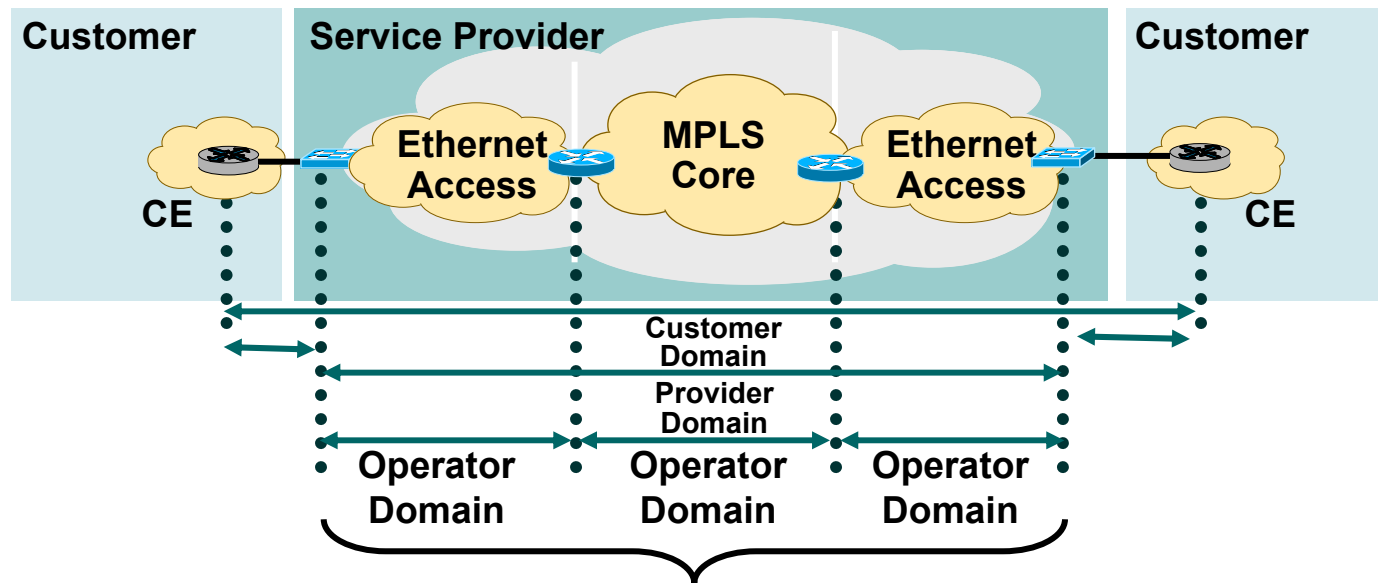
- IEEE 802.1ad defines Q-in-Q “Provider Bridges”. IEEE 802.1ag defines “Connectivity Fault Management” for all IEEE 802 Bridges.
- ITU-T Question 3, Study Group 13, is defining end-to-end Ethernet OAM for both circuit-switched equipment (e.g. Ether-over-SONET) and packet-switched equipment (802.1ad Bridges).
- Both 802.1 and Q.3/13 share common membership and are cooperating fully.
 - 802.1 should define low-level aspects tied closely to bridging technology.
 - Q.3/13 should define high-level aspects tied to the service models.



Domains, Maintenance Levels, and Flow Points



The OAM Environment



- **Customer contracts with Provider for end-to-end service.**
- **Provider contracts with Operator(s) to provide equipment and networks.**
- **Provider and Operator(s)** may or may not be the same company or same division.

Flow Points and Domains

- Domains are defined in terms of “flow points”, which are “MACs” to IEEE 802, and “interfaces” or “ports” to others.
- A flow point (FP) at the edge of a Domain is called a “Maintenance Point” or MP.

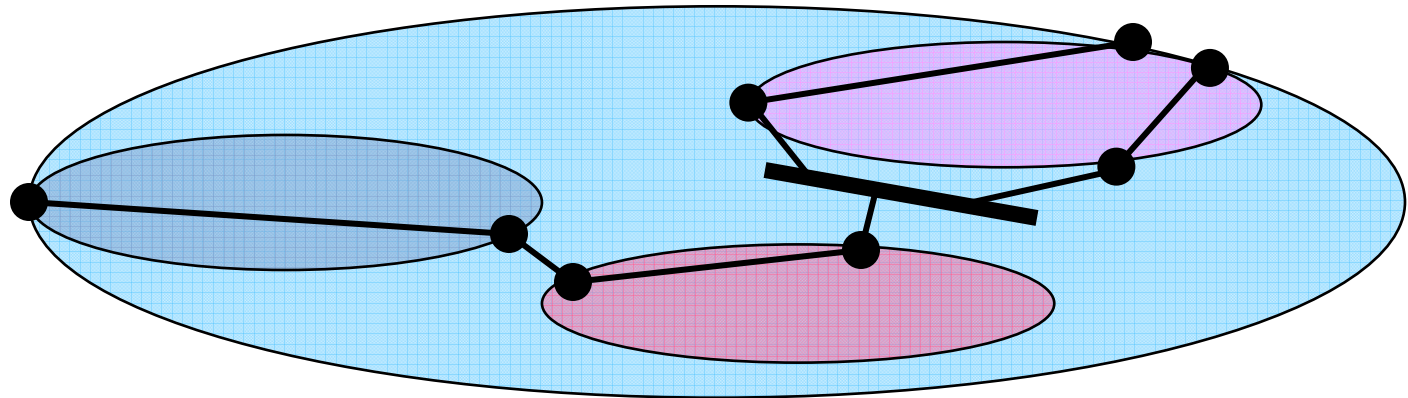
System administrators use MPs to initiate and monitor CFM activity and report the results.

- A flow point inside a Domain, and visible to an MP, is called a “Loopback Point”.

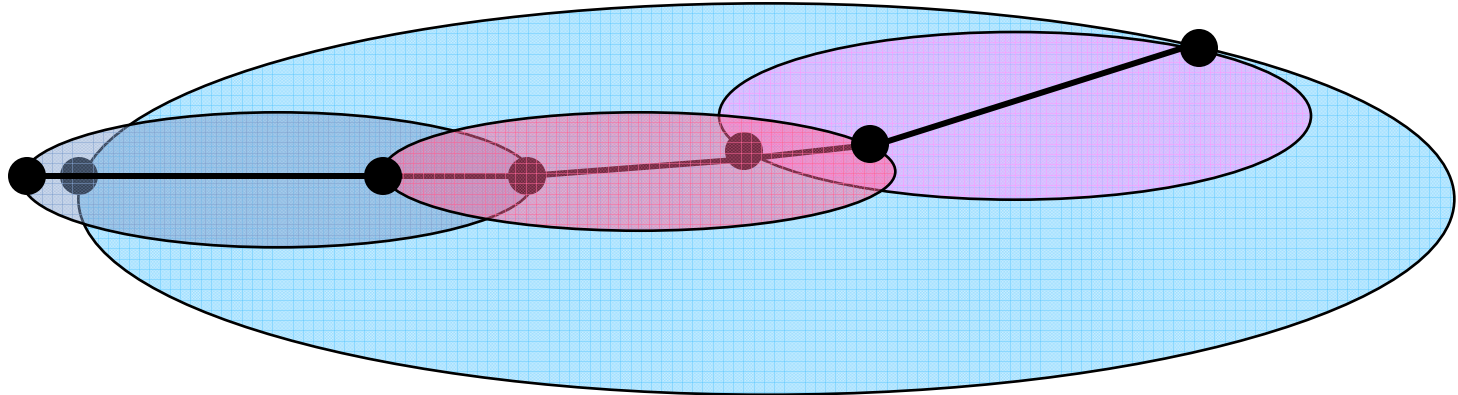
Loopback Points (LPs) passively receive and respond to CFM packets initiated by MPs.

Domains

OK

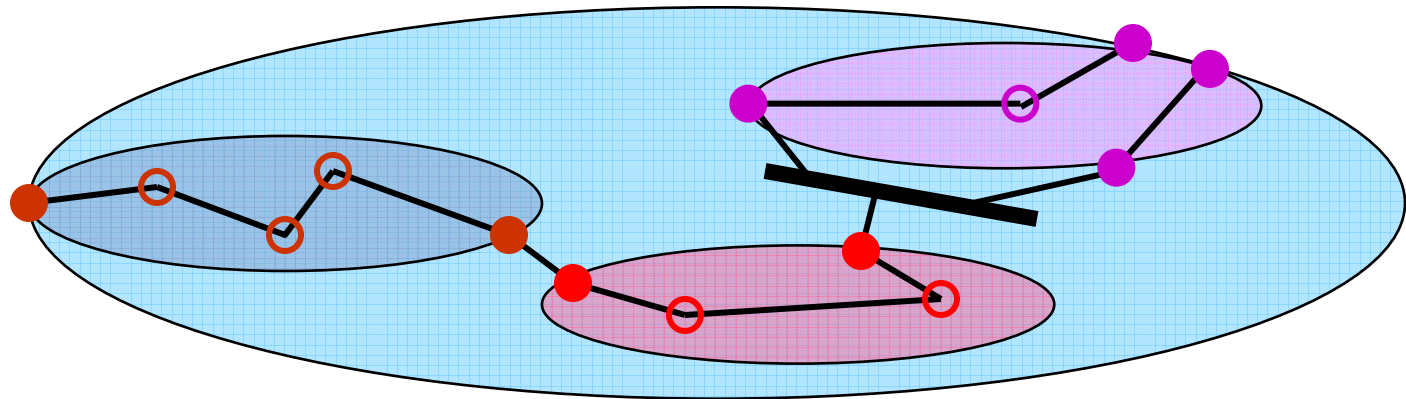


NO



- Domains may nest or touch, but must never intersect.

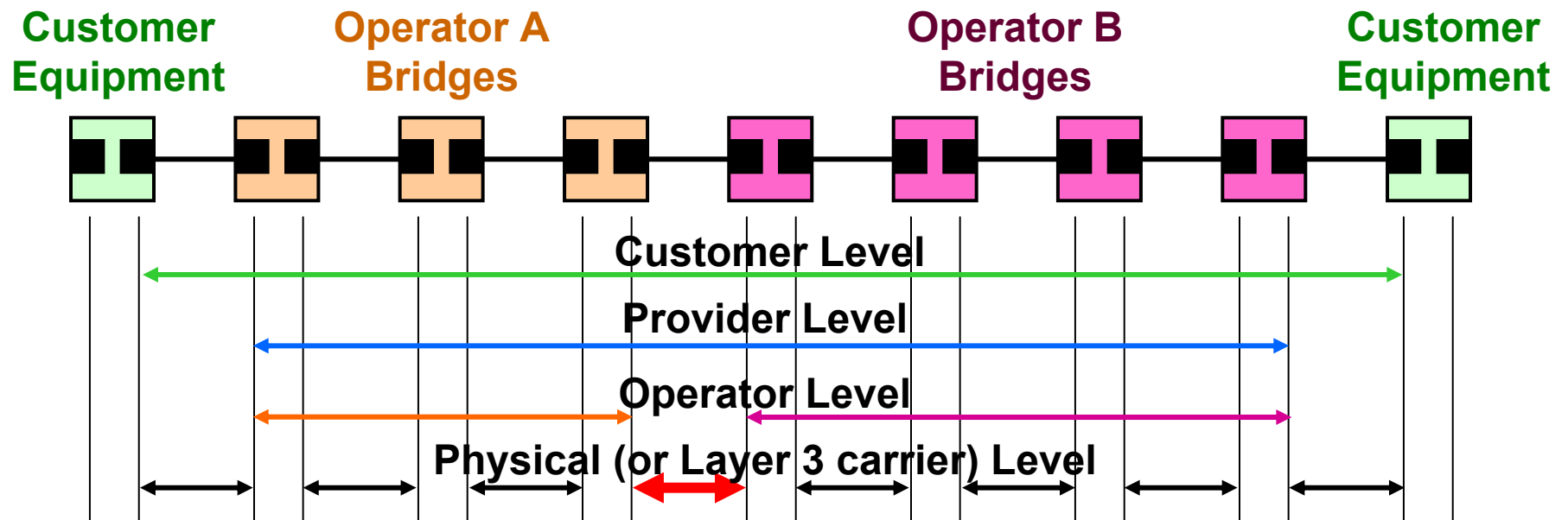
Domains



● ● ● **Maintenance Points** ○ ○ ○ **Loopback Points**

- Maintenance Points are always at the **edges** of Domains.
- Loopback Points are always **within** Domains.

Maintenance Levels

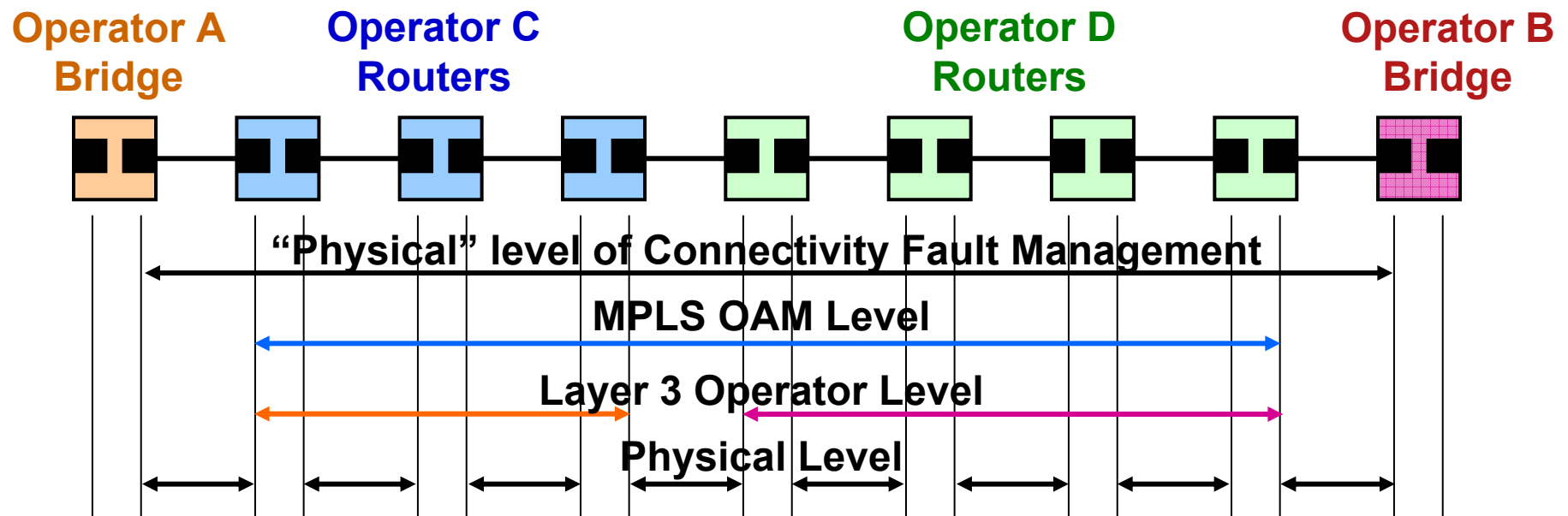


- At (at least) Operator and Physical levels, there may be multiple Domains.

There *could* be multiple Domains at any level.

Lower CFM Levels

(Expanding red link in the previous slide)

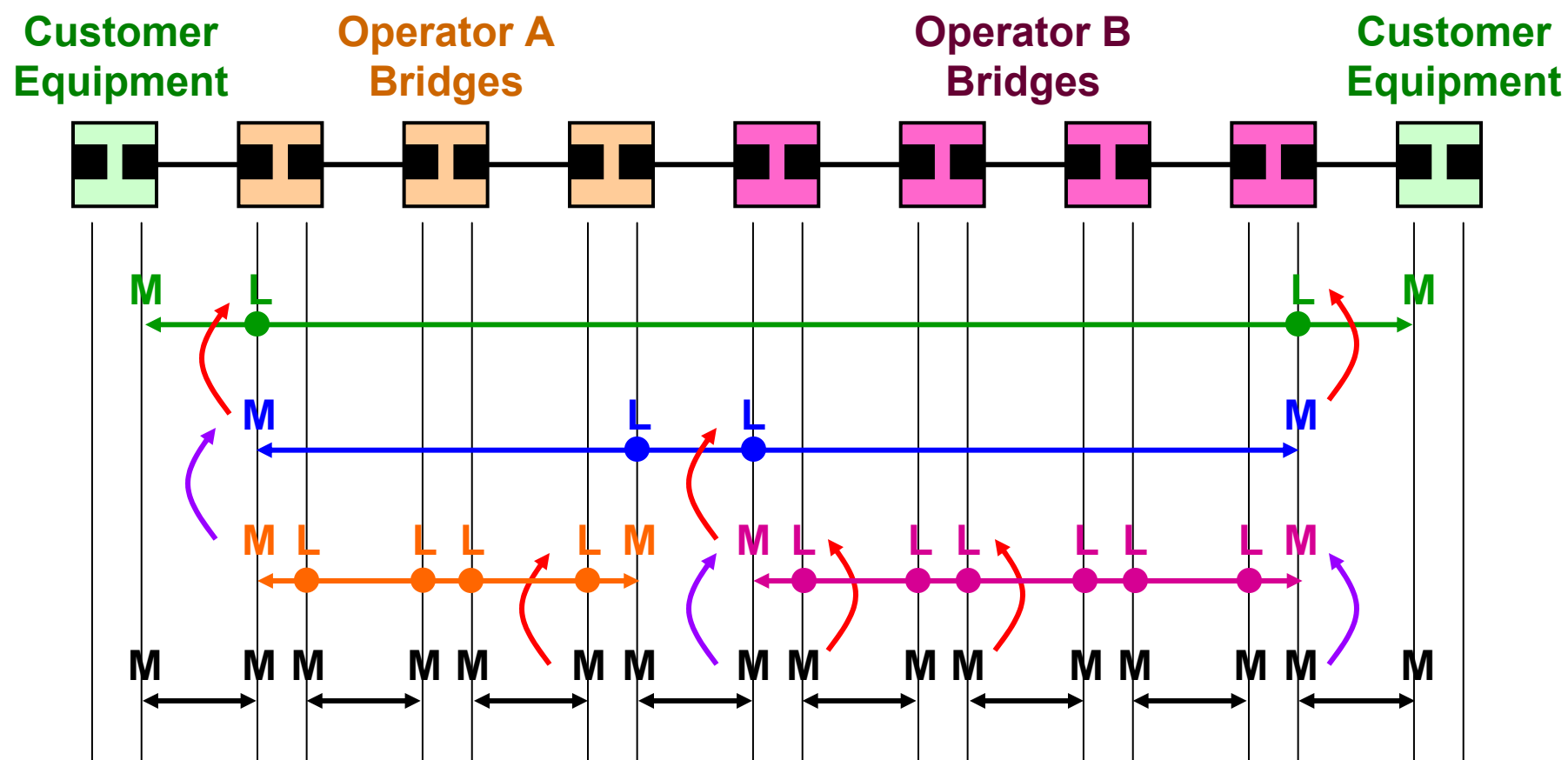


- There are levels below CFM.

This is where MPLS OAM, ATM OAM, etc., live.

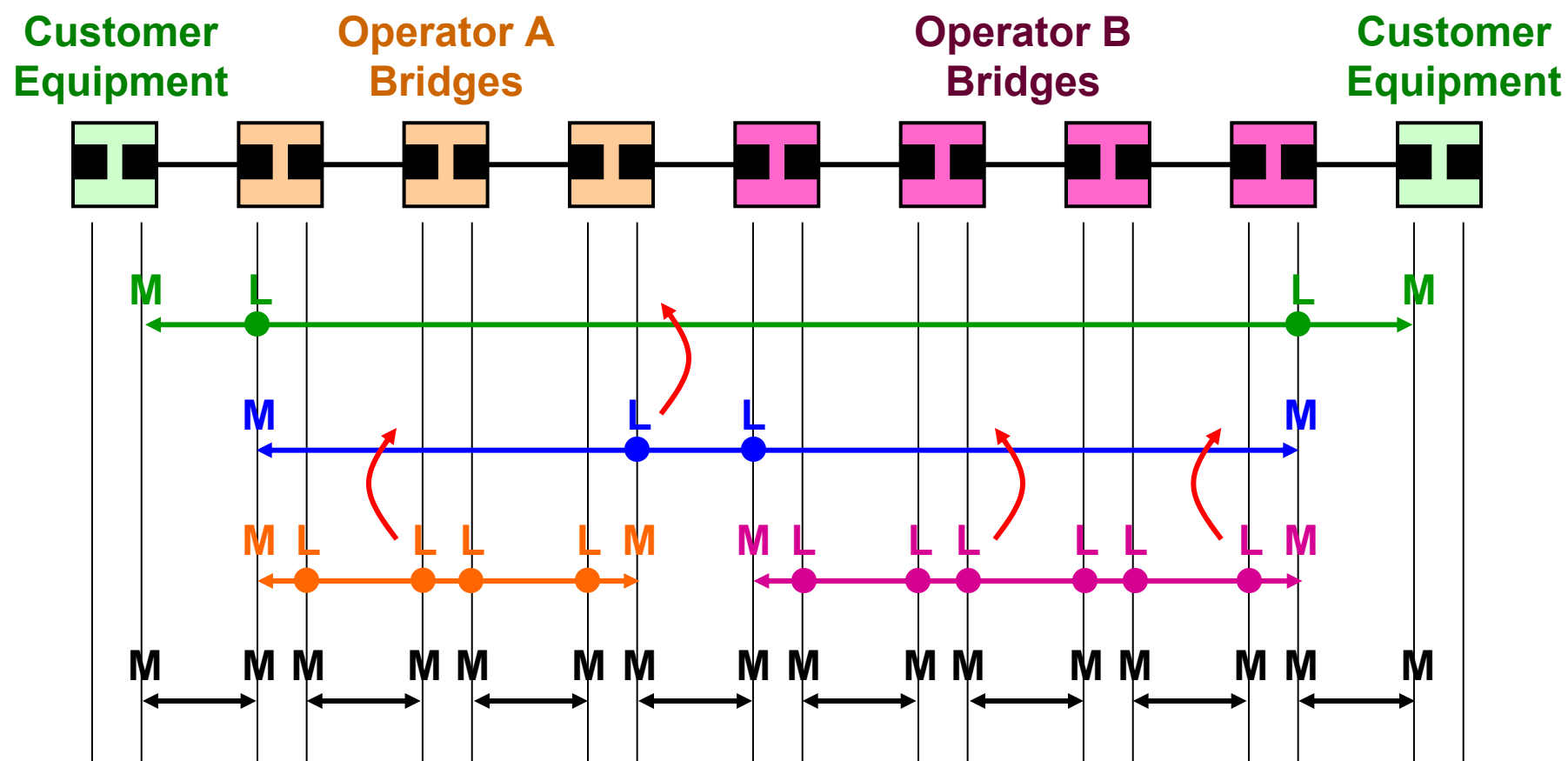
These OAM functions *ought to*, but do not *necessarily*, follow the MP/LP/FP model.

Loopback Points, Maintenance Points



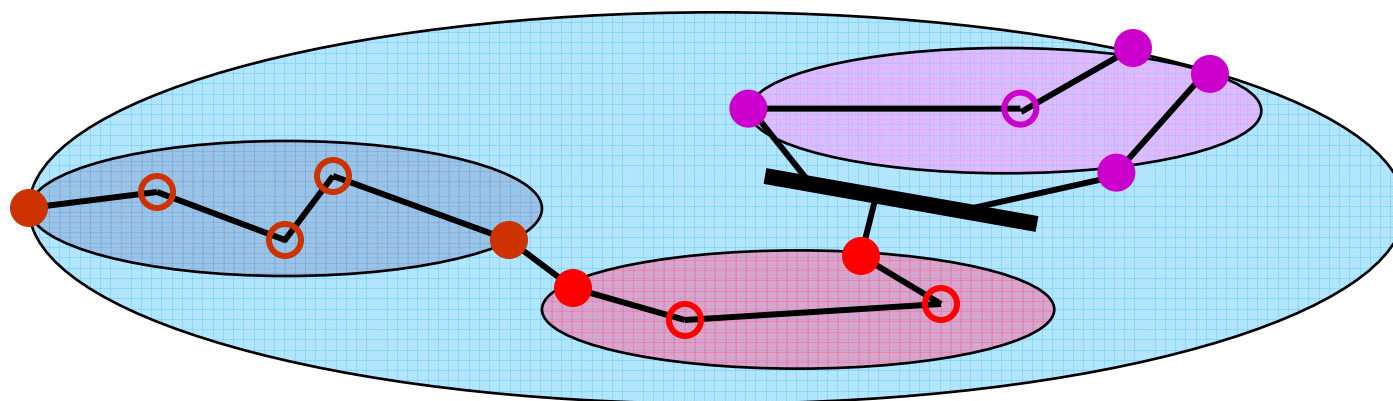
- Each Level's Maintenance Points are the next-higher-level's Maintenance or Loopback Points.

Loopback Points, Maintenance Points



- Each Level's Loopback Points are **invisible** to all higher levels.

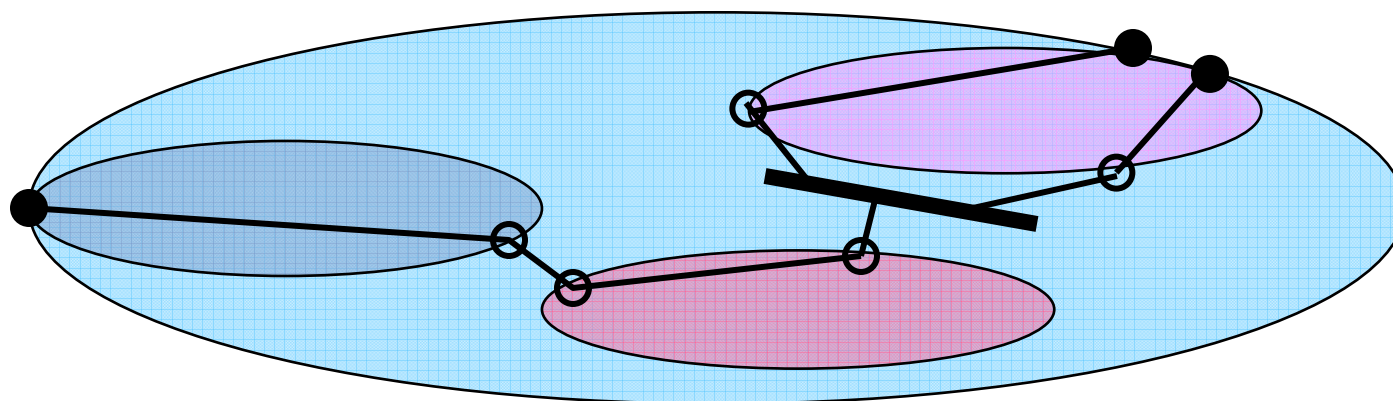
Loopback Points and Maintenance Points: Operator Levels (x3)



● ● ● **Maintenance Points** ○ ○ ○ **Loopback Points**

- Each Level's Maintenance Points are the next-higher-level's Maintenance or Loopback Points.
- Each Level's Loopback Points are invisible to all higher levels.

Loopback Points and Maintenance Points: Provider Level



● Maintenance Points

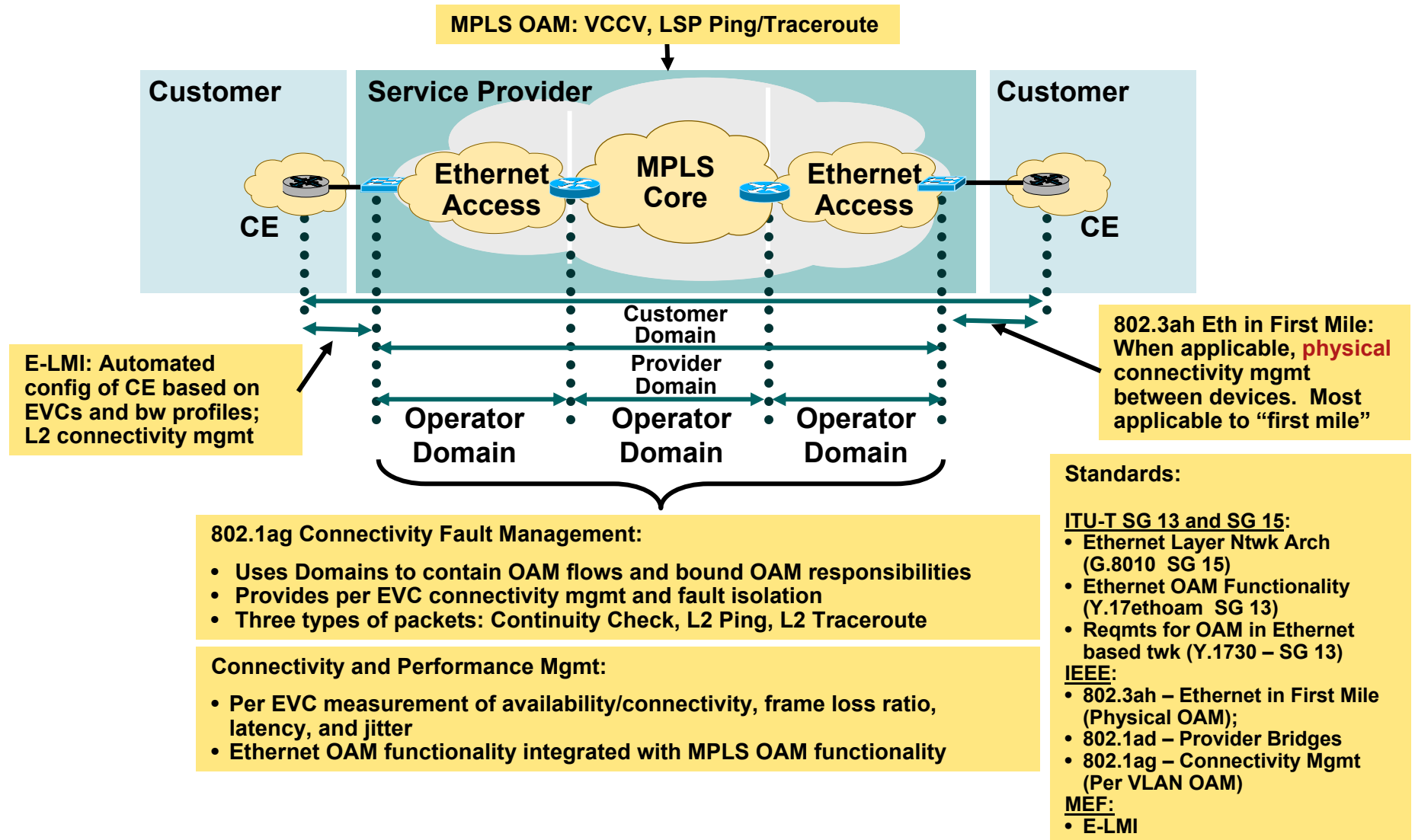
○ Loopback Points

- Each Level's Maintenance Points are the next-higher-level's Maintenance or Loopback Points.
- Each Level's Loopback Points are invisible to all higher levels.

Connectivity Fault Management

- Overview
- CFM Technology Primer
- CFM implementation

Standards-Based Ethernet OAM — Comprehensive Approach



CFM Technology Primer

- The Basics

CFM uses standard Ethernet Frames.

CFM frames are distinguishable by Ether-Type (and MAC Address for multicast messages).

CFM frames are sourced, terminated, processed and relayed by Provider Bridges – only Bridges see CFM.

- The Players

Customer contracts with Metro-E **Provider** for end-to-end Ethernet service. Provider sub-contracts with **Operator(s)** to provide equipment and networks.

CFM Technology Primer

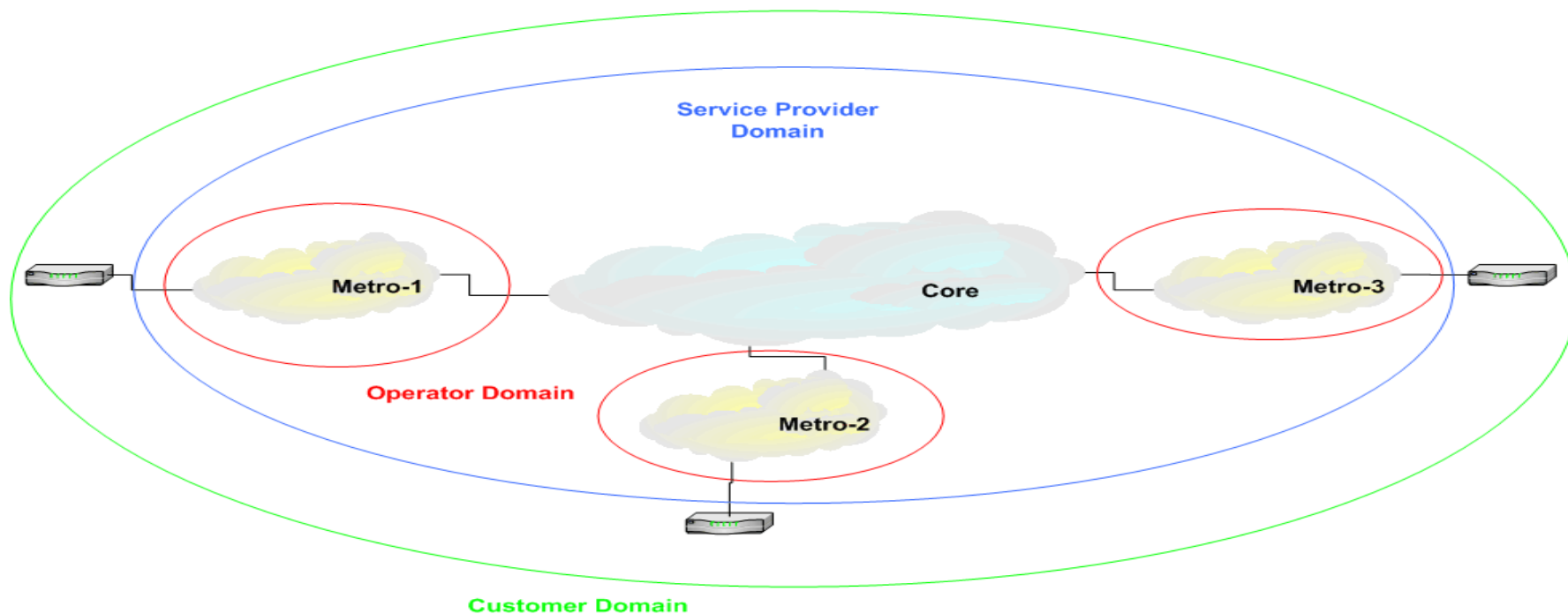
■ Maintenance Domains & Levels

A “Management Space” owned and operated by a single organization (department).

CFM message exchanges and operations are per-domain.

A Domain has a Maintenance Level associated with it (value 0 to 7). Two (or more) disjoint domains may be at the same Level, even on the same device.

Domains have a hierarchical relationship that parallels the structure of the “Players”.

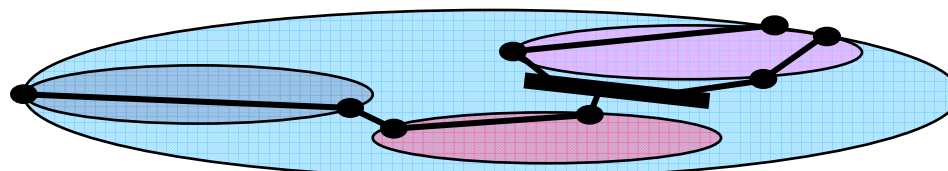


CFM Technology Primer

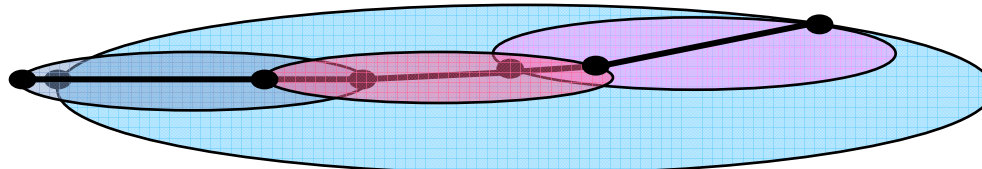
- Maintenance Domains & Levels (continued...)

Domains may nest but cannot intersect.

OK



NO



As of this writing, higher Maintenance Levels are more “Phyward”, lower Maintenance Level are more “Custward”.

CFM Technology Primer

- Maintenance Points

A Maintenance Point (MP) is a demarcation point on an interface (port) that participates in CFM within a Maintenance Domain.

Two classes of MPs:

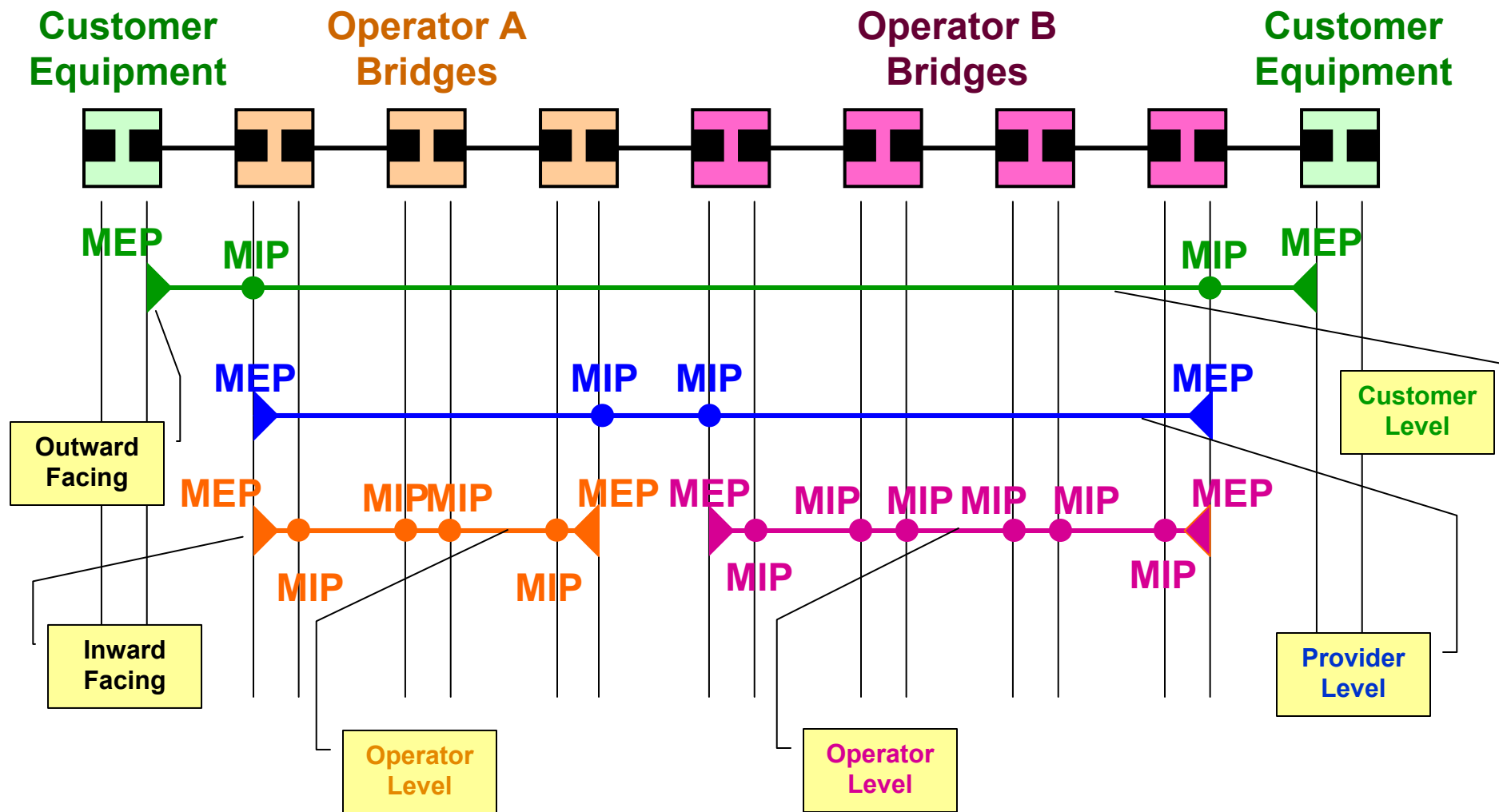
Maintenance End Points (MEPs): At the edge of a Domain. Actively source CFM messages. Are directional (inward or outward facing).

Maintenance Intermediate Points (MIPs): Internal to a Domain. Passive points, only respond when triggered by certain CFM messages.

MPs should be explicitly provisioned on Cisco IOS devices.

The level of a MIP (or level 7 MEP) defines the port level.

CFM Technology Primer



CFM Technology Primer

- CFM Messages

All CFM Messages are per Maintenance Domain and per S-VLAN (PE-VLAN or Provider-VLAN).

Regular Ethernet Frames, distinguishable by Destination MAC and/or Ethertype.

Provider Bridges that cannot interpret CFM Messages must forward them as normal data frames.

Four types of Messages:

- Continuity Check (CC)

- Loopback

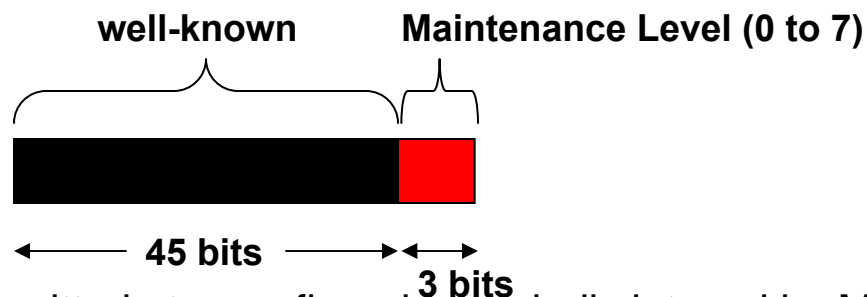
- Traceroute

- Alarm Indication Signal (AIS)

CFM Technology Primer

- Continuity Check (CC)

Per-Domain & per-VLAN Multicast “heart-beat” messages. Destination address format:



Transmitted at a configurable periodic interval by MEPs (default is 30 seconds, range from 10 sec to 65535 sec.)

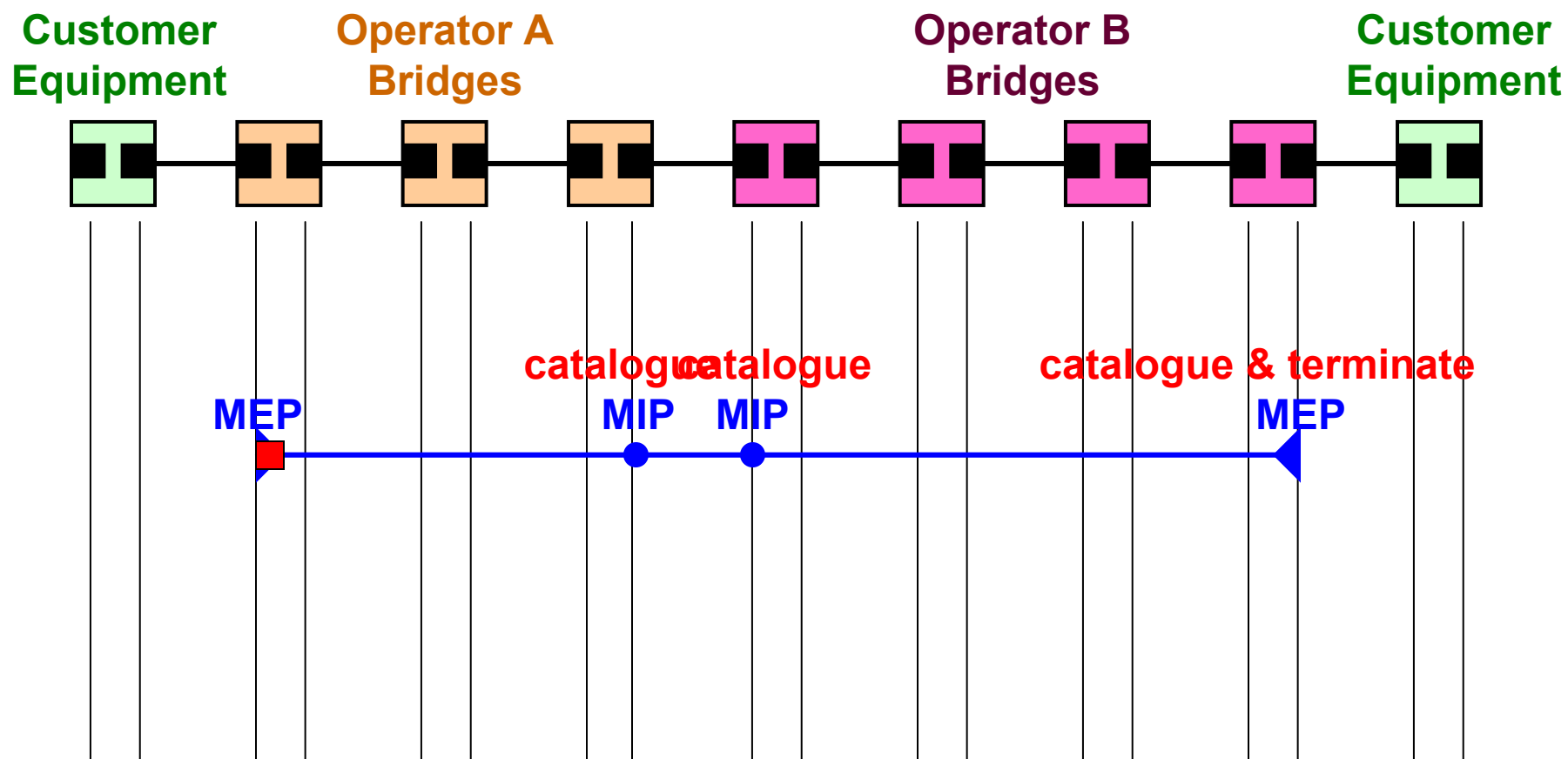
Catalogued by MIPs at the same Maintenance Level.

Terminated by remote MEPs at the same Maintenance Level.

Uni-directional and do not solicit a response

CFM Technology Primer

- Continuity Check (continued ...)



CFM Technology Primer

- Loopback

Unicast frame, source must be a MEP, destination may be a MEP or a MIP.
Reply is unicast too.

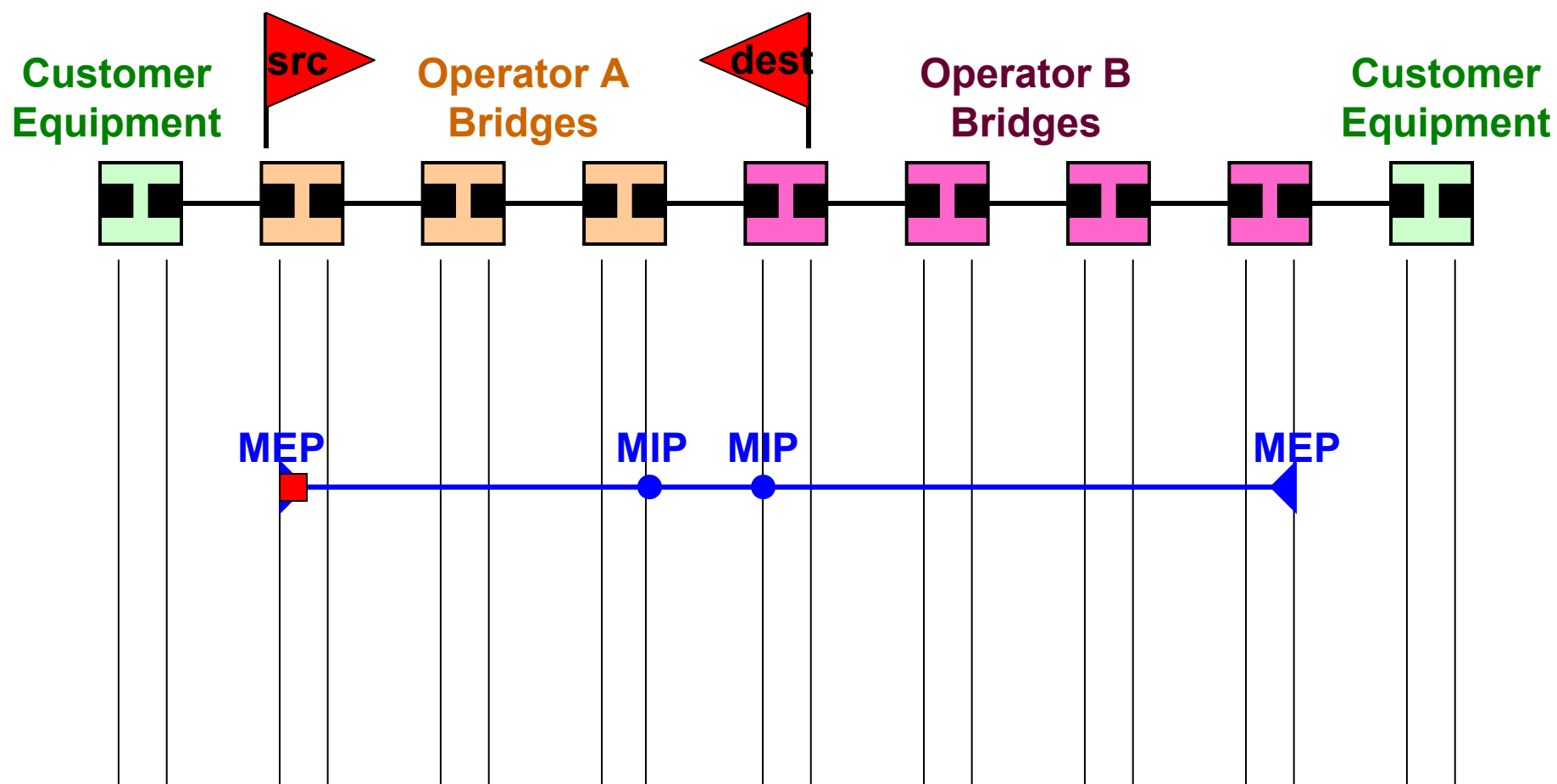
Generated on-demand via MIB or CLI.

Loopback is specific to a Maintenance Domain and a VLAN.

Timestamps embedded in Loopback Message can be used to measure Round-Trip Delay and One-Way Jitter.

CFM Technology Primer

- Loopback (continued...)



CFM Technology Primer

- Traceroute

Multicast message, source must be a MEP, destination must be a MEP too.
Reply is a unicast.

Generated on-demand via MIB or CLI.

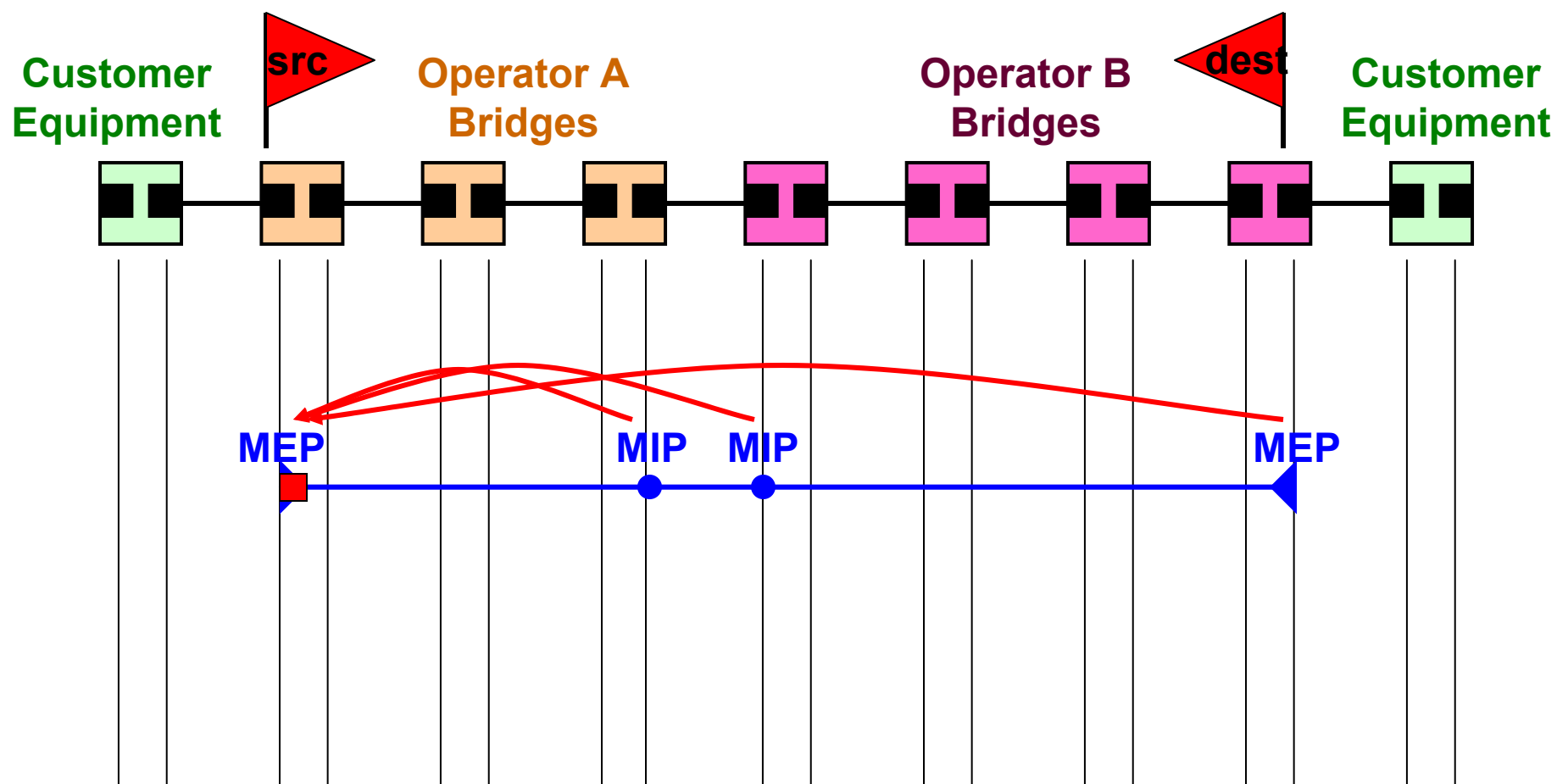
Traceroute is specific to a Maintenance Domain & a VLAN.

Allows the discovery of all MIPs belonging to the same Maintenance Domain along the path to destination MEP.

On each visible hop indicate: Ingress Action, Relay Action, Egress Action.

CFM Technology Primer

- Traceroute (continued ...)



SNMP Support (cont'd)

- **No standardization yet**
- **Traps**

Generated by MEPs

Two classes of traps:

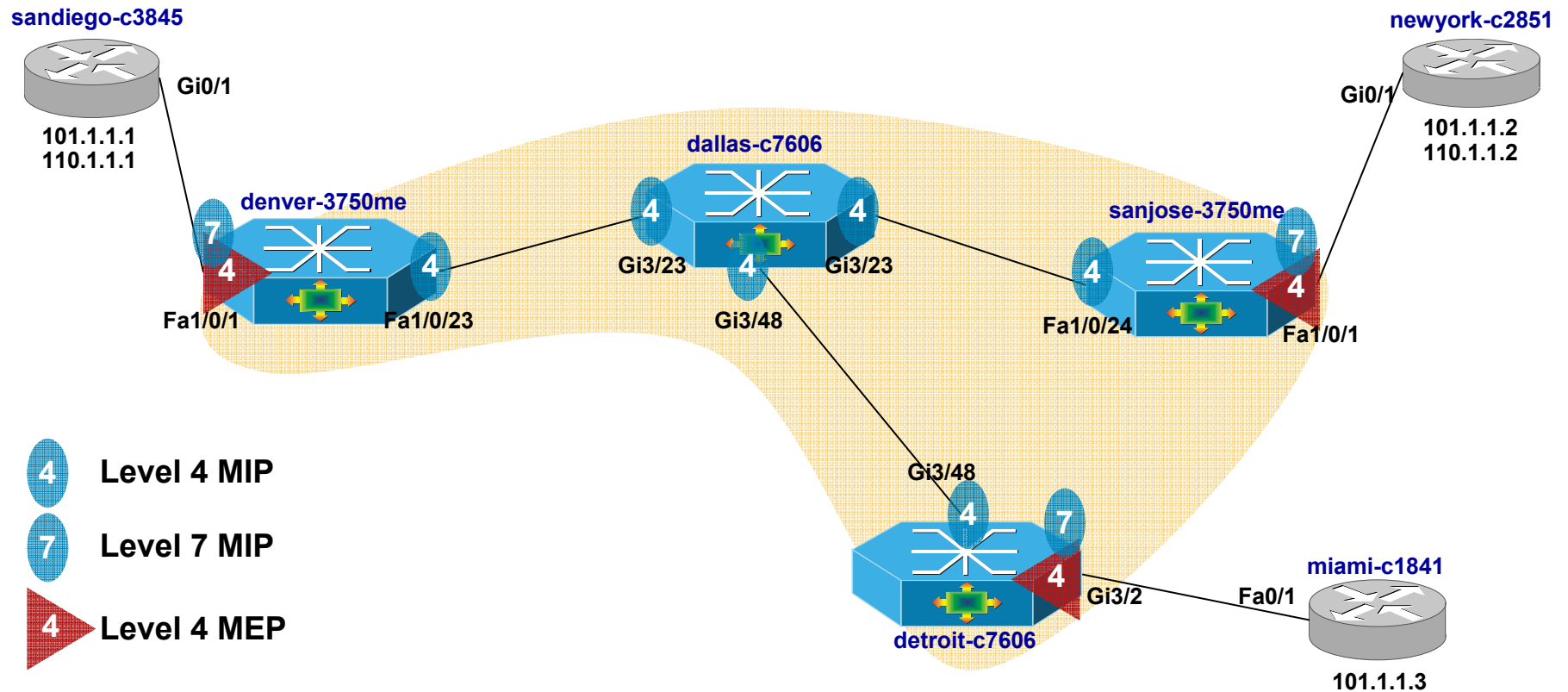
CC

**MEP Up/Down, Remote Port Status Change, CC Loop,
Configuration Error, Cross-connected Service**

Crosscheck (provisioned state against running state)

Missing MEP, Unknown MEP, Service Operational

Sample Topology



Configuring CFM

- **Network Provisioning**

Done once at network bring-up or when devices are added or removed.

- **Service Provisioning**

Done every time a service is enabled on the network.

Configuring CFM

Network Provisioning

1. Configure Global parameters/attributes

Router (config)# ethernet cfm enable

2. Configure Global parameters/attributes (Optional)

Router (config)# ethernet cfm traceroute cache [size *entries* | max-hold-time *minutes*]

3. Configure Domains

Router (config)# ethernet cfm domain *domain-name* level *level-id*

Configuring CFM

Network Provisioning

4. Configure Operator Level MIPs

Router(config-if)# ethernet cfm mip level level-id

5. Configure per-Domain parameters (optional)

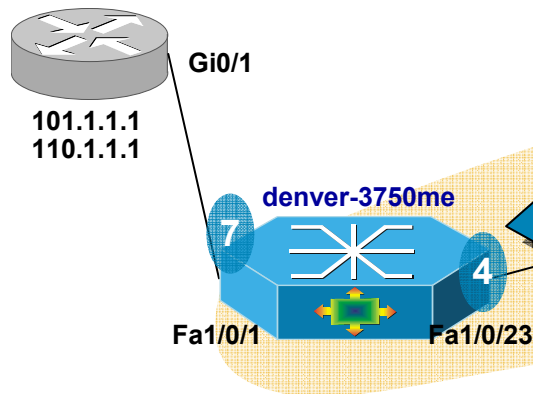
Router (config-ether-cfm)# mep archive-hold-time *minutes*

Router (config)# ethernet cfm cc {level *level-id* | any} vlan *any* [interval *seconds*] [loss-threshold *num_msgs*]

Sample Topology

Network Provisioning

sandiego-c3845



- 4 Level 4 MIP
- 7 Level 7 MIP

```
ethernet cfm domain CUSTOMER_DOMAIN level 7
ethernet cfm domain PROVIDER_DOMAIN level 4
  mep archive-hold-time 60
ethernet cfm enable
ethernet cfm traceroute cache
!
interface FastEthernet1/0/1
description connected to sandiego-c3845
switchport trunk encapsulation dot1q
switchport mode trunk
ethernet cfm mip level 7
!
interface FastEthernet1/0/23
description connected to dallas-c7606
switchport trunk encapsulation dot1q
switchport mode trunk
ethernet cfm mip level 4
```


Configuring CFM

Service Provisioning

1. Configure Service IDs

Router (config-ether-cfm)# service *csi-id* vlan *vlan-id*

2. Configure Customer Level MIPs (optional)

Router(config-if)# ethernet cfm mip level *level-id*

Configuring CFM

Service Provisioning

3. Configure Service Provider Level MIPs

Router(config-if)# ethernet cfm mip level *level-id*

4. Configure MEPs for all Maintenance Levels

**Router(config-if)# ethernet cfm mep level {*level-id*} [inward]
mpid *id* vlan {*vlan-id* | any | *vlan-id-vlan-id* [, *vlan-id-vlan-id*]}**

Configuring CFM

Service Provisioning

5. Configure per-service parameters (optional)

```
Router (config)# ethernet cfm cc {level level-id | any} vlan {vlan-id | vlan-id-vlan-id [, vlan-id-vlan-id]} [interval seconds] [loss-threshold num_msgs]
```

6. Enable Traps (optional)

```
Router (config)# snmp-server enable traps ethernet cfm cc [mep-up | mep-down | config | loop | cross-connect]
```

```
Router (config)# snmp-server enable traps ethernet cfm crosscheck [mep-unknown | mep-missing | service-up]
```

Configuring CFM

Service Provisioning

7. Enable CC (all enabled by default)

```
Router (config)# ethernet cfm cc enable level {any | level-id | level-id-level-id [, level-id-level-id]} vlan {vlan-id | any | vlan-id-vlan-id [, vlan-id-vlan-id]}
```

8. Configure and Enable Crosscheck (optional)

```
Router (config)# ethernet cfm mep crosscheck start-delay delay
```

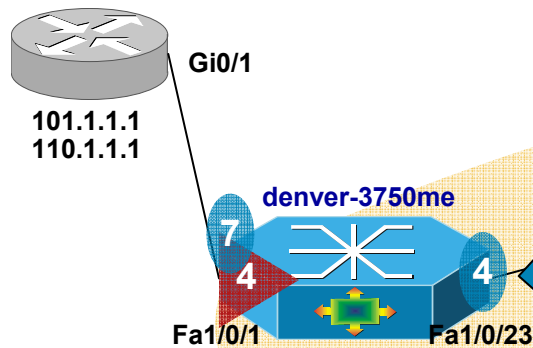
```
Router (config-ether-cfm)# mep crosscheck mpid id vlan vlan-id [mac mac-address]
```

```
Router (# ethernet cfm mep crosscheck {enable | disable} level {level-id | level-id-level-id [, level-id-level-id]} vlan {vlan-id | any | vlan-id-vlan-id [, vlan-id-vlan-id]})
```

Sample Topology

Network Provisioning

sandiego-c3845



4 Level 4 MIP

7 Level 7 MIP

4 Level 4 MEP

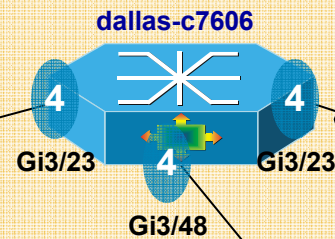
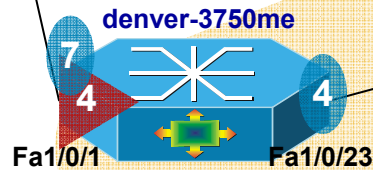
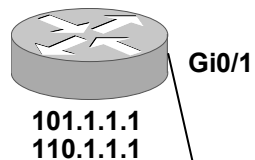
```

ethernet cfm domain CUSTOMER_DOMAIN level 7
ethernet cfm domain PROVIDER_DOMAIN level 4
  mep archive-hold-time 60
  service customer_101_provider vlan 101
  service customer_110_provider vlan 110
ethernet cfm enable
ethernet cfm traceroute cache
!
interface FastEthernet1/0/1
  description connected to sandiego-c3845
  switchport trunk encapsulation dot1q
  switchport mode trunk
  ethernet cfm mip level 7
  ethernet cfm mep level 4 mpid 1110 vlan 110
  ethernet cfm mep level 4 mpid 1101 vlan 101
!
interface FastEthernet1/0/23
  description connected to dallas-c7606
  switchport trunk encapsulation dot1q
  switchport mode trunk
  ethernet cfm mip level 4
!
ethernet cfm cc enable level 0-7 vlan 1-4095
  
```

Sample Topology

Network Provisioning

sandiego-c3845



4 Level 4 MIP

7 Level 7 MIP

4 Level 4 MEP

```

ethernet cfm domain CUSTOMER_DOMAIN level 7
ethernet cfm domain PROVIDER_DOMAIN level 4
  service customer_101_provider vlan 101
  service customer_110_provider vlan 110
ethernet cfm enable
!
interface Gi gabitEthernet3/23
description connected to denver-c3750me
switchport
switchport mode trunk
ethernet cfm mip level 4
!
interface Gi gabitEthernet3/24
description connected to sanjose-c3750me
switchport
switchport mode trunk
ethernet cfm mip level 4
!
interface Gi gabitEthernet3/48
description connected to detroit-c7606
switchport
switchport mode trunk
ethernet cfm mip level 4
!
ethernet cfm cc enable level 0-7 vlan 1-4095
  
```

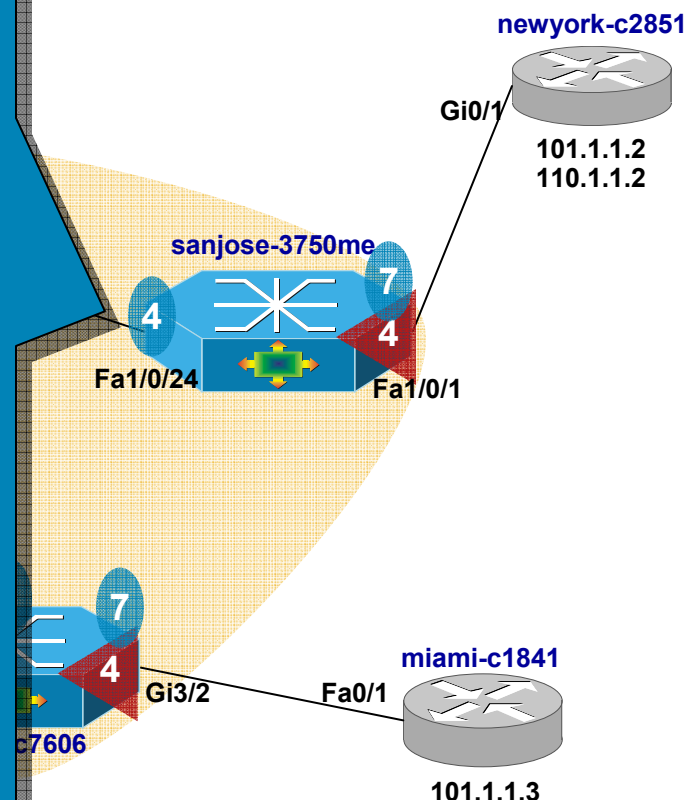
Sample Topology

Network Provisioning

```

ethernet cfm domain CUSTOMER_DOMAIN level 7
ethernet cfm domain PROVIDER_DOMAIN level 4
  mep archive-hold-time 60
  service customer_101_provider vlan 101
  service customer_110_provider vlan 110
ethernet cfm enable
ethernet cfm traceroute cache
!
interface FastEthernet1/0/1
description connected to newyork-c3851
switchport trunk encapsulation dot1q
switchport mode trunk
ethernet cfm mip level 7
ethernet cfm mep level 4 mpid 3101 vlan 101
ethernet cfm mep level 4 mpid 3110 vlan 110
!
interface FastEthernet1/0/24
description connected to dallas-c7606
switchport trunk encapsulation dot1q
switchport mode trunk
ethernet cfm mip level 4
!
ethernet cfm cc enable level 0-7 vlan 1-4095

```

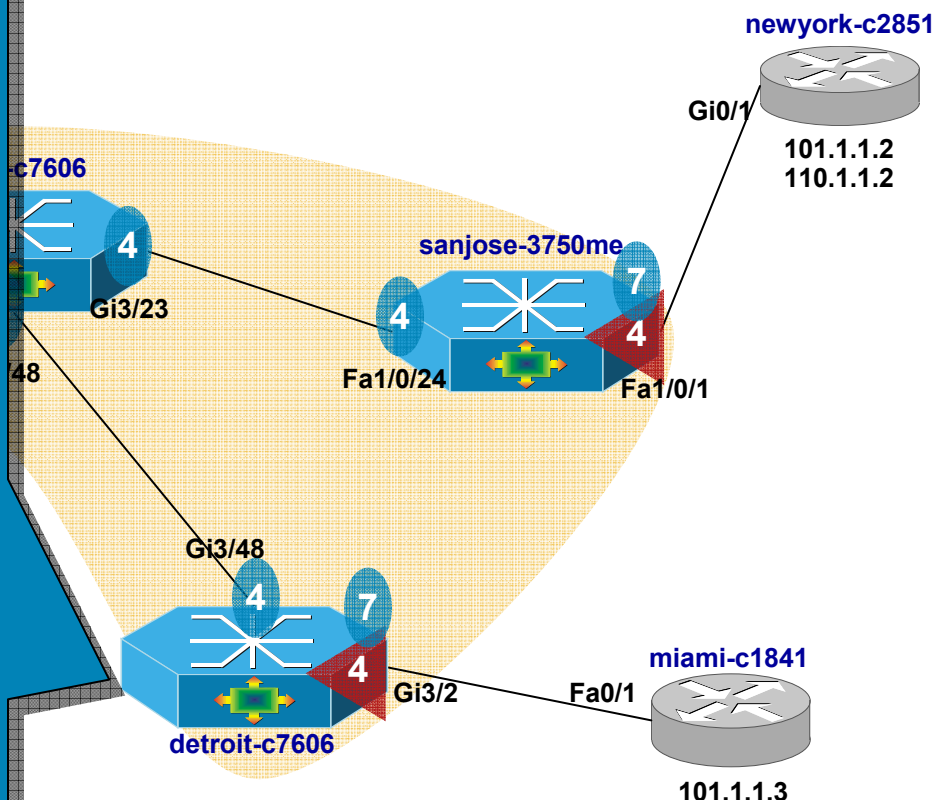


Sample Topology

Network Provisioning

```

ethernet cfm domain CUSTOMER_DOMAIN level 7
ethernet cfm domain PROVIDER_DOMAIN level 4
  mep archive-hold-time 60
  service customer_101_provider vlan 101
  service customer_110_provider vlan 110
ethernet cfm enable
ethernet cfm traceroute cache
!
interface GigabitEthernet3/2
description connected to miami-c1841
switchport
switchport mode trunk
ethernet cfm mip level 7
ethernet cfm mep level 4 mpid 4101 vlan 101
!
interface GigabitEthernet3/48
description connected to dallas-c7606
switchport
switchport mode trunk
ethernet cfm mip level 4
!
ethernet cfm cc enable level 0-7 vlan 1-4095
  
```



Show Commands

Show Local Maintenance Points

```
denver-c3750me#show ethernet cfm maintenance-points local
```

MPI D	DomainName	Level	Type	VLAN	Port	CC-Status	MAC
1101	PROVIDER_DOMAIN 0013.c33c.5680	4	MEP	101	Fa1/0/1	Enabled	
1110	PROVIDER_DOMAIN 0013.c33c.5680	4	MEP	110	Fa1/0/1	Enabled	
Level	Type	Port	MAC				
7	MIP	Fa1/0/1	0013.c33c.5680				
4	MIP	Fa1/0/23	0013.c33c.5680				

```
dallas-c7606#show ethernet cfm maintenance-points local
```

Level	Type	Port	MAC
4	MIP	Gi 3/48	0015.6215.3e85
4	MIP	Gi 3/24	0015.6215.3e85
4	MIP	Gi 3/23	0015.6215.3e85

Show Commands

Show Local Maintenance Points: CC-Status

Possible values for Local MEP CC-Status:

Enabled

Disabled

Inactive

```
denver-c3750me#show ethernet cfm maintenance-points local
```

MPI D	DomainName	Level	Type	VLAN	Port	CC-Status	MAC
1101	PROVIDER_DOMAIN	4	MEP	101	Fa1/0/1	Enabled	0013. c33c. 5680
1110	PROVIDER_DOMAIN	4	MEP	110	Fa1/0/1	Enabled	0013. c33c. 5680

Level	Type	Port	MAC
7	MI P	Fa1/0/1	0013. c33c. 5680
4	MI P	Fa1/0/23	0013. c33c. 5680

Show Commands

Show Local Maintenance Points: CC-Status

```
denver-c3750me(config)#ethernet cfm cc enable level 4 vlan 101
```

```
denver-c3750me#show ethernet cfm maintenance-points local
```

MPI D	DomainName	Level	Type	VLAN	Port	CC-Status	MAC
1101	PROVIDER_DOMAIN	4	MEP	101	Fa1/0/1	Enabled	0013. c33c. 5680
1110	PROVIDER_DOMAIN	4	MEP	110	Fa1/0/1	Disabled	0013. c33c. 5680

Level	Type	Port	MAC
7	MIP	Fa1/0/1	0013. c33c. 5680
4	MIP	Fa1/0/23	0013. c33c. 5680

```
detroit-c7606(config)#interface GigabitEthernet3/2
```

```
detroit-c7606(config-if)#switchport trunk allowed vlan 200
```

```
detroit-c7606#show ethernet cfm maintenance-points local
```

MPI D	DomainName	Level	Type	VLAN	Port	CC-Status	MAC
4101	PROVIDER_DOMAIN	4	MEP	101	Gi 3/2	Inactive	0015. 6215. 46c5

Level	Type	Port	MAC
7	MIP	Gi 3/2	0015. 6215. 46c5
4	MIP	Gi 3/48	0015. 6215. 46c5

Show Commands

Show Domains

```
denver-c3750me#show ethernet cfm domain
```

Domain Name : CUSTOMER_DOMAIN

Index : 1

Level : 7

Total Services : 0

Domain Name : PROVIDER_DOMAIN

Index : 2

Level : 4

Total Services : 2

Services:

VLAN Crosscheck ServiceID

101 Disabled customer_101_provider

110 Disabled customer_110_provider

Show Commands

Show Remote Maintenance Points

denver-c3750me#show ethernet cfm maintenance-points remote

MPID	Level	Mac Address	Vl an	PortState	InGressPort	Age(sec)	Servi ce ID
3101	4	0015. 637b. 4e00	101	UP	Fa1/0/23	19	customer_101_provi der
4101	4	0015. 6215. 46c5	101	UP	Fa1/0/23	6	customer_101_provi der
3110	4	0015. 637b. 4e00	110	UP	Fa1/0/23	6	customer_110_provi der

dall as-c7606#show ethernet cfm maintenance-points remote

MPID	Level	Mac Address	Vl an	PortState	InGressPort	Age(sec)	Servi ce ID
1101	4	0013. c33c. 5680	101	UP	Gi 3/23	12	customer_101_provi der
3101	4	0015. 637b. 4e00	101	UP	Gi 3/24	25	customer_101_provi der
4101	4	0015. 6215. 46c5	101	UP	Gi 3/48	2	customer_101_provi der
1110	4	0013. c33c. 5680	110	UP	Gi 3/23	3	customer_110_provi der
3110	4	0015. 637b. 4e00	110	UP	Gi 3/24	12	customer_110_provi der

Show Commands

Other CFM Show Commands

```
denver-c3750me#show ethernet cfm traceroute-cache
```

```
Traceroute to 0015.637b.4e00 on Domain PROVIDER_DOMAIN, Level 4, vlan 101 issued at 1d04h
```

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

B 1	dallas-c7606	0015.6215.3e85	Gi3/23	Ingress OK	Relay CCDB	
		Forwarded	Gi3/24	Egress OK	sanjose-c3750me	
! 2	sanjose-c3750me	0015.637b.4e00	Fa1/0/2	Ingress OK	Relay None	
		Not Forwarded				

Clear Commands

denver-c3750me#clear ethernet cfm ?

errors CFM errors

maintenance-points CFM Maintenance Points

traceroute-cache Clear Contents of traceroute cache

CFM Crosscheck

- Allows configuring static list of expected remote MEPs per service, and then crosschecks this list against what is learnt dynamically from CC messages. Generates appropriate alarms when errors are detected.

Configure and Enable Crosscheck:

- `ethernet cfm mep crosscheck start-delay delay`
- `mep crosscheck mpid id vlan vlan-id [mac mac-address]`
- `ethernet cfm mep crosscheck {enable | disable} level {level-id | level-id-level-id [, level-id-level-id]} vlan {vlan-id | any | vlan-id-vlan-id [, vlan-id-vlan-id]}`

CFM Debugs

Ethernet CFM Debugs:

```
debug ethernet cfm all [domain domain-name | level level-id]  
[vlan vlan-id]
```

```
debug ethernet cfm diagnostic [events | packets]
```

```
debug ethernet cfm errors
```

```
debug ethernet cfm events [domain domain-name | level  
level-id] [vlan vlan-id]
```

```
debug ethernet cfm packets [domain domain-name | level  
level-id] [vlan vlan-id]
```

CFM Debugs

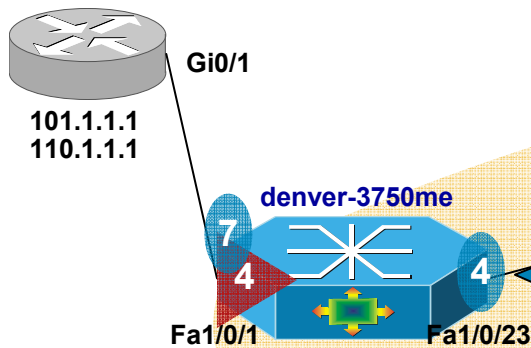
```
21:56:15: CFM-PKT: Received a cc packet from interface FastEthernet1/0/24
21:56:15: CFM-PKT: cfm packet dump - 104 bytes, interface FastEthernet1/0/24, vlan 110
21:56:15: CFM-PKT: ethernet CFM message dump,
                dest: 0100.0ccc.ccc4
                src: 0013.c33c.5680
                Version: 0
                Maintenance Level: 4
                MsgType: CC(0)
                Transaction Id: 3334414845

21:56:15: 01 00 0C CC CC C4 00 13 C3 3C 56 80 00 5A AA AA
21:56:15: 03 00 00 0C 01 26 00 04 00 08 C6 BF 21 FD 01 00
21:56:15: 26 00 63 75 73 74 6F 6D 65 72 5F 31 31 30 5F 70
21:56:15: 72 6F 76 69 64 65 72 3A 50 52 4F 56 49 44 45 52
21:56:15: 5F 44 4F 4D 41 49 4E 02 00 02 04 56 03 00 02 00
21:56:15: 4B 04 00 02 00 01 05 00 0E 64 65 6E 76 65 72 2D
21:56:15: 63 33 37 35 30 6D 65 00
21:56:15:
21:56:15: CFM-PKT: TLV Service ID 'customer_110_provider: PROVIDER_DOMAIN'
21:56:15: CFM-PKT: TLV MPID 1110
21:56:15: CFM-PKT: TLV LIFETIME 75
21:56:15: CFM-PKT: TLV PORT_STATE 0x1 (UP)
21:56:15: CFM-PKT: Received a CC packet with MPID 1110, level 4, vlan 110 from interface
                FastEthernet1/0/24
21:56:15: CFM-EVT: Found remote mep for level 4 svlan 110, mpid 1110
```

Sample Topology

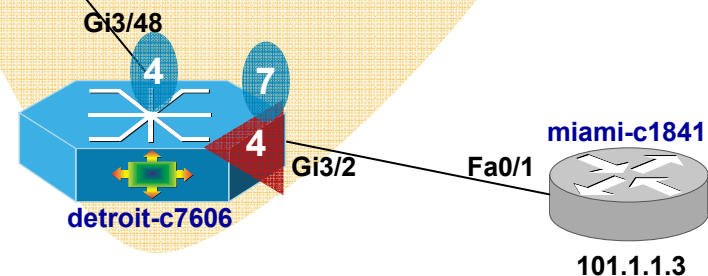
Crosscheck

sandiego-c3845



```

ethernet cfm domain PROVIDER_DOMAIN level 4
  mep archive-hold-time 60
  service customer_101_provider vlan 101
  service customer_110_provider vlan 110
  mep crosscheck mpid 3101 vlan 101 mac 0015.637b.4e00
  mep crosscheck mpid 4101 vlan 101 mac 0015.6215.46c5
  mep crosscheck mpid 3110 vlan 110 mac 0015.637b.4e00
!
ethernet cfm cc enable level 0-7 vlan 1-4095
ethernet cfm mep crosscheck start-delay 60
  
```



CFM Crosscheck

```
denver-c3750me#ethernet cfm mep crosscheck enable level any vlan any
```

```
denver-c3750me#show ethernet cfm domain
```

```
Domain Name : CUSTOMER_DOMAIN
```

```
Index : 1
```

```
Level : 7
```

```
Total Services : 0
```

```
Domain Name : PROVIDER_DOMAIN
```

```
Index : 2
```

```
Level : 4
```

```
Total Services : 2
```

```
Services:
```

```
VLAN Crosscheck ServiceID
```

```
101 Enabled customer_101_provider
```

```
110 Enabled customer_110_provider
```

```
Crosscheck:
```

```
MPI D  Vlan  Remote-Mac      Mep-Up
```

```
3101  101    0015.637b.4e00 Yes
```

```
4101  101    0015.6215.46c5 Yes
```

```
3110  110    0015.637b.4e00 Yes
```

CFM Crosscheck

```
denver-c3750me#show ethernet cfm maintenance-points remote crosscheck
```

MPI D	Level	VLAN	Mep-Up	Remote Mac
3101	4	101	Yes	0015. 637b. 4e00
4101	4	101	Yes	0015. 6215. 46c5
3110	4	110	Yes	0015. 637b. 4e00

Troubleshooting with CFM

- **Proactive**

Traps give asynchronous fault notification

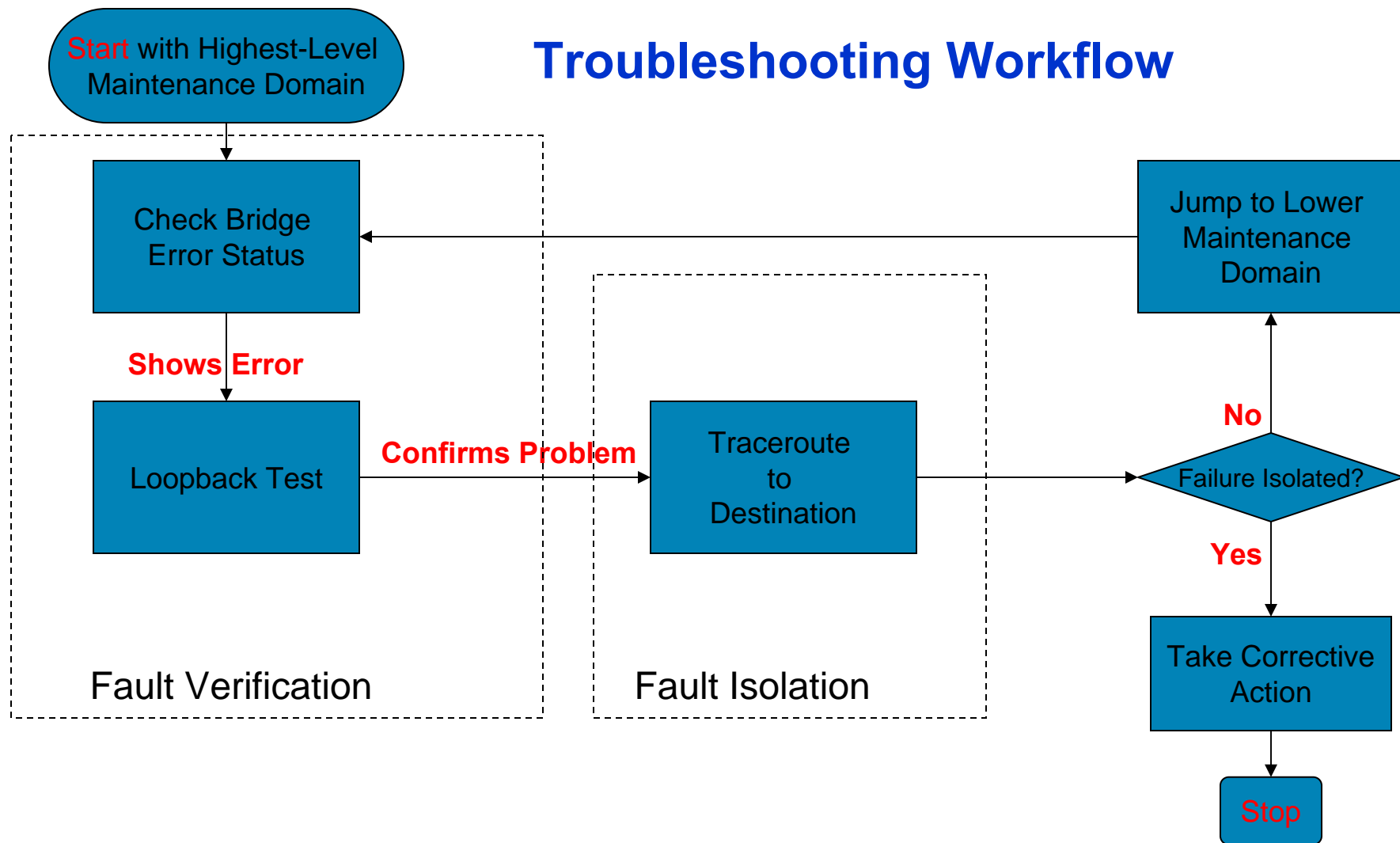
Use Loopback and Traceroute to verify and isolate faults

- **Reactive**

Use Loopback and Traceroute to verify and isolate faults

Troubleshooting with CFM

Troubleshooting Workflow



Troubleshooting with CFM

Commands

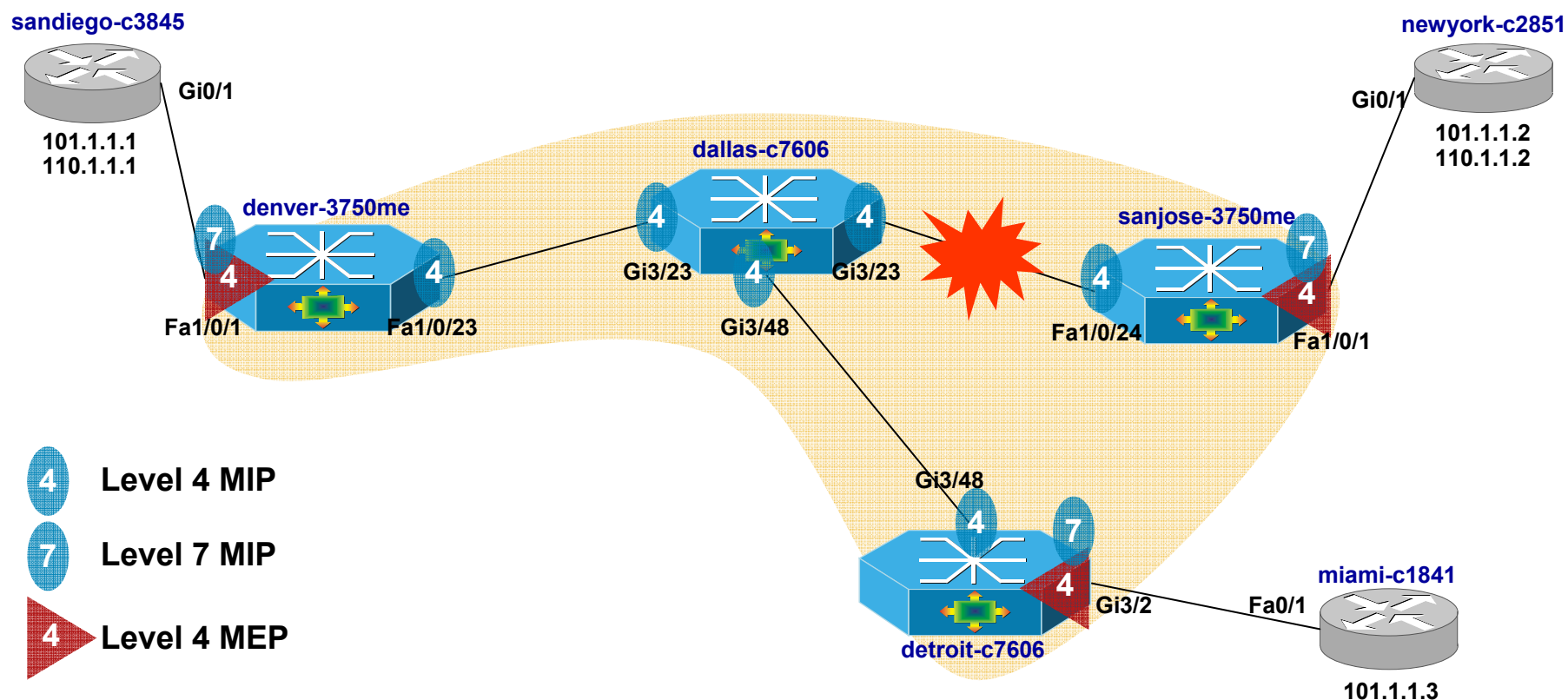
- Loopback

ping ethernet *mac-address* {**domain** *domain-name* | **level** *level-id*} **vlan** *vlan-id*

- Traceroute

traceroute ethernet {*mac-address*} {**domain** *domain-name* | **level** *level-id*} **vlan** *vlan-id*

Troubleshooting with CFM



Troubleshooting with CFM

- SNMP Traps are generated when a remote MEP is not heard from.

Received SNMPv2c Trap:

Community: TEST

From: 127.0.0.1

sysUpTimeInstance = 46593

snmpTrapOID.0 = cEtherCfmCcMepDown

cEtherCfmEventServiceId.1.3.4 = customer_110_provider <===

cEtherCfmEventLclMacAddress.1.3.4 = 00 15 63 7b 4e 00 <===

cEtherCfmEventLclMepCount.1.3.4 = 1 <==== this is the total # of local MEPs in this vlan

cEtherCfmEventLclIfCount.1.3.4 = 1 <==== total number of distinct interfaces that host the local MEPs

cEtherCfmEventRmtMepId.1.3.4 = 110 <====

cEtherCfmEventRmtMacAddress.1.3.4 = 00 15 63 7b 4e 00 <====

cEtherCfmEventCode.1.3.4 = 5

- Show ethernet cfm errors

denver-c3750me#show ethernet cfm errors

Level	Vlan	MPID	Remote MAC	Reason	Service ID
4	110	3110	0015.637b.4e00	Lifetime Timer Expir	customer_110_provider

Troubleshooting with CFM

- Traceroute shows location and reason for failure.

```
denver-c3750me#traceroute ethernet 0015.637b.4e00 level 4 vlan 101
```

```
Type escape sequence to abort. TTL 255. Per-Hop Timeout is 10 seconds
```

```
Tracing the route to 0015.637b.4e00 on Domain PROVIDER_DOMAIN, Level 4, vlan 101
```

```
Traceroute sent via FastEthernet1/0/23
```

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

B 1	dallas-c7606	0015.6215.3e85	Gi3/23	Ingress	Ok	RI yCCDB
		Not Forwarded	Gi3/24	Egress	Down	sanjose-c3750me

Troubleshooting with CFM

Other Errors Reported by CFM:

- **CC Lifetime Expiration**
- **CC Lifetime Zero**
(Remote MEP removed or disabled)
- **Loop Error**
(Receiving a CC with the same source MAC and MPID as a local MEP)
- **Crossconnect Error**
(Receiving a CC who's CSI does not match the local configuration)
- **Configuration Error**
(Receiving a CC with the same MPID as a local MEP)
- **MEP Missing**
(Crosscheck: Did not receive a CC from a statically configured remote MEP)
- **Unknown MEP**
(Crosscheck: Received a CC from a remote MEP that was not statically configured)



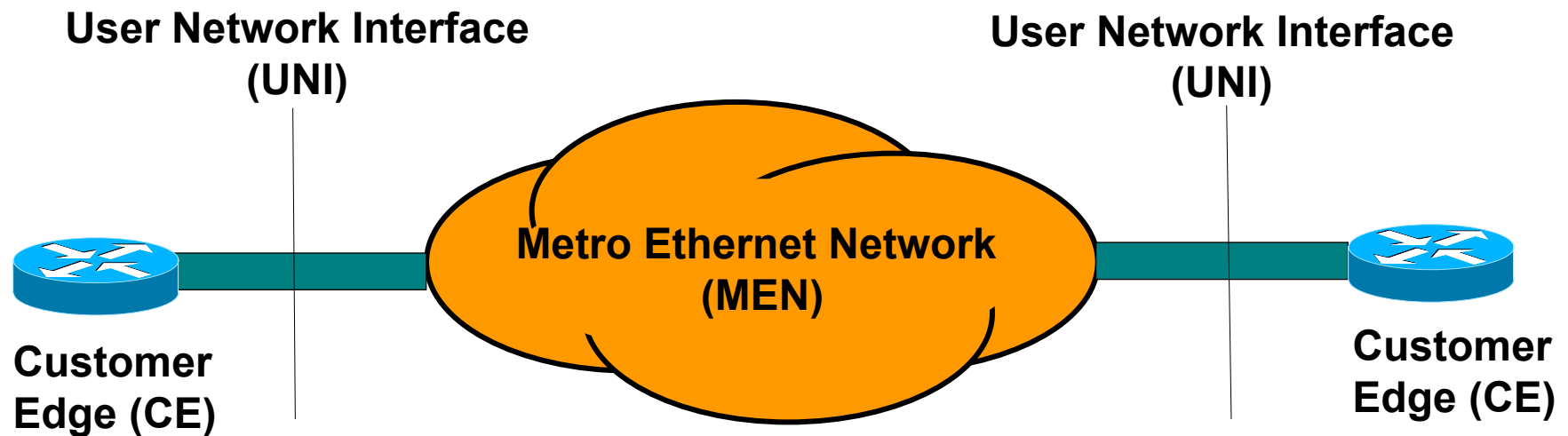
Ethernet LMI



Ethernet Link Management Interface (E-LMI)

- **Ethernet Services Model & MEF Terminology**
- **Ethernet LMI Overview**

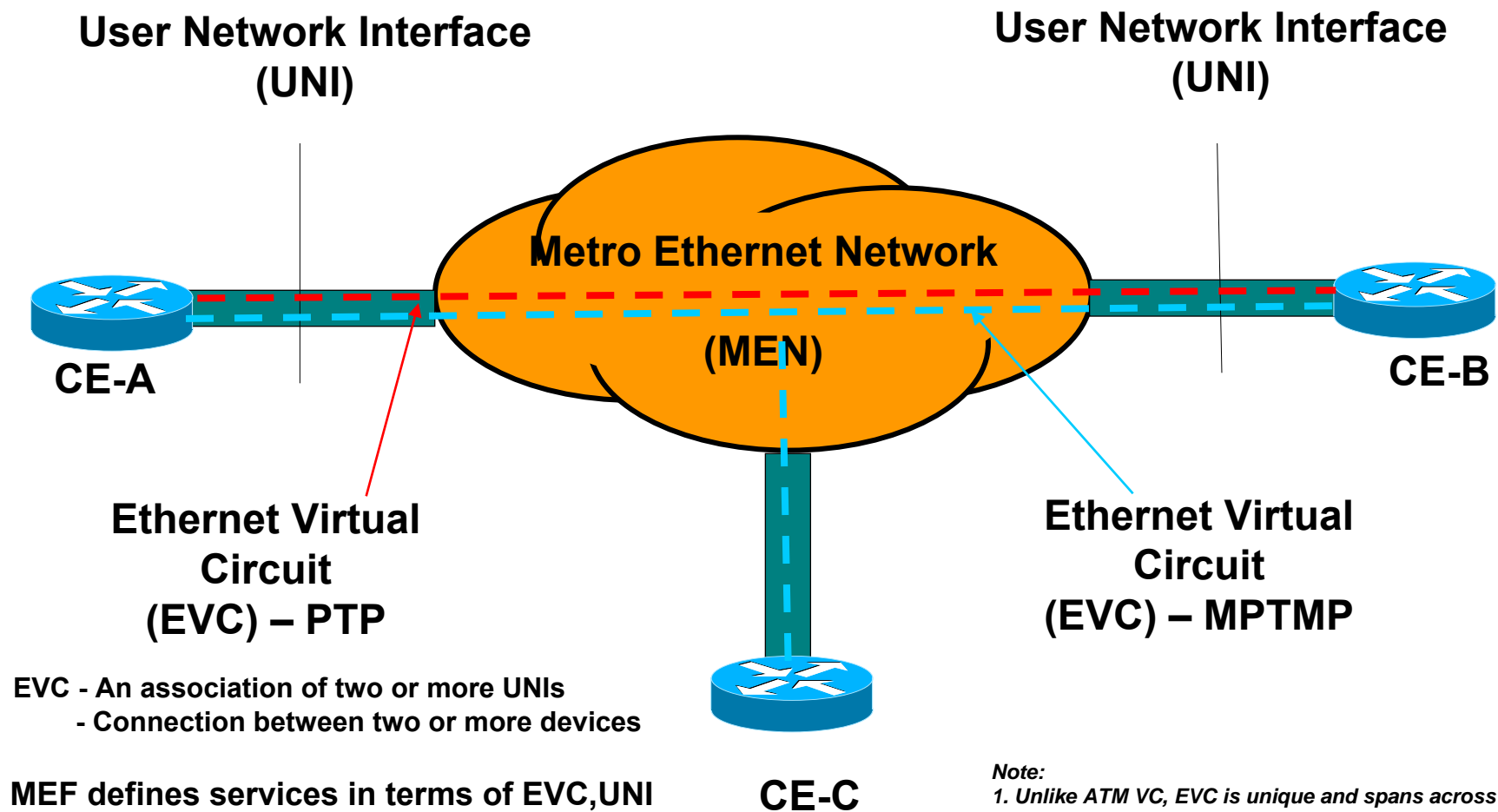
Ethernet Services Model



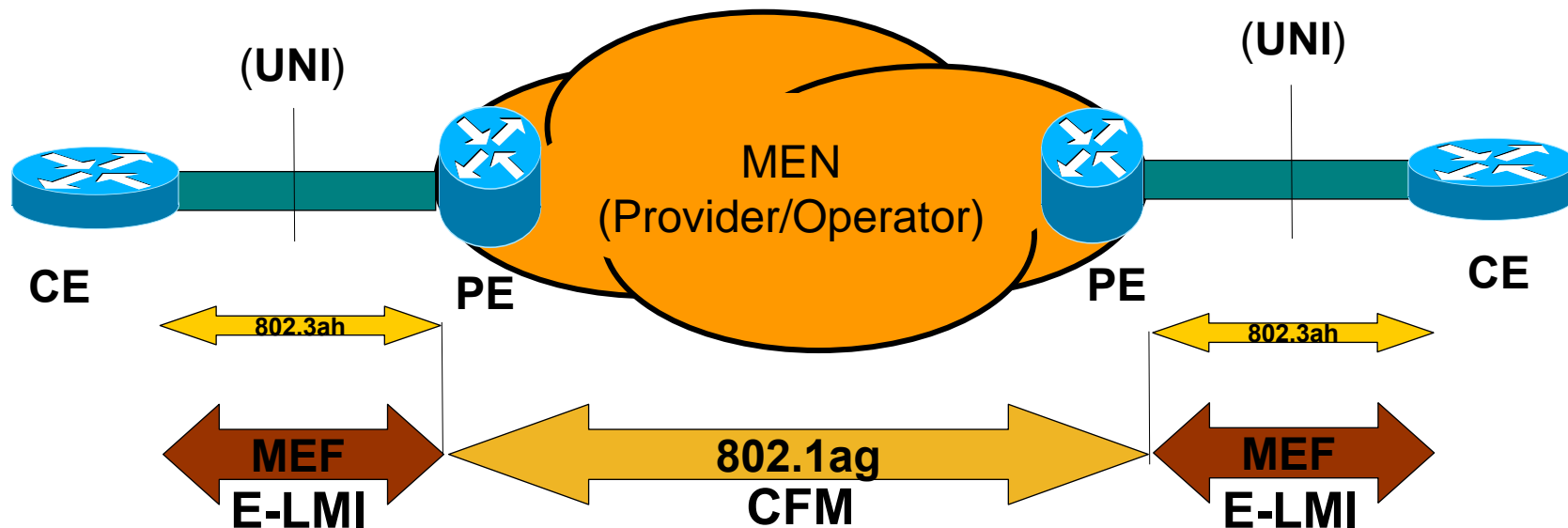
UNI: Point of Demarcation between CE and SP's MEN

MEF view: MEN provides service to CE

MEF Terminology



End-to-End Ethernet OAM



- E-LMI** : Ethernet Provisioning and Management entity across UNI (CE-PE)
- 802.1ag** : Ethernet Service Layer Monitoring entity across MEN (PE-PE)
- 802.3ah** : Link Layer Monitoring

Ether LMI Requirement

- **Report Connectivity Status to CE**

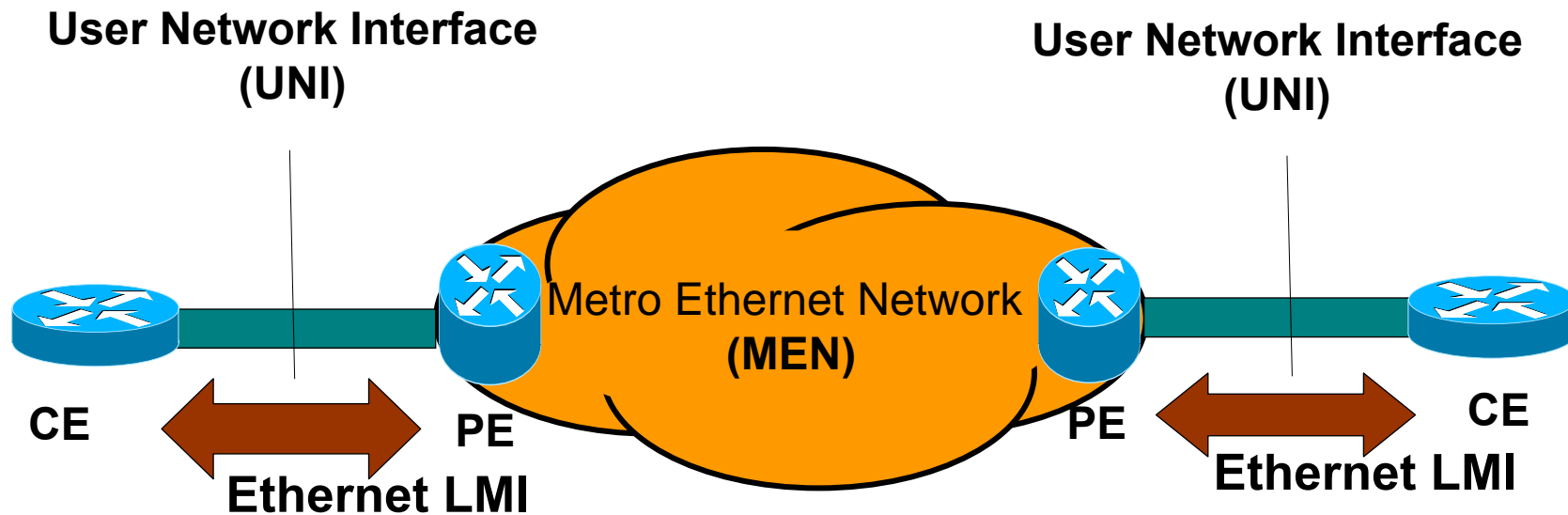
Status of EVC across MEN

Remote UNI state

- **Auto Configure CE**

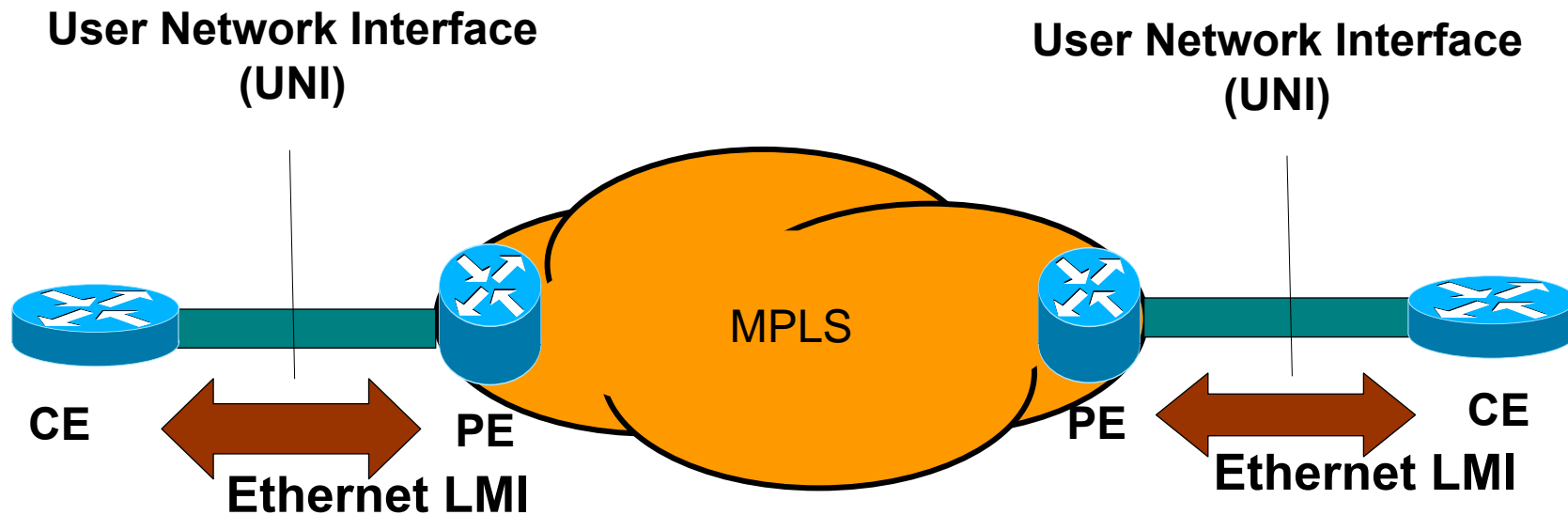
Creation, deletion of EVCs, VLANs, Bandwidth profile changes...

Ethernet Local Management Interface – Deployment with Ethernet Core



Ethernet LMI: Ethernet Provisioning and Management entity across UNI (CE-PE)

Ethernet Local Management Interface – Deployment with MPLS core



Ethernet LMI: Ethernet Provisioning and Management entity across UNI (CE-PE)

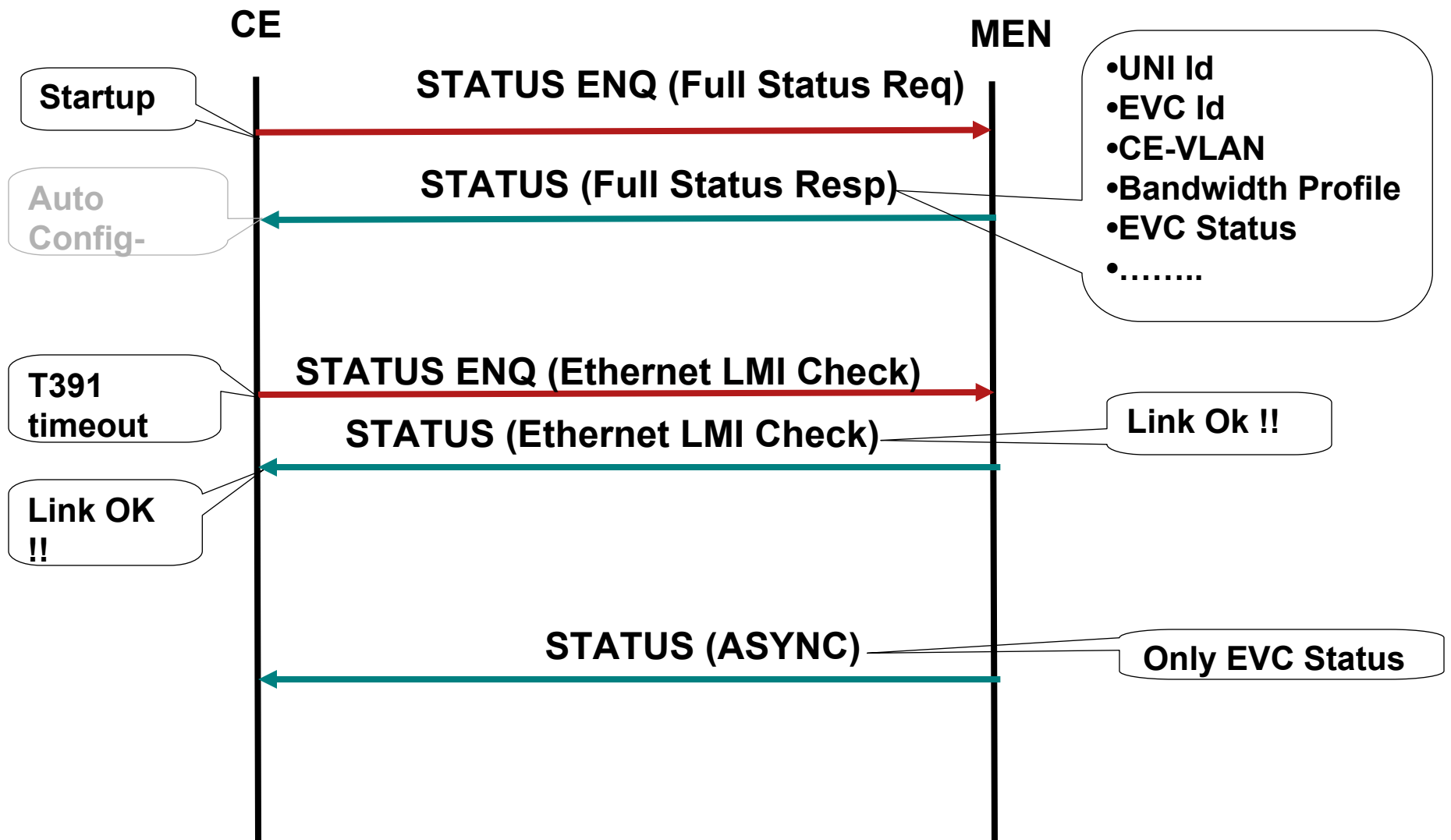
Information Carried by Ethernet LMI

- **Configuration Data**
 - CE-VLANs**
 - Bandwidth Profile per EVC**
 - Bandwidth Profile per UNI**
- **Provisioned Data**
 - EVC service Identifier**
 - UNI Identifiers for EVC**
 - UNI Type**
 - Remote UNI Identifier for EVC**
- **Dynamic Data (Learned via MEN OAM)**
 - EVC status**
 - Remote UNI state**

Ethernet LMI Protocol

- **Based on Polling procedure invoked by CE**
 - **Heartbeat messages every T391 seconds**
 - **Will get all data from PE when change is notified / CE**
 - **needs data (startup/ N391)**
 - **MEN may asynchronously update EVC state**

Typical Flow



E-LMI Configurations

- **Ethernet LMI Configuration Commands**

PE : More config involved

CE : Less config

Ethernet LMI Configuration - PE

1. EVC Configuration (Global)

EVC Id

UNI Count

EVC MEN OAM Protocol

2. UNI Configuration (Per Interface)

UNI Id

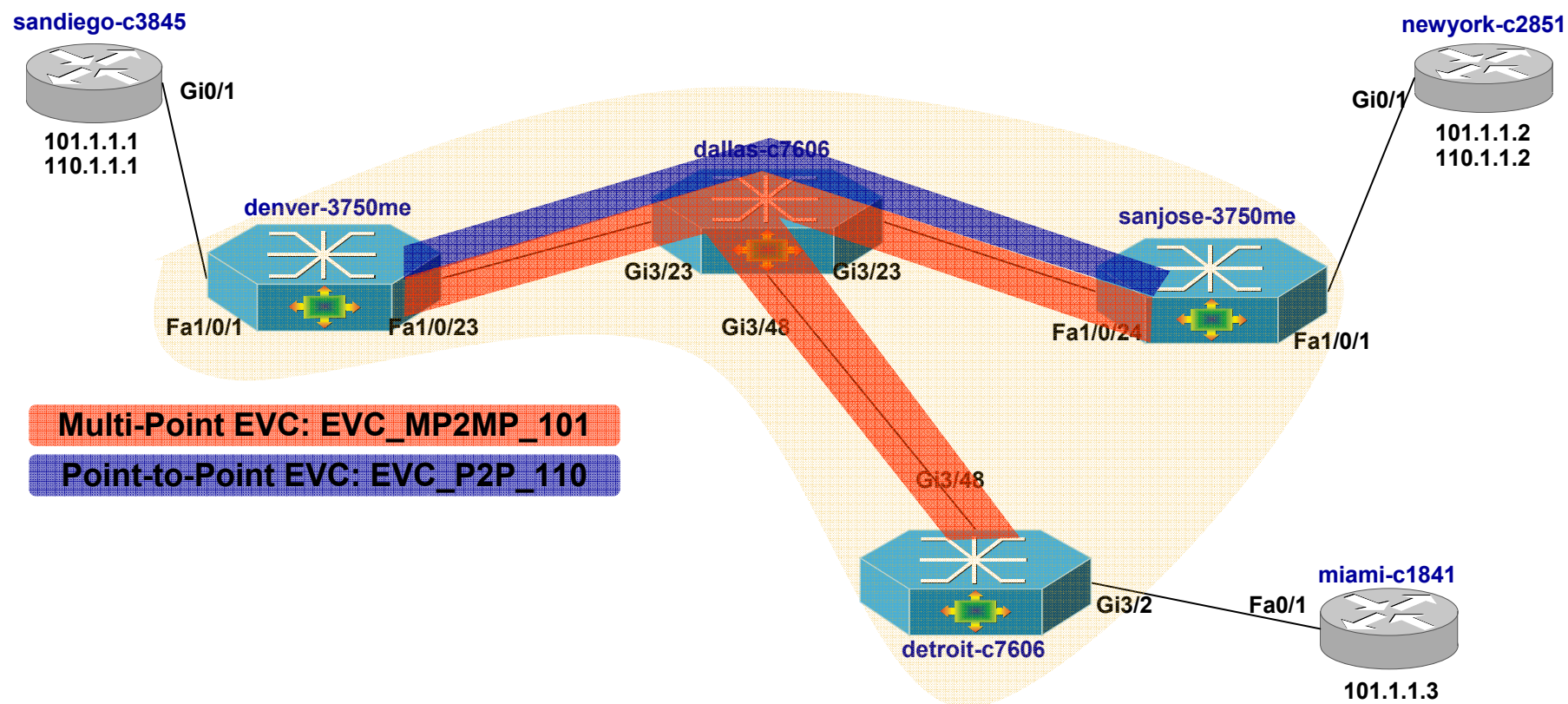
Service Instance (CE Vlans Config)

3. Enable Ethernet LMI (Global/Per Interface)

Enable Ethernet LMI

Modify Ethernet LMI default parameters (Optional)

Objective:



- We will configure above EVCs on denver.
- This config needs to be repeated on detroit, sanjose with appropriate parameters

Step 1: Configure EVC

■ Global Config

■ Multi Point EVC:

- `denver-c3750me(config)# ethernet evc EVC_MP2MP_101`
- `denver-c3750me(config-efc)# uni count 3`
- `denver-c3750me(config-efc)# oam protocol cfm svlan 101 domain PROVIDER_DOMAIN`
- `denver-c3750me(config-efc)# end`

a. EVC NAME

b. Num of UNIs associated with EVC

c. MEN OAM CFM and its params.
If MPLS-xconnect is used, use “oam protocol ldp”

■ Point-Point EVC:

- `denver-c3750me(config)# ethernet evc EVC_P2P_110`
- `denver-c3750me(config-efc)# oam protocol cfm svlan 110 domain PROVIDER_DOMAIN`
- `denver-c3750me(config-efc)# end`

- ***Note: UNI count is 2 by default. Hence no need for explicit configuration of this for P2P EVC.***

Step 2: Configure UNI

■ UNI Config

- `denver-c3750me(config)#int e0/0`
- `denver-c3750me(config-if)# ethernet uni bundle`
- `denver-c3750me(config-if)# ethernet uni id cisco_sandiego`
- `denver-c3750me(config-if)# service instance 101 ethernet EVC_MP2MP_101`
- `denver-c3750me(config-if-srv)# ethernet lmi ce-vlan map 101`
- `denver-c3750me(config-if)# service instance 110 ethernet EVC_P2P_110`
- `denver-c3750me(config-if-srv)# ethernet lmi ce-vlan map 110`
- `denver-c3750me(config-if)#end`

a. UNI service

b. Uni Id

c. Map Vlan
used by UNI
for this EVC

Step 2: Contd..

Other possible options for UNI type

- `denver-c3750me(config-if)#ethernet uni ?`
- `bundle` bundling service without multiplexing
- `multiplex` multiplexing service without bundling
- *Note: Default is - bundle-multiplex*

Step 3: Enable Ethernet LMI

- Global: Enables Ethernet LMI per Box
 - `denver-c3750me(config)# ethernet lmi global`
- Interface: Enables Ethernet LMI per interface/UNI
 - `denver-c3750me(config-if)# ethernet lmi interface`

Step 3. (Cont...): Ethernet LMI Config – Modify default params

■ PE:

- `denver-c3750me(config)#in f1/0/1`
- `denver-c3750me(config-if)#ethernet lmi ?`
- `interface` Enable Ethernet LMI on this interface
- `n393` Error counter
- `t392` Polling verification timer

■ CE:

- `sandiego-c3845(config-if)#ethernet lmi ?`
- `interface` Enable Ethernet LMI on this interface
- `n391` Polling counter
- `n393` Error counter
- `t391` Polling timer

Ethernet LMI Configuration - CE

- Enable Ethernet LMI (Global/Per Interface)
 - Enable Ethernet LMI
 - Modify Ethernet LMI default parameters (Optional)

Complete E-OAM configuration - PE

```

■ !
■ ethernet lmi global
■ ethernet cfm domain CUSTOMER_DOMAIN level 7
■ ethernet cfm domain PROVIDER_DOMAIN level 4
■   service customer_101_provider vlan 101
■   service customer_110_provider vlan 110
■ ethernet cfm enable
■ !
■ !
■ ethernet evc EVC_P2P_110
■   oam protocol cfm svlan 110 domain PROVIDER_DOMAIN
■ !
■ ethernet evc EVC_MP2MP_101
■   uni count 3
■   oam protocol cfm svlan 101 domain PROVIDER_DOMAIN
■ !
■ !
■ interface FastEthernet1/0/1
■   description connected to sandiego-c3845
■   service instance 101 ethernet EVC_MP2MP_101
■     ethernet lmi ce-vlan map 101
■     service instance 110 ethernet EVC_P2P_110
■       ethernet lmi ce-vlan map 110
■ ethernet uni id cisco_sandiego
■   ethernet cfm mip level 7
■   ethernet cfm mep level 4 mpid 1110 vlan 110
■   ethernet cfm mep level 4 mpid 1101 vlan 101
■ !

```

NOTE: Required DATA plane configuration should be done as done today.

Complete E-OAM configuration on CE

- `!`
- `interface GigabitEthernet0/1`
- `no ip address`
- `logging event subif-link-status`
- `negotiation auto`
- `ethernet lmi interface`
- `end`

NOTE: Required DATA plane configuration should be done as done today.

EVC, Ethernet LMI show commands

- Start with root words “show ethernet service”

```
denver-c3750me#show ethernet service ?  
evc          Ethernet EVC  
instance     Ethernet Service Instance  
interface    Ethernet Service Interface
```

“ether service” commands
reflect
what is configured.

- Start with root words “show ethernet lmi”

```
pe#show ethernet lmi ?  
evc          Ethernet Virtual Connection  
parameters   Ethernet LMI Parameters  
statistics    Ethernet LMI statistics  
uni          UNI information
```

“ether lmi” commands
on PE reflect
what is sent to CE

show ethernet service evc

- `denver-c3750me#show ethernet service evc`

Identifier	Type	Act-UNI-cnt	Status
EVC_P2P_110	P-P	2	Active
EVC_MP2MP_101	MP-MP	3	Active

show ethernet service evc detail

- denver-c3750me#show ethernet service evc detail

EVC ID: EVC_P2P_110

EVC Type: P-P

UNI Count: Configured = 2, Active = 2

EVC Status: Active

Associated Local Interfaces:

Interface	CE-Vlans
FastEthernet1/0/1	110

Associated UNIs:

UNI-Identifier	Status	Location
cisco_sandiego	Up	Fa1/0/1
cisco_newyork	Up	Remote

EVC ID: EVC_MP2MP_101

EVC Type: MP-MP

UNI Count: Configured = 3, Active = 3

EVC Status: Active

Associated Local Interfaces:

Interface	CE-Vlans
FastEthernet1/0/1	101

Associated UNIs:

UNI-Identifier	Status	Location
cisco_sandiego	Up	Fa1/0/1
cisco_newyork	Up	Remote

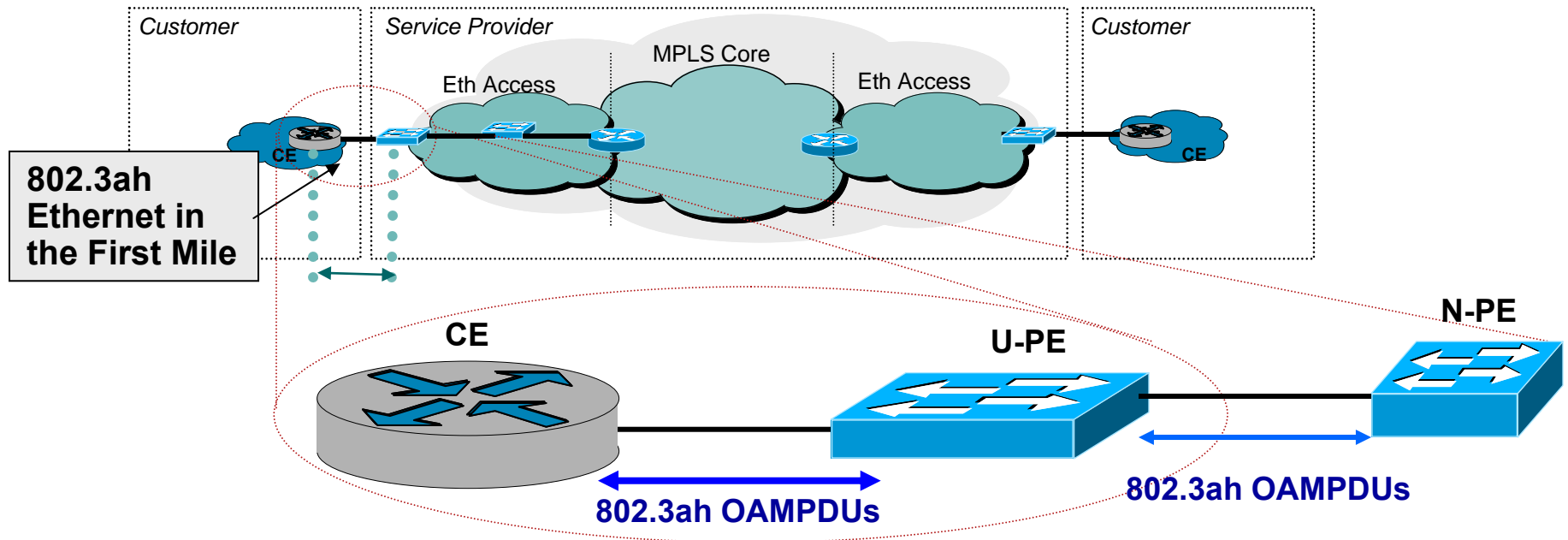
802.3ah Ethernet in the First Mile Connectivity Verification



Agenda

- Overview
- Ethernet OAM Technology
- Ethernet OAM Configuration
- Ethernet OAM Commands
- Ethernet OAM Implementation

802.3ah Overview



- Operates on a single point-to-point link between 2 devices
- Slow protocol using packets called OAMPDUs which are never forwarded
- Provides 5 functions:
 - Remote failure indication – Inform peer device that receive path is down. Requires unidirectional operation support.
 - Remote loopback – Puts device in a state such that all non-OAM packets are looped back. Normal forwarding is suspended. Statistics can be collected while testing link.
 - Link monitoring – Event notification and link information. Also provides polling and response (but not writing) of 802.3ah MIB
 - OAM discovery – Discovers OAM support and capabilities on peer device
 - Mib Variable Retrieval

Overview

- What is 802.3ah Ethernet OAM?

Point-to-point link-level OAM

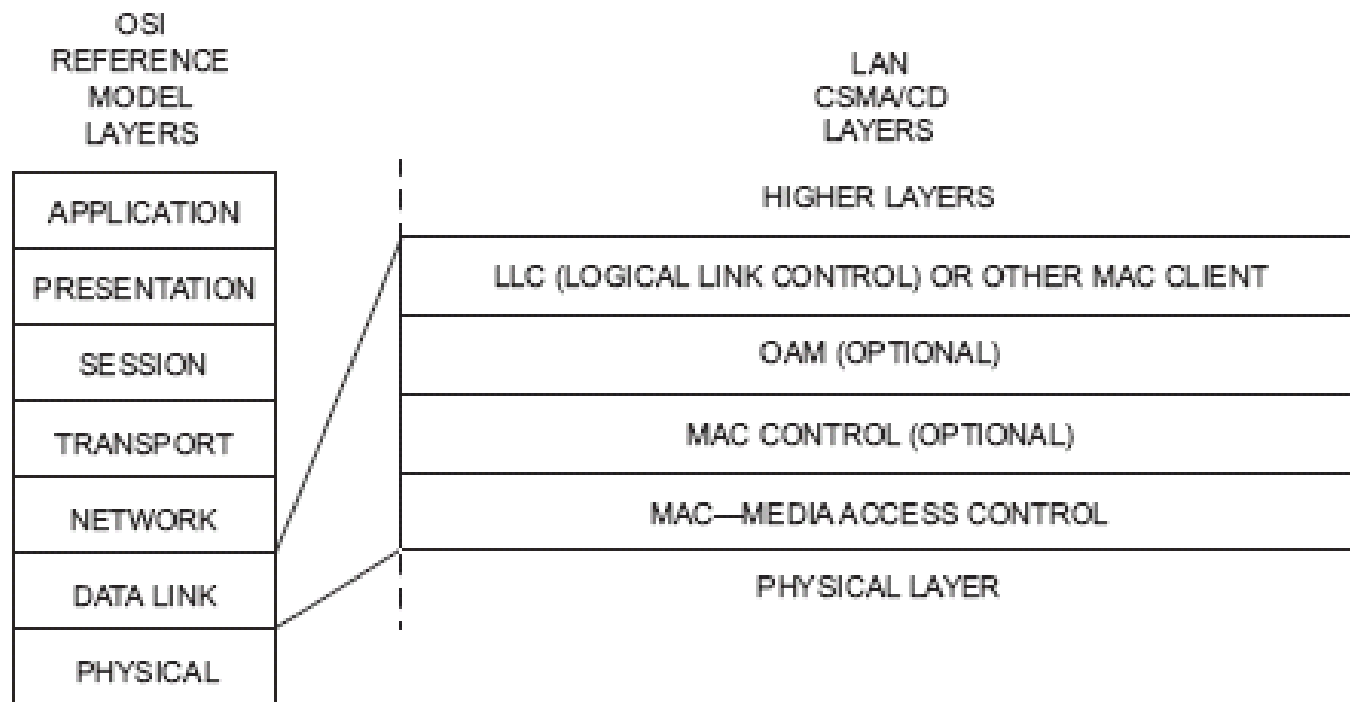
- Why it is needed?

Monitor the health of a link

Determine the location of failing links or fault conditions

Complement applications that reside in higher layers

802.3ah Technology



OAM sublayer relationship to the ISO/IEC Open Systems

802.3ah Technology

- What does Ethernet OAM support?

Discovery :- Discovery is the first phase of Ethernet OAM. It identifies the devices in the network along with their OAM capabilities.

Remote failure indication :- Ethernet OAM provides a mechanism for an OAM entity to convey slow degradation of Ethernet link to its peer via specific flags in the OAMPDU.

Link monitoring :- Link monitoring in Ethernet OAM serves for detecting and indicating link faults under a variety of conditions.

Remote loopback :- An OAM entity can put its remote peer into loopback mode using the Loopback control OAMPDU. This helps the administrator ensure the quality of links during installation or when troubleshooting.

Polling of MIB variables :- Ethernet OAM provides a read-only access to remote MIB variables limited to a specific MIB branch and leaf.

802.3ah Technology

■ The Basics

Ethernet OAM uses standard Ethernet frames, called OAMPDUs.

OAMPDU uses IEEE Slow Protocol's MAC address (0180.c200.0002) and Ether-Type (8809) but has a unique subtype (03).

OAMPDU is sourced and terminated at both ends of a link. It is not relayed by bridges.

802.3ah Technology

■ OAMPDU format

Destination Address	Source Address	Ether-Type	Sub-type	Data/Pad	FCS
6 octets	6 octets	2 octets	1 octet	45 ~ 1499 octets	4 octets

Destination Address **01-80-C2-00-00-02**
(slow protocol address)

Ether-Type **88-09**

Subtype **03**

Ethernet 802.3ah Technology

- **OAMPDU types**

Information OAMPDU

Event Notification OAMPDU

Variable Request OAMPDU

Variable Response OAMPDU

Loopback Control OAMPDU

Organization Specific OAMPDU

802.3ah Technology

■ OAM Discovery

Ethernet OAM and it identifies the devices in network along with their capabilities.

- 1. Send Information OAMPDU in a periodic fashion (once a second, by default).**
- 2. Discover OAM configurations (capabilities, eg:- LB), state (Active/Passive), OUI (Organizational unique identifier), OAMPDU configuration (max. oampdu size and rate) of remote OAM client.**
- 3. Decide whether OAM clients can be fully operational on the link.**

802.3ah Technology

- **OAM Remote Failure Indication**

Three types of remote failures

Link Fault – *hardware detected fault that occurred in the receive direction of the local equipment*

Dying Gasp – *an unrecoverable failure (eg:- power failure).*

Oam client administrative turned off

1. Interface error disabled.

2. reload

Critical Event

The definition of the specific faults is implementation specific.

802.3ah Technology

■ OAM Link Monitoring

Four types of errors

Errored Symbol Period :- Number of symbol errors (coding error) that occurred during a specified period exceeded the threshold.

Errored Frame :- Number of frame errors detected during a specified period exceeded a threshold.

Errored Frame Period :- Number of frame errors within the last N frames has exceeded a threshold

Errored Frame Seconds :- Number of errored seconds (one second intervals with at least one frame error) within the last M seconds has exceeded a threshold.

Event Notification OAMPDU is sent to remote OAM client if any of the above errors is detected locally.

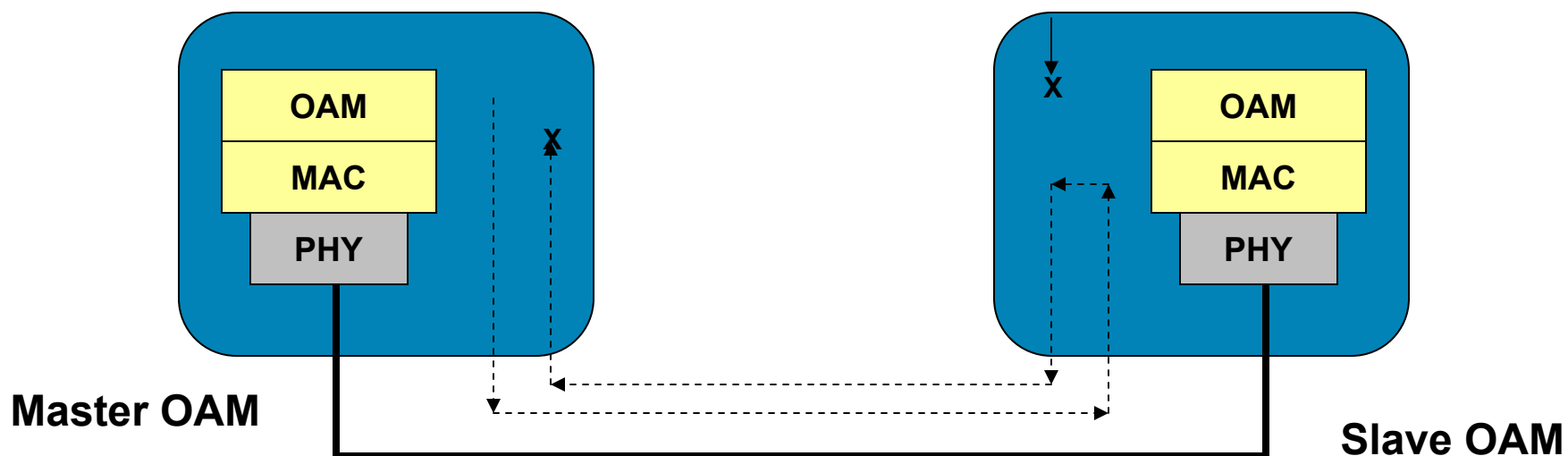
802.3ah Technology

■ OAM 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.



802.3ah Technology

- **OAM MIB variable retrieval**

Variable Request OAMPDU and Variable Response OAMPDU are used to fetch a MIB variable.

Query variables can be implementation specific.

802.3ah Configuration

■ Ethernet OAM Interface Configuration

device(config-if)# Ethernet oam ?

link-monitor Ethernet OAM Link Monitor

max-rate Maximum transmission rate (number of OAMPDUs per second)

min-rate Minimum transmission rate(one OAMPDU per number of seconds)

mode Ethernet OAM client mode

remote-failure Ethernet OAM remote failure indication

remote-loopback Ethernet OAM Remote Loopback

timeout Ethernet OAM client link timeout setting

802.3ag Template configuration

template oam

```
ethernet oam link-monitor symbol-period threshold low 10
ethernet oam link-monitor symbol-period threshold high 100
ethernet oam link-monitor frame window 100
ethernet oam link-monitor frame threshold low 10
ethernet oam link-monitor frame threshold high 100
ethernet oam link-monitor frame-period window 100
ethernet oam link-monitor frame-period threshold low 10
ethernet oam link-monitor frame-period threshold high 100
ethernet oam link-monitor frame-seconds window 1000
ethernet oam link-monitor frame-seconds threshold low 10
ethernet oam link-monitor frame-seconds threshold high 100
ethernet oam link-monitor receive-crc window 100
ethernet oam link-monitor receive-crc threshold high 100
ethernet oam link-monitor transmit-crc window 100
ethernet oam link-monitor transmit-crc threshold high 100
ethernet oam remote-failure link-fault action error-disable-interface
ethernet oam remote-failure dying-gasp action error-disable-interface
ethernet oam remote-failure critical-event action error-disable-interface
```

!

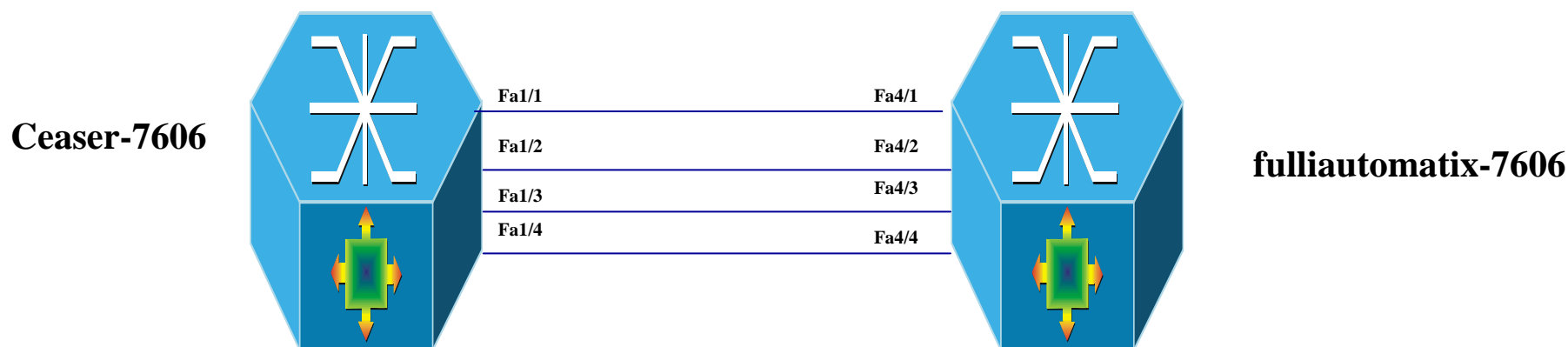
Ceasar# conf t

Enter configuration commands, one per line. End with CNTL/Z.

Ceasar(config)# int fas 1/25

Ceasar(config-if)# source template oam

802.3ah Configuration -Topology



```
!
interface FastEthernet1/1
no ip address
ethernet oam
!
interface FastEthernet1/2
no ip address
ethernet oam
!
interface FastEthernet1/3
ip address 6.6.6.6
255.255.255.0
ethernet oam
!
interface FastEthernet1/4
no ip address
ethernet oam
```

```
!
interface FastEthernet4/1
no ip address
ethernet oam
!
interface FastEthernet4/2
no ip address
source template oam
ethernet oam
!
interface FastEthernet4/3
ip address 6.6.6.7 255.255.255.0
ethernet oam remote-loopback supported
ethernet oam
!
interface FastEthernet4/4
no ip address
ethernet oam max-rate 5
ethernet oam min-rate 2
ethernet oam mode passive
ethernet oam timeout 30
ethernet oam remote-failure link-fault action error-disable-interface
ethernet oam remote-failure dying-gasp action error-disable-interface
ethernet oam remote-failure critical-event action error-disable-interface
ethernet oam
```

Configuration Verification

- **show ethernet oam status [interface <interface name>]**

```
fulliautomatix#show ethernet oam status int fas 4/4
```

```
FastEthernet4/4
```

```
General
```

```
-----
```

```
Admin state:      enabled
```

```
Mode:             passive
```

```
PDU max rate:     5 packets per second
```

```
PDU min rate:     1 packet per 2 seconds
```

```
Link timeout:     30 seconds
```

```
High threshold action: no action
```

```
Link fault action: error disable interface
```

```
Dying gaps action: error disable interface
```

```
Critical event action: error disable interface
```

```
Link Monitoring
```

```
-----
```

```
Status: supported (on)
```

```
Symbol Period Error
```

```
Window:           100 x 1000000 symbols
```

```
Low threshold:    1 error symbol(s)
```

```
High threshold:   none
```

```
Frame Error
```

```
Window:           10 x 100 milliseconds
```

```
Low threshold:    1 error frame(s)
```

```
High threshold:   none
```

```
.....
```

```
.....
```

```
.....
```

```
fulliautomatix#
```

Ethernet OAM Commands:- Discovery

- **show ethernet oam summary**
- **show ethernet oam discovery [interface <interface name>]**

Ceasar#show ethernet oam summary

Symbols: * - Master Loopback State, # - Slave Loopback State

Capability codes: L - Link Monitor, R - Remote Loopback

U - Unidirection, V - Variable Retrieval

Local Interface	Remote MAC Address	OUI	Mode	Capability
Fa1/1	0011.9321.1640	00000C	active	L
Fa1/2	0011.9321.1640	00000C	active	L
Fa1/3	0011.9321.1640	00000C	active	L R
Fa1/4	0011.9321.1640	00000C	passive	L

Ceasar#

fulliautomatix# show ethernet oam summary

Symbols: * - Master Loopback State, # - Slave Loopback State

Capability codes: L - Link Monitor, R - Remote Loopback

U - Unidirection, V - Variable

Retrieval

Local Interface	Remote MAC Address	OUI	Mode	Capability
Fa4/1	000b.45b5.3140	00000C	active	L
Fa4/2	000b.45b5.3140	00000C	active	L
Fa4/3	000b.45b5.3140	00000C	active	L
Fa4/4	000b.45b5.3140	00000C	active	L

Ethernet OAM Commands:- Discovery

```
Ceasar#show ethernet oam discovery interface  
fas 1/1
```

```
FastEthernet1/1
```

```
Local client
```

```
-----
```

Administrative configurations:

```
Mode:          active  
Unidirection:  not supported  
Link monitor:  supported (on)  
Remote loopback: not supported  
MIB retrieval: not supported  
Mtu size:      1500
```

Operational status:

```
Port status:    operational  
Loopback status: no loopback  
PDU revision:   0
```

Remote client

```
-----
```

```
MAC address: 0011.9321.1640  
Vendor(oui): 00000C(cisco)
```

Administrative configurations:

```
PDU revision:  1  
Mode:          active  
Unidirection:  not supported  
Link monitor:  supported  
Remote loopback: not supported  
MIB retrieval: not supported  
Mtu size:      1500
```

```
Ceasar#
```

Ethernet OAM Commands:- Link monitoring

- **Show ethernet oam statistics [interface <interface name>]**

FastEthernet4/2

Counters:

```
-----
Information OAMPDU Tx           : 3
Information OAMPDU Rx           : 3
Unique Event Notification OAMPDU Tx : 0
Unique Event Notification OAMPDU Rx : 0
Duplicate Event Notification OAMPDU TX : 0
Duplicate Event Notification OAMPDU RX : 0
Loopback Control OAMPDU Tx      : 0
Loopback Control OAMPDU Rx      : 0
Variable Request OAMPDU Tx      : 0
Variable Request OAMPDU Rx      : 0
Variable Response OAMPDU Tx     : 0
Variable Response OAMPDU Rx     : 0
Cisco OAMPDU Tx                 : 0
Cisco OAMPDU Rx                 : 0
Unsupported OAMPDU Tx           : 0
Unsupported OAMPDU Rx           : 0
Frames Lost due to OAM          : 0
```

Local Faults:

```
-----
0 Link Fault records
0 Dying Gasp records
0 Critical Event records
```

```
-----
0 Link Fault records
0 Dying Gasp records
0 Critical Event records
```

Local event logs:

```
-----
0 Errored Symbol Period records
0 Errored Frame records
0 Errored Frame Period records
0 Errored Frame Second records
```

Remote event logs:

```
-----
0 Errored Symbol Period records
0 Errored Frame records
0 Errored Frame Period records
0 Errored Frame Second records
```

fulliautomatix#

Ethernet OAM Commands:- Remote Fault Indication

```
Ceasar(config)#int fas 1/4
```

```
Ceasar(config-if)#sh
```

```
fulliautomatix#
```

```
1w0d: %ETHERNET_OAM-SP-6-RFI: The client on interface Fa4/4 has  
received a remote failure indication from its remote peer(failure  
reason = remote client administratively turned off)
```

```
1w0d: %PM-SP-4-ERR_DISABLE: oam-remote-failure error detected on  
Fa4/4, putting Fa4/4 in err-disable state
```

```
01:18:54: %ETHERNET_OAM-SP-STDBY-6-EXIT_SESSION: The client  
on interface Fa4/4 has left the OAM session.
```

```
1w0d: %ETHERNET_OAM-SP-6-EXIT_SESSION: The client on interface  
Fa4/4 has left the OAM session.
```

```
01:18:55: %PM-SP-STDBY-4-ERR_DISABLE: oam-remote-failure error  
detected on Fa4/4, putting Fa4/4 in err-disable state
```

```
fulliautomatix#
```

```
fulliautomatix#show int fas 4/4
```

```
FastEthernet4/4 is down, line protocol is down (err-disabled)
```

Ethernet OAM Commands:- Remote Fault Indication

Ceasar(config)#int fas 1/4

Ceasar(config-if)#no ethernet oam

fullyautomatix#

1w0d: %ETHERNET_OAM-SP-6-RFI: The client on interface Fa4/4 has received a remote failure indication from its remote peer(failure reason = remote client administratively turned off)

1w0d: %PM-SP-4-ERR_DISABLE: oam-remote-failure error detected on Fa4/4, putting Fa4/4 in err-disable state

01:22:28: %ETHERNET_OAM-SP-STDBY-6-EXIT_SESSION: The client on interface Fa4/4 has left the OAM session.

1w0d: %ETHERNET_OAM-SP-6-EXIT_SESSION: The client on interface Fa4/4 has left the OAM session.

01:22:29: %PM-SP-STDBY-4-ERR_DISABLE: oam-remote-failure error detected on Fa4/4, putting Fa4/4 in err-disable state

Ethernet OAM Commands:- Remote loopback

- `ethernet oam remote-loopback start interface <interface name>` puts the ports in loopback state.

Ceasar#ethernet oam remote-loopback start interface fas1/3

Ceasar#

6d22h: %ETHERNET_OAM-SP-6-LOOPBACK: Interface Fa1/3 has entered the master loopback mode.

fulliautomatix#

1w0d: %ETHERNET_OAM-SP-6-LOOPBACK: Interface Fa4/3 has entered the slave loopback mode.

1w0d: SP: EOAM LB(Fa4/3): new status = 2

fulliautomatix#

Ethernet OAM Commands:- Remote loopback

Ceasar#show ethernet oam summary

Symbols: * - Master Loopback State, # - Slave Loopback State

Capability codes: L - Link Monitor, R - Remote Loopback

U - Unidirection, V - Variable Retrieval

Local	Remote
Interface	MAC Address OUI Mode Capability
Fa1/1	0011.9321.1640 00000C active L
Fa1/2	0011.9321.1640 00000C active L
* Fa1/3	0011.9321.1640 00000C active L R
Fa1/4	0011.9321.1640 00000C passive L

fulliautomatix#show ethernet oam summary

Symbols: * - Master Loopback State, # - Slave Loopback State

Capability codes: L - Link Monitor, R - Remote Loopback

U - Unidirection, V - Variable Retrieval

Local	Remote
Interface	MAC Address OUI Mode Capability
Fa4/1	000b.45b5.3140 00000C active L
Fa4/2	000b.45b5.3140 00000C active L
# Fa4/3	000b.45b5.3140 00000C active L
Fa4/4	000b.45b5.3140 00000C active L

Ethernet OAM Commands :- Remote loopback

- show interface counters are used to verify that traffic is looped back.

Ceasar#show interface counters | inc Fa1/3

Port	InOctets	InUcastPkts	InMcastPkts	InBcastPkts	
Fa1/3	42271953	374	606773	6	←Input packets
Fa1/3	42184101	392	606934	1	←Output packets

Ceasar#ping 5.5.5.5

Type escape sequence to abort.

Sending 5, 100-byte ICMP Echos to 5.5.5.5, timeout is 2 seconds:

.....

Success rate is 0 percent (0/5)

Ceasar#show interface counters | inc Fa1/3

Fa1/3	42282215	379	606917	8	←Input packets
Fa1/3	42187315	397	606975	1	←Output packets

Ethernet OAM debug commands

- Ceasar#debug ethernet oam ?

all **All Ethernet OAM debugging messages**

config **Ethernet OAM configurations**

ha **Ethernet OAM High Availability events**

link-monitor **Ethernet OAM link monitor**

loopback **Ethernet OAM loopback**

packet **Ethernet OAMPDU**

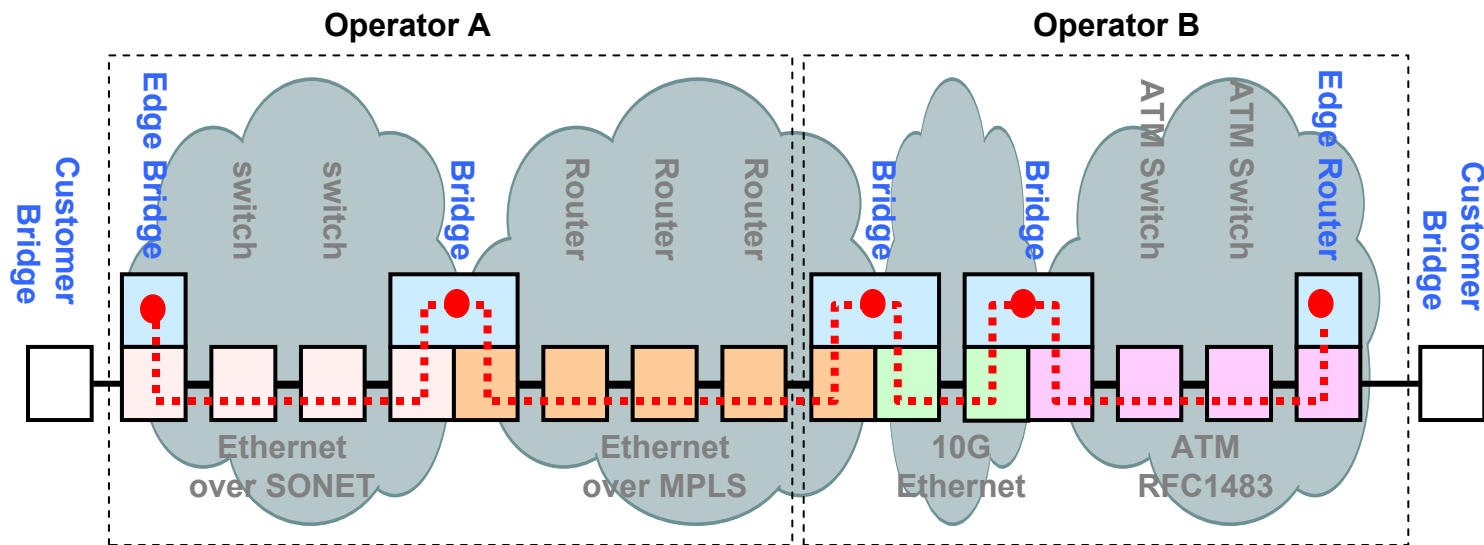
sm **Ethernet OAM state machine**

OAM Inter-working



What is OAM Inter-working?

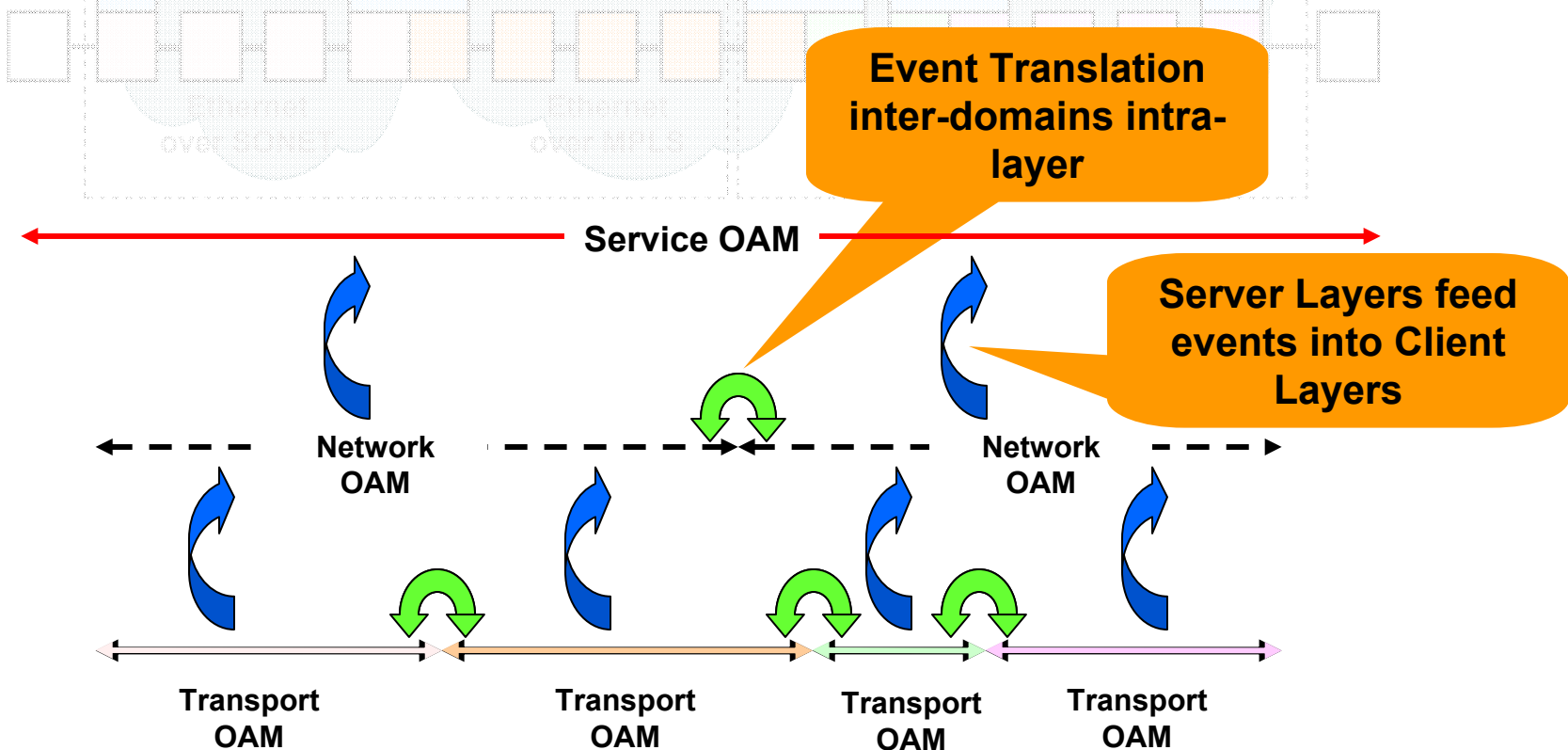
This is NOT OAM inter-working!



- Transport OAM message with embedded MAC address carried from bridge to bridge, visible to ETH layer (when present), and translated to new transport's OAM format when crossing physical media boundaries.
- Creates dependency on Physical layer and inter-operability issues.

What is OAM Inter-working?

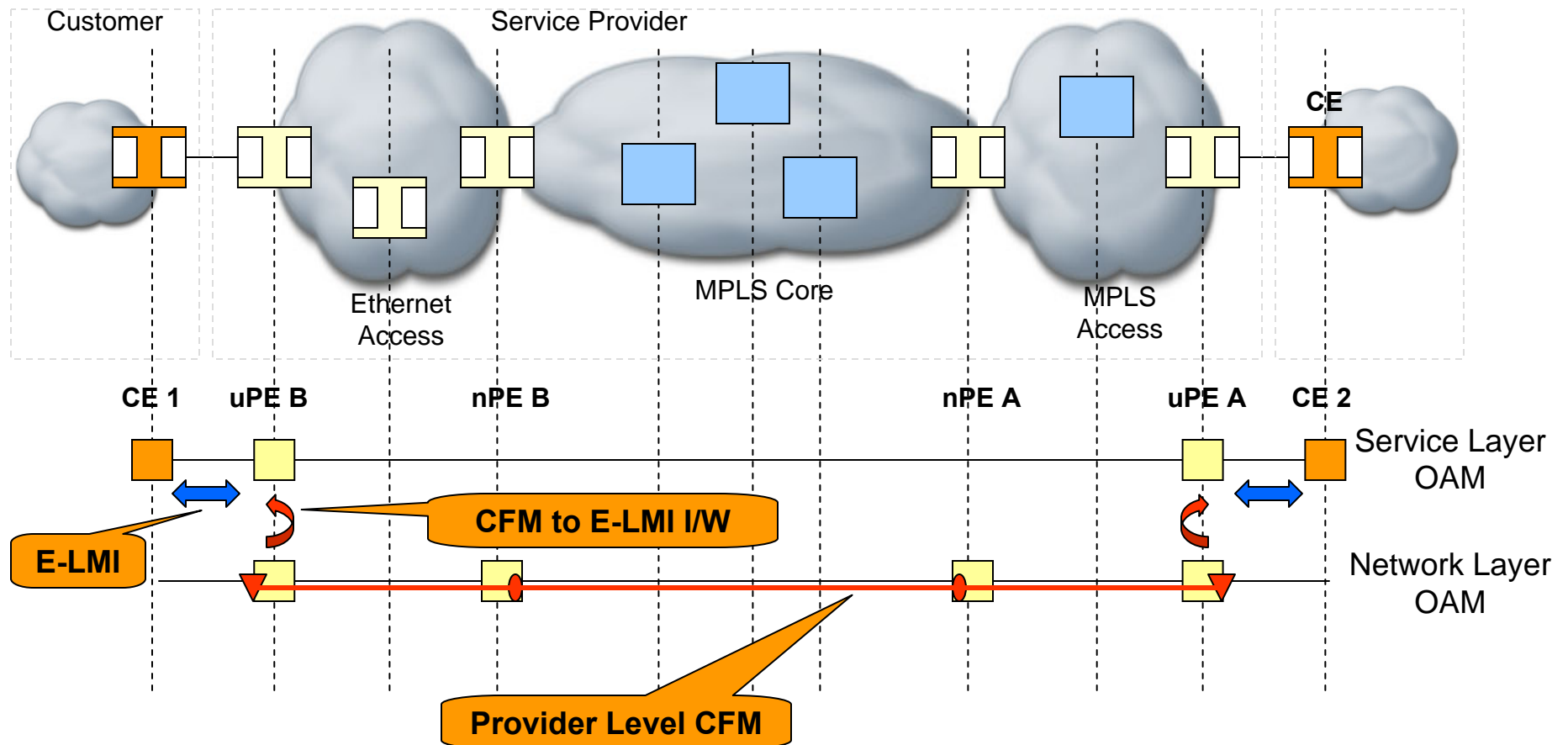
- Strict OAM layering should be honored: messages should not cross layers
- OAM Messages should not leak outside domain boundaries within a layer
- Inter-working is **event translations** & **not necessarily 1:1 message mapping**
- Inter-working may be inter-layer and intra-layer



Why OAM Inter-working?

- Enable management of ubiquitous Ethernet service offerings on:
 - mixed media
 - heterogeneous networks/transport
 - legacy equipment
- Leverage the benefits of server layer OAM mechanisms when applicable
 - Potentially faster failure detection times
 - Redundant Alarm Suppression (daisy chain effect)

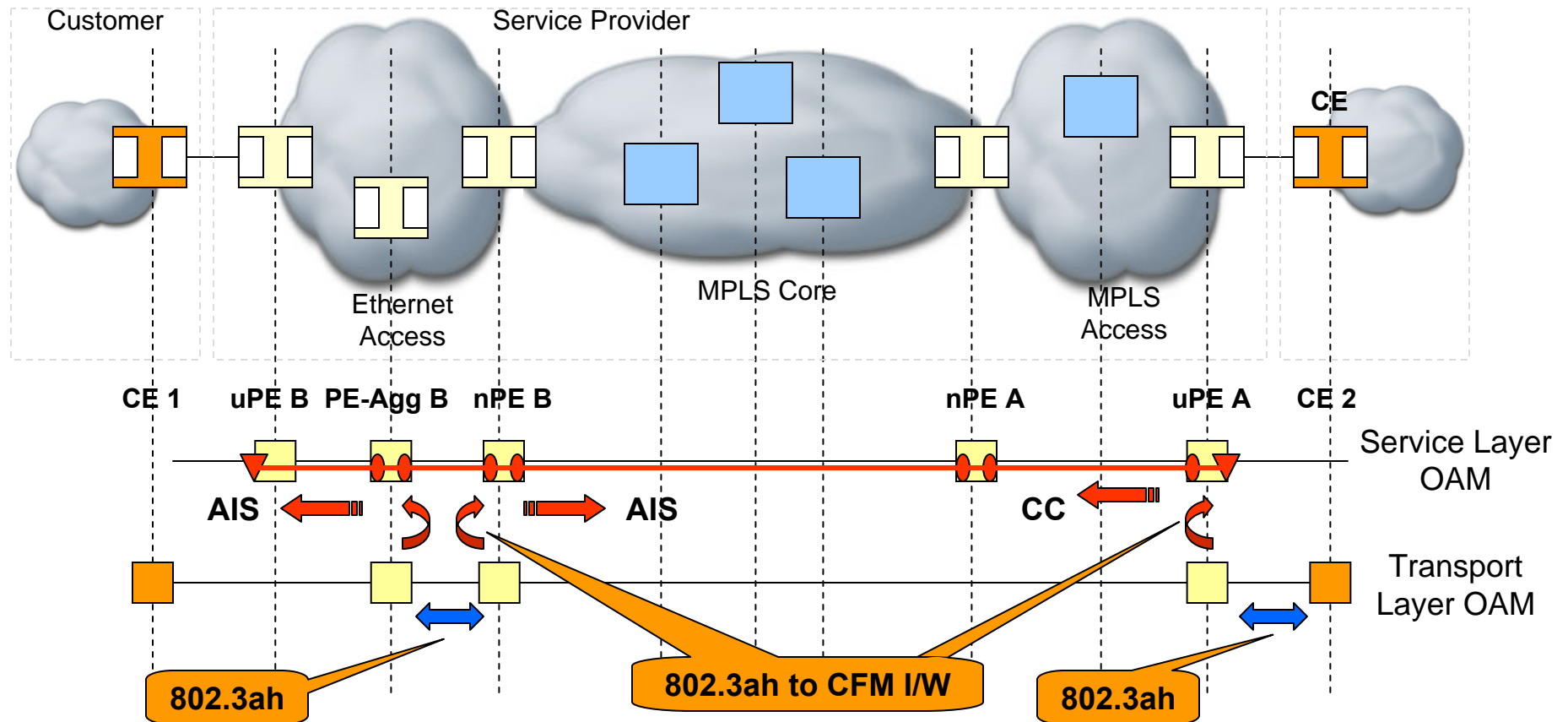
Inter-working Scenarios: CFM to E-LMI



CFM @ Provider Level acts as MEN OAM: provides EVC Status and Remote UNI Status/Name to E-LMI

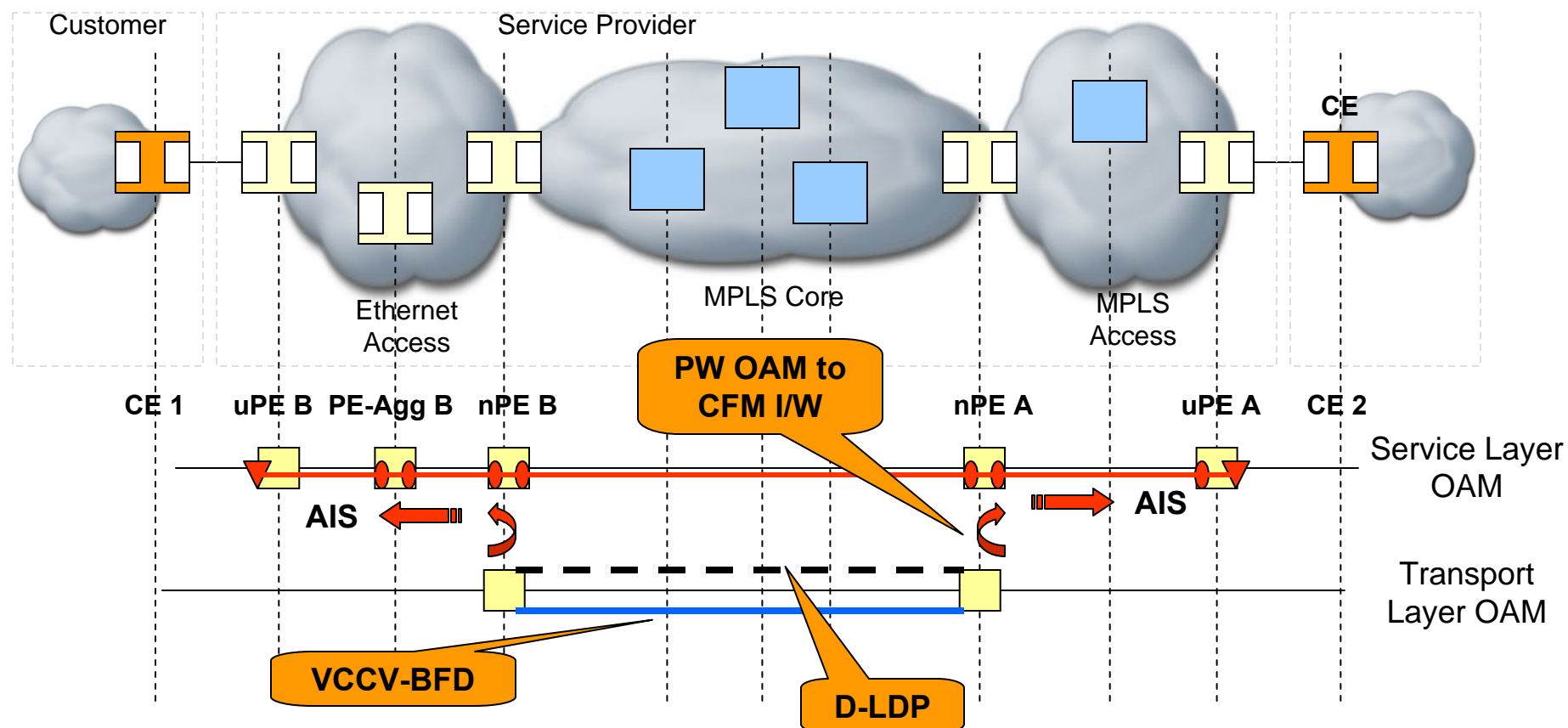
- Port State TLV of CC Messages carry remote UNI status
- MEP Name TLV of CC Messages carry remote UNI name
- Status of remote MEP in CCDB indicates EVC State

Inter-working Scenarios: 802.3ah to CFM



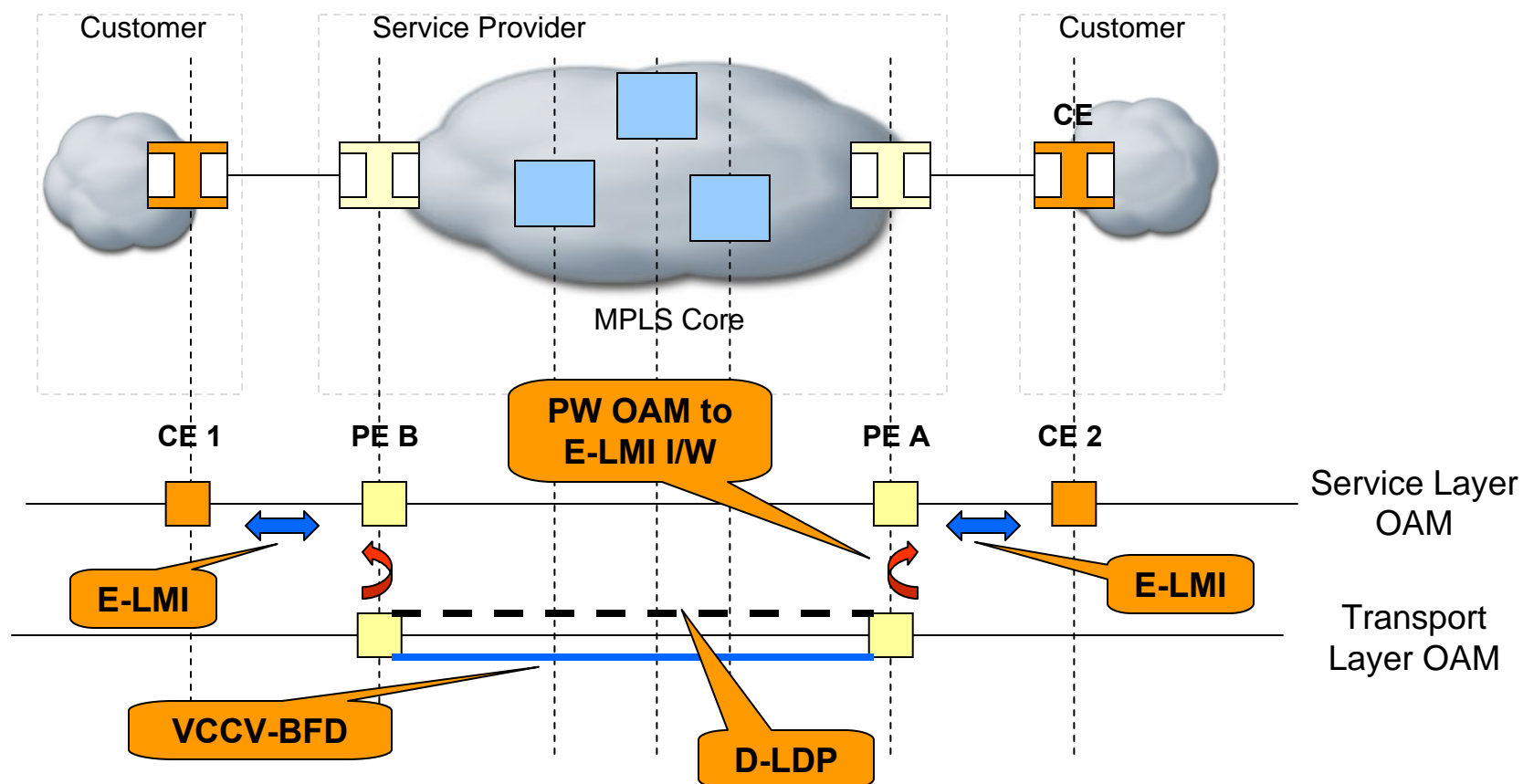
- Link Layer Defects detected by 802.3ah, relayed to CFM on same device.
- CFM notifies remote devices of localized fault.
- Two variants:
 - CC based (802.3ah on edge of domain)
 - AIS based (802.3ah within domain)

Inter-working Scenarios: MPLS PW OAM to CFM



- Directed-LDP & VCCV (BFD mode) running between nPEs.
- D-LDP for defect notification, VCCV for defect detection
- 3-way I/W function at nPE
- Requires CFM AIS/RDI

Inter-working Scenarios: MPLS PW OAM to E-LMI

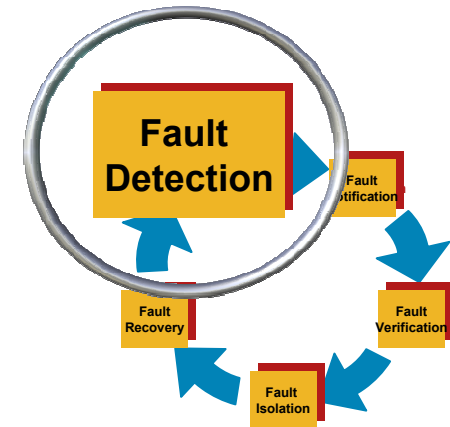


- Directed-LDP & VCCV (BFD mode) running between PEs.
- D-LDP for defect notification, VCCV for defect detection
- Defects detected/communicated by PW OAM are relayed to E-LMI via I/W function on PE.

Ethernet OAM Summary



E-OAM Toolkit for Fault Management (1 of 5)



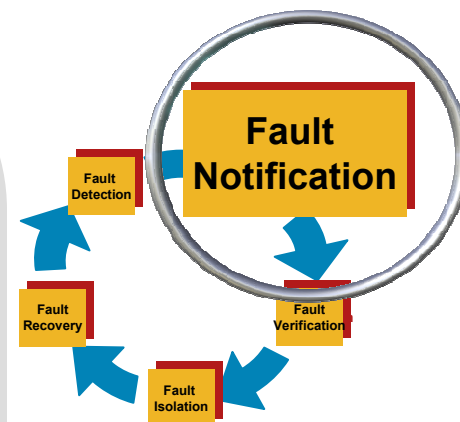
Fault Detection

	<u>Mechanism</u>	<u>Detectable Faults</u>
802.1ag (CFM)	Continuity Check (CC)	<ul style="list-style-type: none">• Unintended connectivity/service leaks• Unexpected sites• Loss of connectivity to a site• Link Connectivity failure• Device failure (soft & hard)• Forwarding plane loops• CFM Configuration Errors
802.3ah	Link Monitoring	<ul style="list-style-type: none">• Unidirectional Link• Slowly deteriorating link quality (Frame/Symbol Errors)

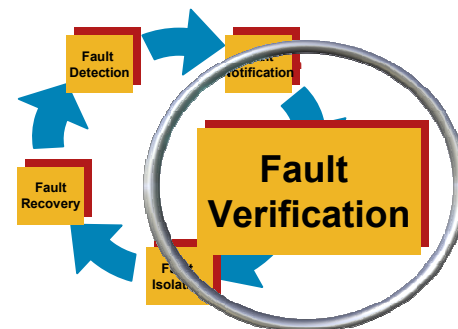
E-OAM Toolkit for **Fault Management** (2 of 5)

Fault Notification

	<u>Mechanism</u>	<u>Triggers</u>
Y.1731	Alarm Indication Signal (AIS)	<ul style="list-style-type: none"> • Loss of CFM Continuity Check • Indication from Server Layer OAM • Indication from lower ME Level CFM Domain
802.1ag (CFM)	Remote Defect Indication (RDI)	<ul style="list-style-type: none"> • Unidirectional service Connectivity (p2p) • Partial service connectivity (mp)
802.3ah	Remote Failure Indication	<ul style="list-style-type: none"> • Link Fault (receive path) • Dying Gasp • Critical Event
	Event Notification	<ul style="list-style-type: none"> • Error thresholds exceeded (frames/symbols per interval)
E-LMI	Status Message	<ul style="list-style-type: none"> • EVC Status Change • Remote UNI(s) Status Change



E-OAM Toolkit for **Fault Management** (3 of 5)



Fault Verification

Mechanism

Capability

802.1ag
(CFM)

Loopback

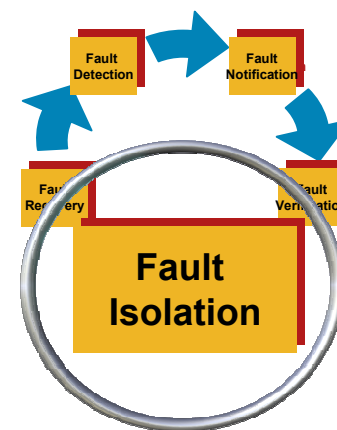
- Per EVC MAC Ping (source to single destination)
- Verify bidirectional connectivity between two CFM Maintenance Points (for varied frame sizes)

Y.1731

Multicast
Loopback

- Per EVC MAC Ping (source to all destinations)
- Verify bidirectional connectivity between one CFM Maintenance End Point and all other End Points of a service (for varied frame sizes)

E-OAM Toolkit for **Fault Management** (4 of 5)



Fault Isolation

Mechanism

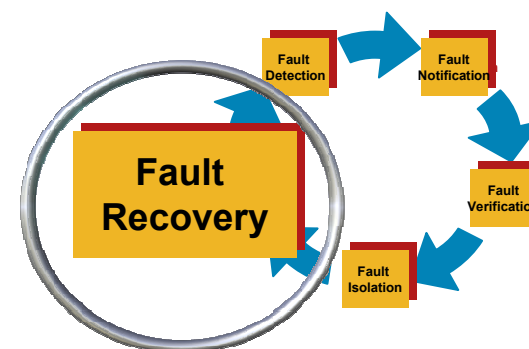
**802.1ag
(CFM)**

Link Trace

Capability

- Per EVC MAC Traceroute
- Discover Maintenance Intermediate Points on path from source End Point to destination End Point
- Report Ingress Action, Relay Action, Egress Action hop by hop.
- Report encountered ACLs or STP-blocked ports

E-OAM Toolkit for **Fault Management** (5 of 5)



Fault Recovery

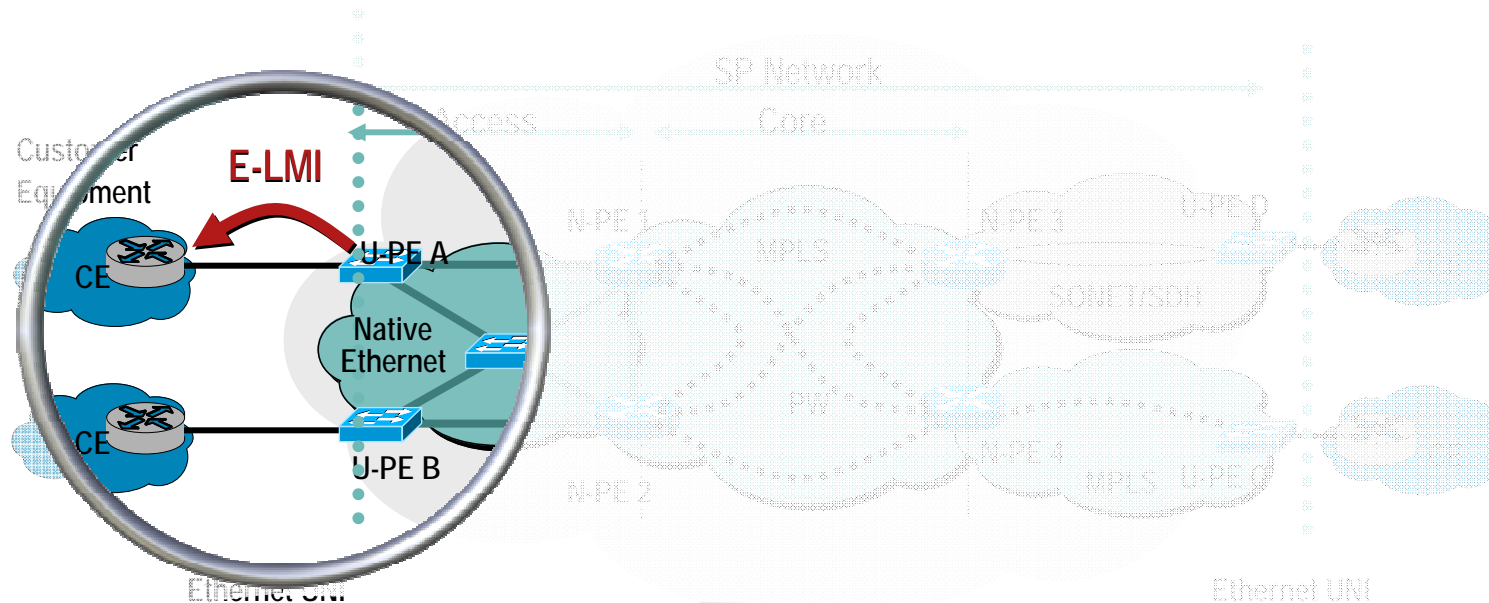
	<u>Mechanism</u>	<u>Capability</u>
G.8031	ETH-APS	<ul style="list-style-type: none">• Use CFM mechanisms for monitoring redundant paths (order of msec)
Non-OAM Mechanisms	xSTP	

E-OAM Toolkit for Performance Management

- Frame loss measurement
- Delay measurement
- Delay variation (Jitter) measurement
- Availability measurement

Performance Management		
	<u>Mechanism</u>	<u>Capability</u>
SLA	CFM Loopback Jitter Probe	<ul style="list-style-type: none">• Uni-directional and Round Trip Latency• Unidirectional Jitter• Unidirectional Frame Loss
Y.1731	LMM / 1DM / DMM	<ul style="list-style-type: none">• Loss Measurement• One way delay• Two way delay

E-OAM Toolkit for Configuration Management



Configuration Management

Mechanism

**CE-VLAN /
EVC Map**

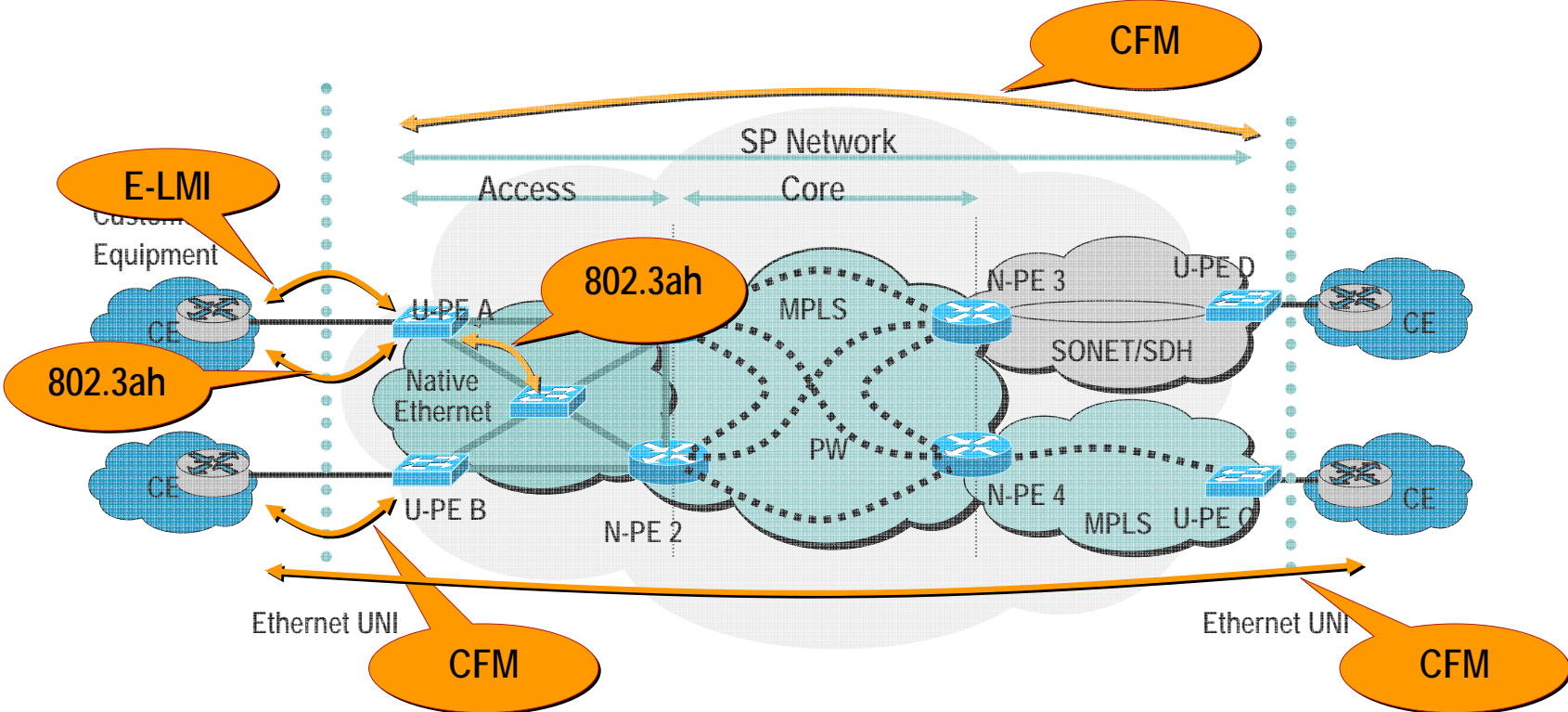
BW Profile

E-LMI

Capability

- Reduce Customer configuration errors
- Ease deployment for Managed Services / Low-Touch Turn-key CE
- Improve service performance by egress CE Shaping
- Reduce Policing configurations on SP gear

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- Choice of protocols, their locality & span of operation varies with network topology & services – many variations possible
- Restrictions (inherent to protocol definitions):
 - E-LMI on UNI (uPE to CE)
 - 802.3ah on pt-to-pt (emulated ok) 802.3 PHY
 - CFM/Y.1731 require Ethernet MAC Layer awareness

Q and A



