OAM and its Performance Monitoring Mechanisms for Carrier Ethernet Transport Networks

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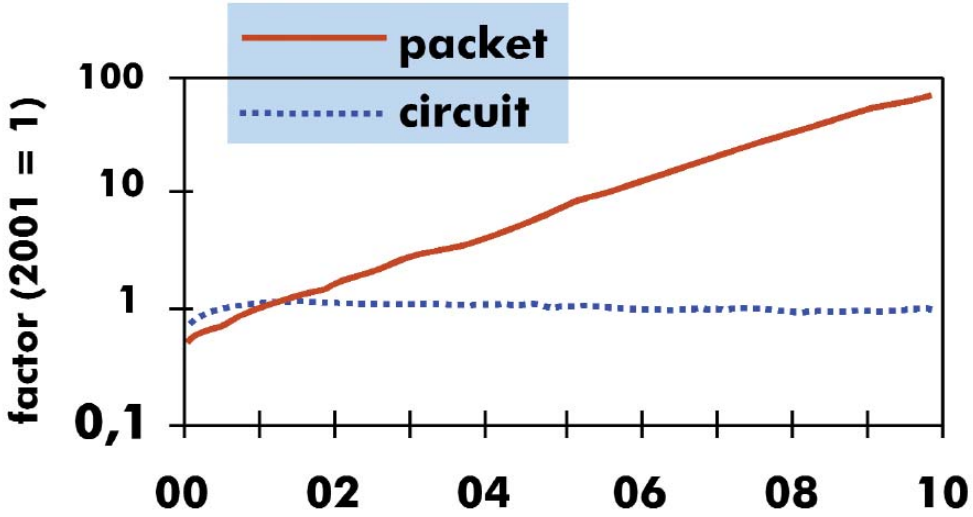
Agenda

- Packet Transport Layer Network
- Carrier Ethernet Service
- Ethernet OAM
- Ethernet Linear Protection

Packet Transport Layer Network



Backbone overlay networks

Backbone overlay networks for data traffic

- IP routers are interconnected by fibers or WDM links normally, TDM transport (SONET/SDH) in some cases.
- 약 50%의 overlay data backbone은 IP/MPLS 기반.
- Advantages:
  - Legacy infrastructure에 영향 없이 새로운 기술 도입
  - Operation and maintenance 노력은 망 성장에 따라 확충해 갈 수 있으며 legacy 망 운용과 별개로 취급.
- Disadvantages:
  - High CAPEX and OPEX as there are two networks in parallel
  - 두 개의 다른 망으로 인한 network optimization 잘 안됨
  - Limitation in flexibility
  - Exponential growth of data traffic → router 크기도 같이 커져야 함 → Terabit 용량이 요구됨 → 그런 router의 cost와 complexity는 매우 큼. → cost and resource efficient networking, 즉 transport layer network이 필요.

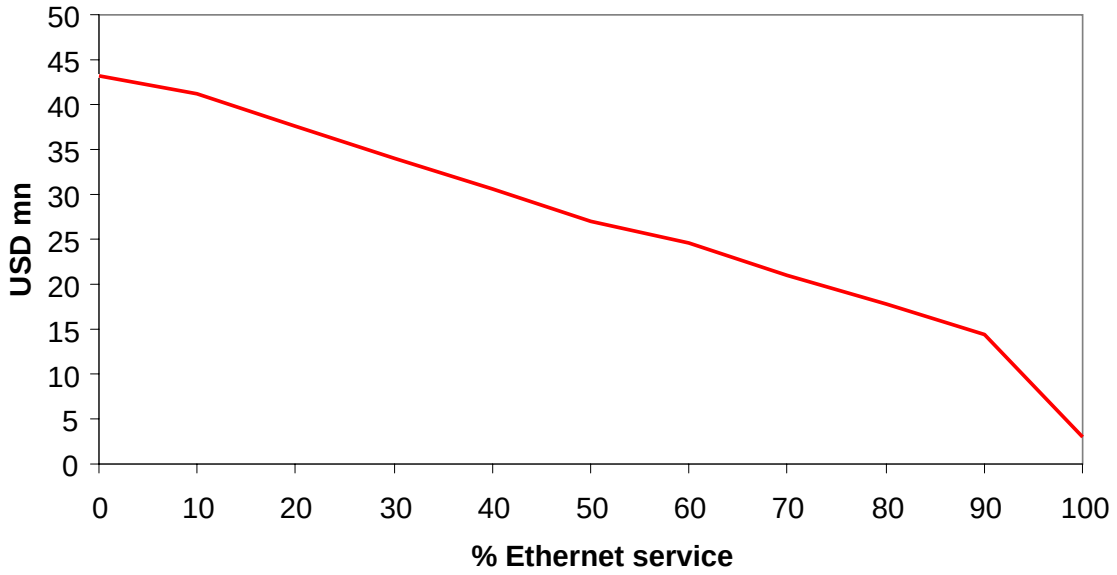
- **Investigation of the IP backbone of a European incumbent operator:**
  - Transit traffic (전체 망 traffic의 70-80%)은 transport layer에서 router를 bypassing시키면 CAPEX를 65-75 % 감소시킬 수 있다.
  - Backbone에서 필요한 router의 최대 용량이 40-50% 감소될 수 있다.
- **ROADM: Router 아래에 a flexible layer 둠 (즉, 라우터는 transit traffic은 routing하지 않을 수 있음)**
  - OPEX/CAPEX savings are also claimed
  - Disadvantage:
    - # of available ports의 한계
    - Wavelength blockings
    - Optical power adjustment issues when wavelengths are reconfigured.

Business Case Study: CAPEX savings by multilayer L2/L3 edge/core compared to IP/MPLS edge/core

- German reference network

- 17 nodes, 26 links
- 2005's traffic pattern

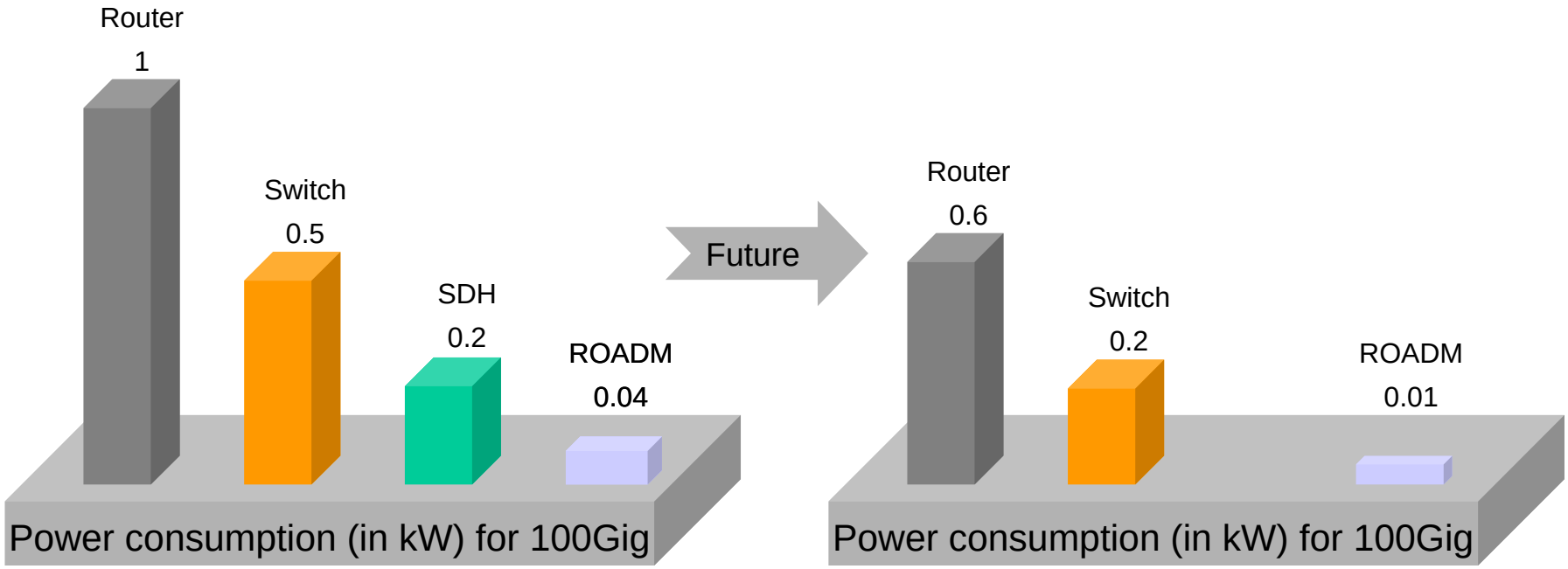
- CAPEX for L2/L3 core



Significant CAPEX savings can be obtained if the Ethernet services are 40% or more of the total packet traffic

Source: Nokia Siemens

Power Consumption is OPEX that we can control



Source: internal analysis

Terabit core router

- Power consumption of 13kW
- 723 kg chassis fully configured

Packet transport layer as a networking layer below L3 router network

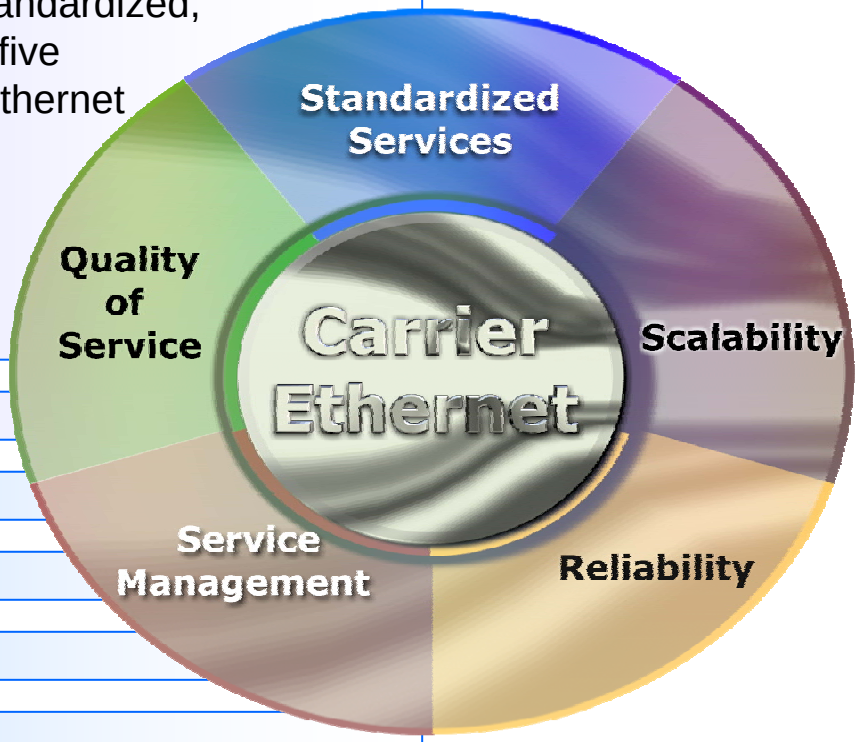
- **Packet transport layer**를 두면,
  - TDM transport layer와 같은 전송 조건 만족할 수 있음
  - Packet flow를 TDM으로 보내는 adaptation이 불필요
  - No granularity issues between layers와 statistical multiplexing 효과
  - Lower cost of L2 switching compared to L3 routing.
- 그리하여, **Carrier grade L2 packet transport layer** 의 출현
  - Transport Ethernet and T-MPLS
  - Control plane: GMPLS for persistent control in multilayer networks.
- **Packet transport layer network**의 실현에는 **OAM/P**이 필수**!**

Carrier Ethernet Service

Carrier Ethernet as Defined in MEF

Carrier Ethernet

- Carrier Ethernet is a ubiquitous, standardized, carrier-class **SERVICE** defined by five attributes that distinguish Carrier Ethernet from familiar LAN based Ethernet
- It brings the compelling business benefit of the Ethernet cost model to achieve significant savings

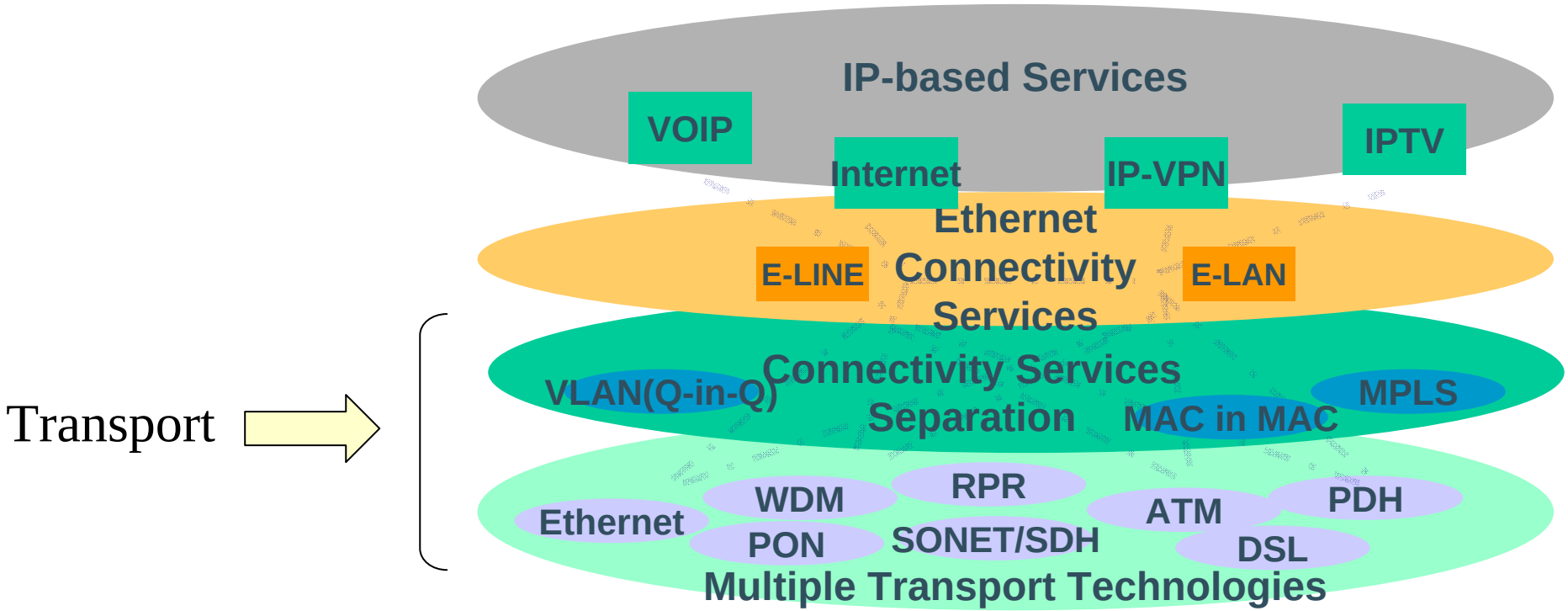


Carrier Ethernet Attributes

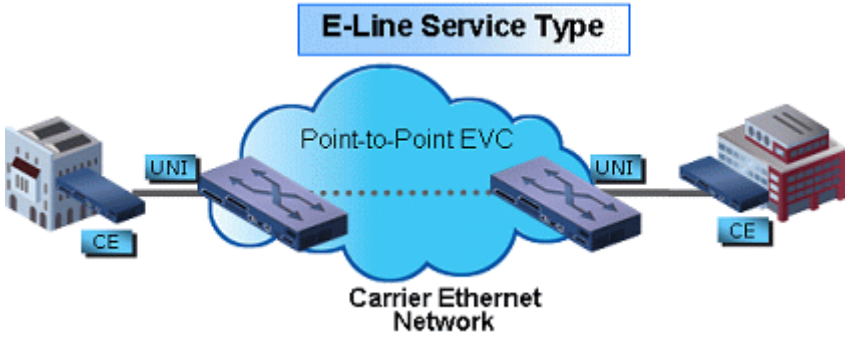
- **Standardized Services**
- **Scalability**
- **Service Management**
- **Reliability**
- **Quality of Service**

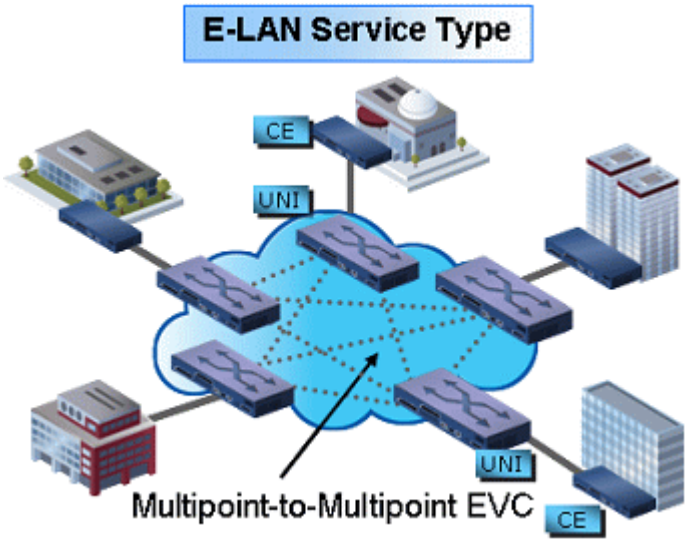
Source: MEF

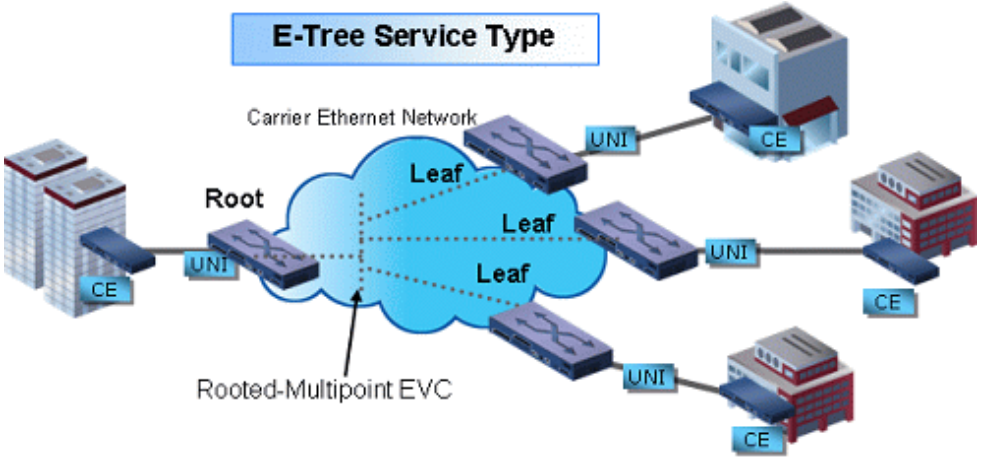
Ethernet Service over Any Infrastructure



E-Line Service, E-LAN Service, & E-Tree Service







Ethernet OAM

OAM PDUs

Function	Ethernet Y.1731	T-MPLS Y.1373	MPLS Y.1711
Continuity Check	CCM	CV	CV, FFD
Loopback	LBM-LBR	LBM-LBR	LBreq-LBrep
Link Trace	LTM-LTR	-	-
Alarm Indication Signal	AIS	FDI	FDI
Remote Defect Indication	CCM	CV	BDI
Lock Signal	LCK	LCK	-
Test Signal	TST	TST	-
Automatic Protection Switching	APS	APS	-
Maintenance Communication Channel	MCC	MCC	-
Signaling Communication Channel	-	SCC	-
Experimental OAM	EXM-EXR	EXM-EXR	-
Vendor Specific OAM	VSM-VSR	VSM-VSR	-
Synchronization Status Message	-	SSM	-
Client Signal Fail	-	CSF	-
Frame Loss Measurement: Dual-ended	CCM	CV	-
Frame Loss Measurement: Single-ended	LMM-LMR	LMM-LMR	-
Frame Delay Measurement: One-way	1DM	1DM	-
Frame Delay Measurement: Two-way	DMM-DMR	DMM-DMR	-

Ethernet OAM의 필요성

- **Ethernet as Metropolitan and Wide-Area Networking technology**
  - Requires carrier grade OAM
- **Layer 2 Ethernet service**에 대한 관리와 **troubleshooting**을 위해 **IP infrastructure**를 **overlay**하는 부담을 없애자.
- **Need to monitor end-to-end Ethernet services across diverse networks**
  - Underlying technologies: native Ethernet, Ethernet over SONET, Ethernet over ATM, Ethernet of MPLS, Ethernet over RPR, etc.
- **Link OAM** 과는 상호 보완 관계
  - IEEE 802.3.ah (single Ethernet link OAM)
  - IEEE 802.17 (single RPR Link OAM)
  - ITU (SONET OAM)
- **Per-customer or per-service granularity**를 가지는 관리
- **Multi-point Ethernet services** 의 출현

ITU-T SG13, IEEE 802.1ag, and MEF have all been driving towards consistent recommendations and standards for Ethernet OAM.

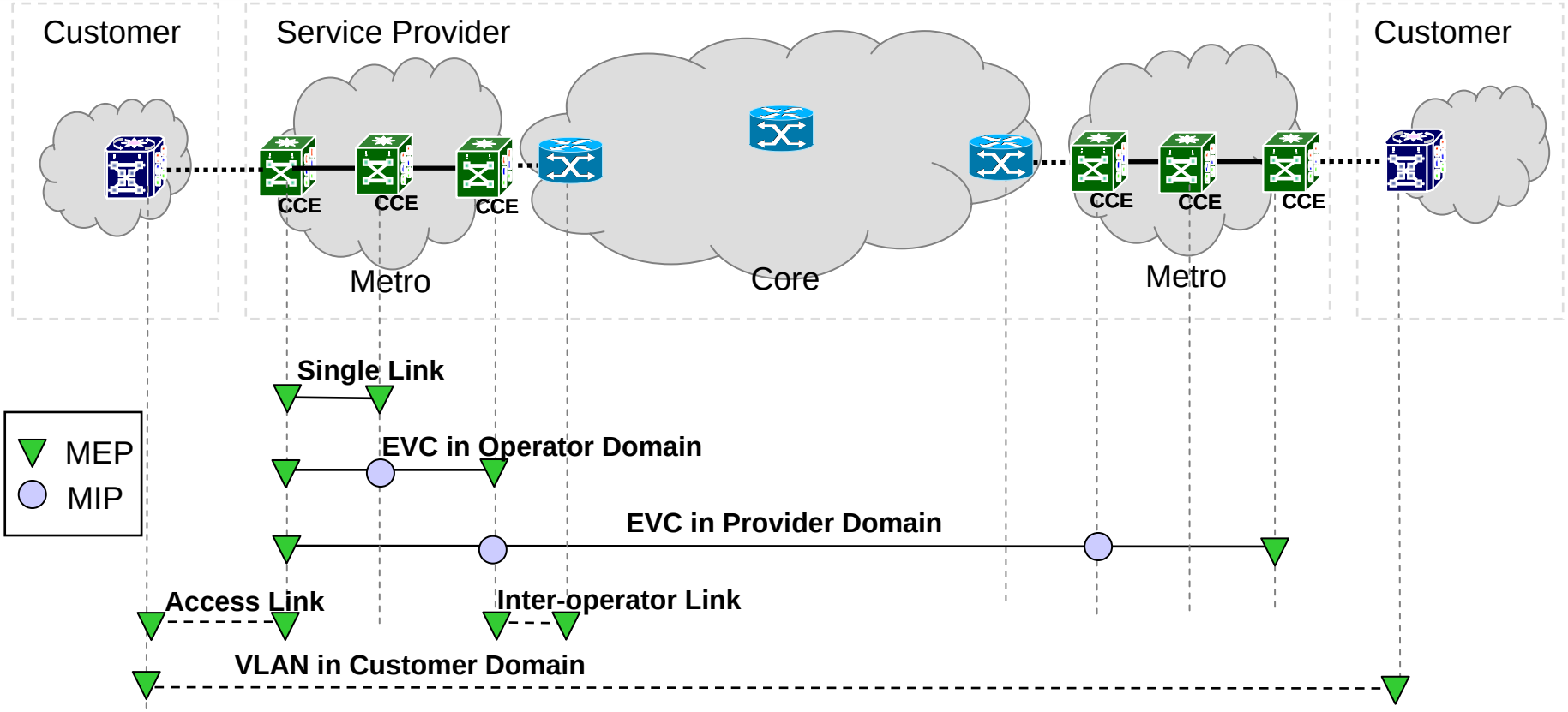
Ethernet OAM 관련 표준 문서

- ITU-T Rec. Y.1730 - Requirements for OAM functions in Ethernet-based networks and Ethernet services
- ITU-T Rec. Y.1731 - OAM Functions and Mechanisms for Ethernet based networks
- ITU-T Rec. G.8031 - Ethernet linear protection switching
- ITU-T Rec. G.8032 – Ethernet ring protection switching
- ITU-T Rec. G.8010 - Architecture of Ethernet layer networks
- ITU-T Rec. G.8021 - Characteristics of Ethernet transport network equipment functional blocks
- IEEE Draft Std. 802.1ag – Connectivity Fault Management
- MEF

Basic Terms

- **ME (Maintenance Entity)**
  - An entity that requires management
  - Relationship (logical connection) between two MEPs
- **MEG (ME Group)**
  - Point-to-point ETH connection: a MEG contains one ME
  - Multipoint ETH connectivity: a MEG contains n*(n-1)/2 MEs
- **MEP (MEG End Point)**
  - Initiates and terminates OAM frames
- **MIP (MEG Intermediate Point)**
  - Passively receives some OAM frames and responds back to the originating MEP.

Carrier Class Ethernet OAM & Protection Domain

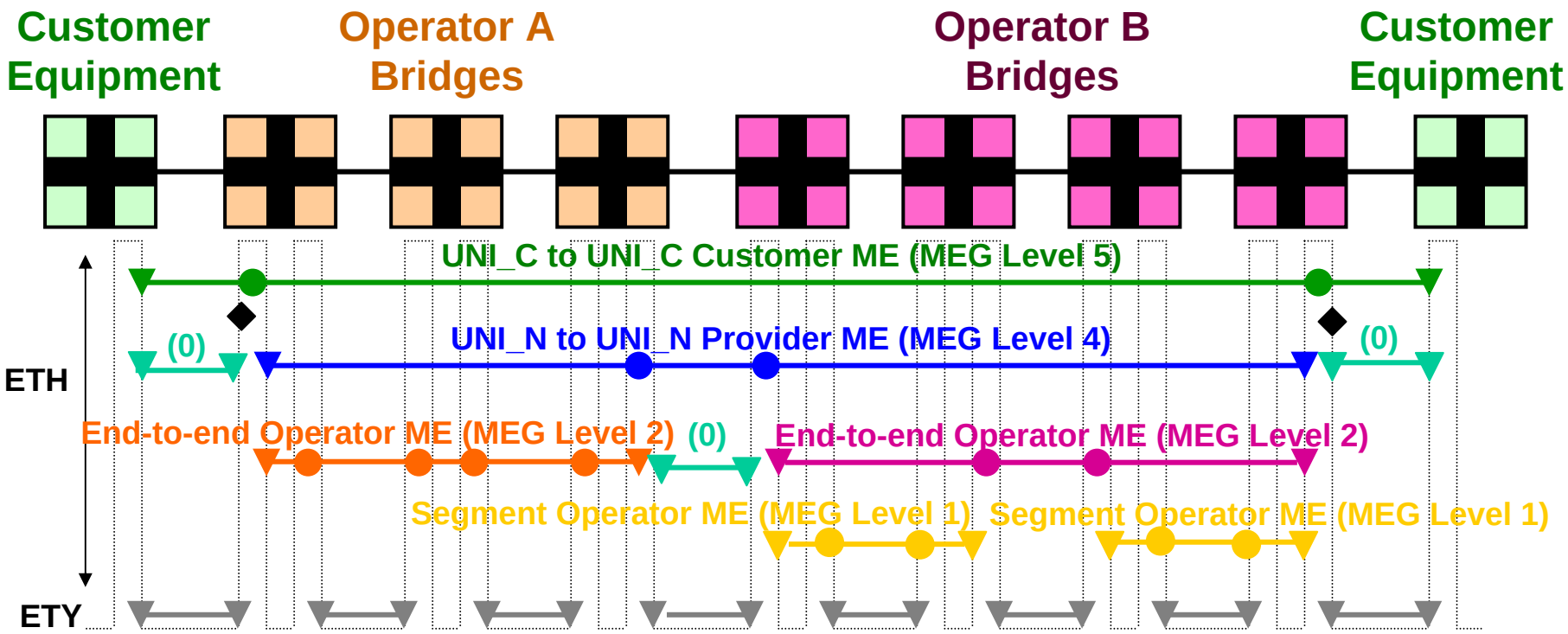


- **Single link connection & network connection in EVC level**
- **Multi-level OAM & protection with a single mechanism**
  - MEPs prevent leaking of OAM frames between domains.
  - MEPs & MIPs dependent on Business Models & Deployment Scenarios

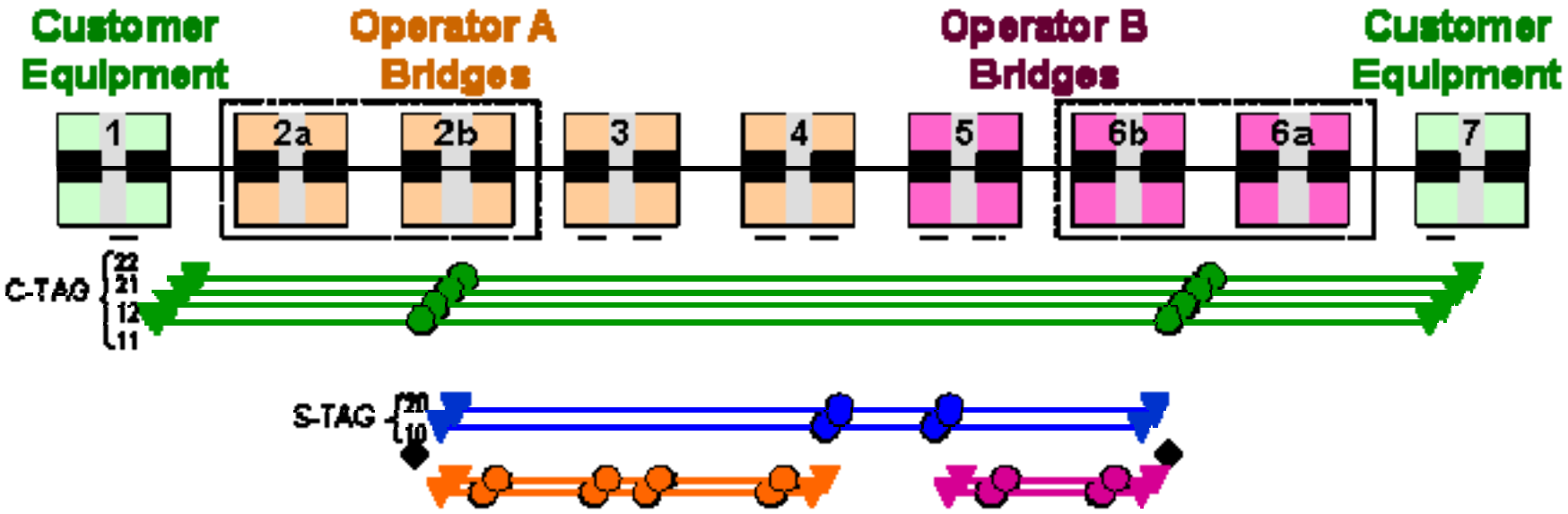
Default Assignments of MEG Level

- **Eight MEG Levels are available.**
- **Level 0 for Provider-Provider, Customer-Provider, Operator-Operator**
- **Two cases based upon ETH layer encapsulation**
  - Shared MEG Levels
    - Customer, Provider, and Operator share the MEG Levels.
    - Customer role = Level 7,6,5;
    - Provider role = Level 4,3;
    - Operator role = Level 2,1
  - Independent MEG Levels
    - Example: Provider bridge (C-Tag, S-Tag)
    - Customer and Provider do not share the MEG Levels.
    - Provider and Operator share the MEG Levels.

Ethernet Network Scenarios – Shared MEG Levels Example



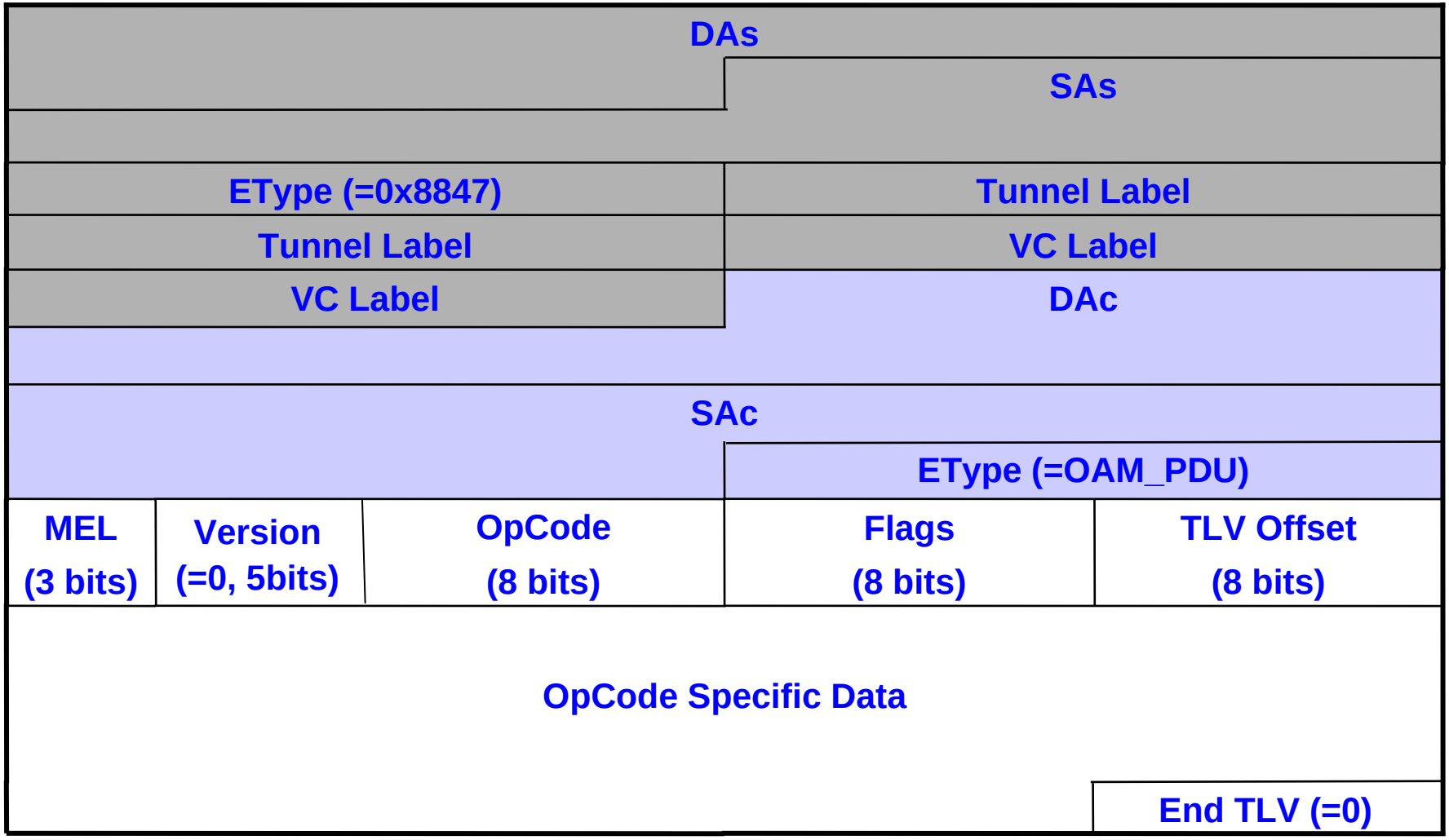
Ethernet Network Scenarios – Independent MEG Levels Example



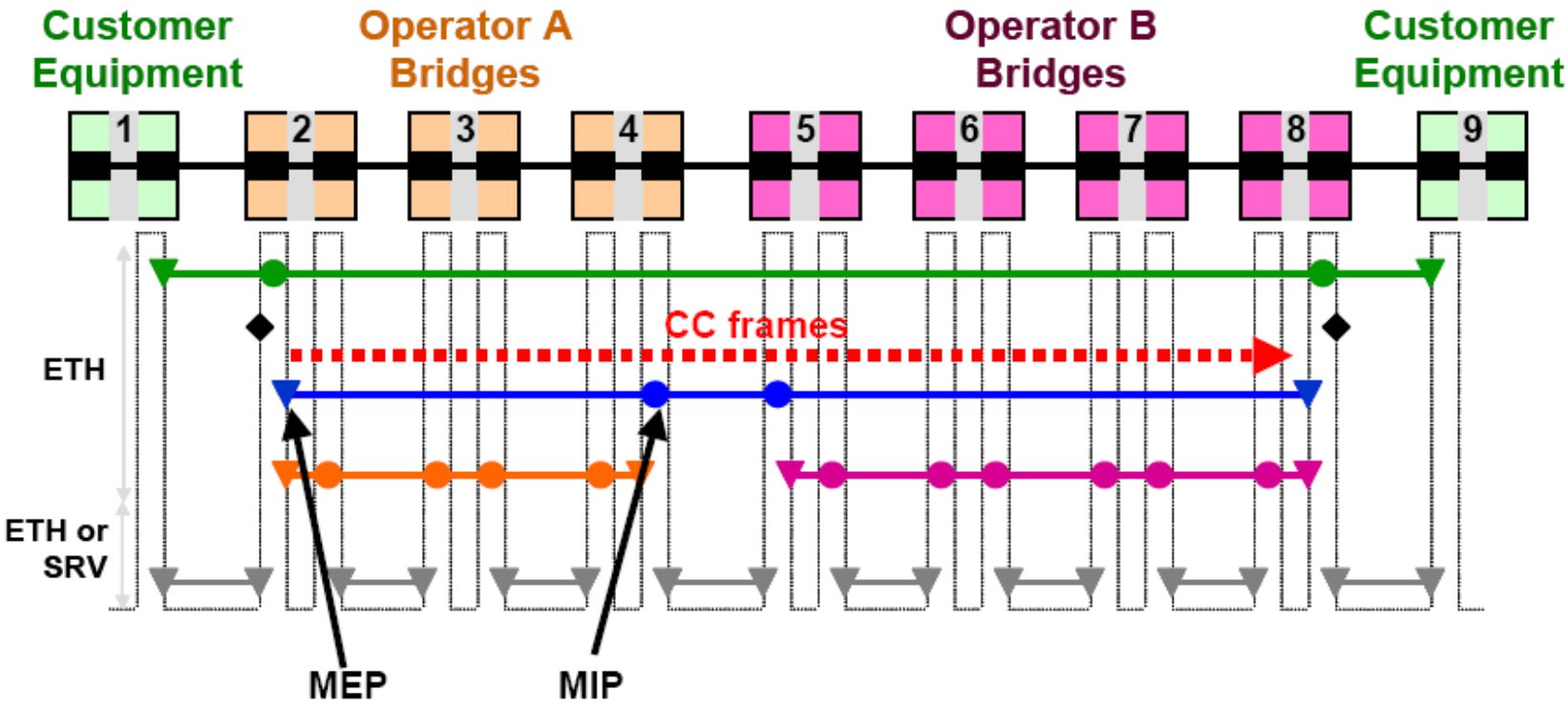
Ethernet OAM Functions

Function	OAM PDU	ITU-T	IEEE
Continuity Check	CCM	Yes	Yes
Loopback	LBM-LBR	Yes	Yes
Link Trace	LTM-LTR	Yes	Yes
Alarm Indication Signal	AIS	Yes	No
Remote Defect Indication	CCM	Yes	Yes
Lock Signal	LCK	Yes	No
Test Signal	TST	Yes	No
Automatic Protection Switching	APS	Yes	No
Maintenance Communication Channel	MCC	Yes	No
Experimental OAM	EXM-EXR	Yes	No
Vendor Specific OAM	VSM-VSR	Yes	No
Frame Loss Measurement: Dual-ended	CCM	Yes	No
Frame Loss Measurement: Single-ended	LMM-LMR	Yes	No
Frame Delay Measurement: One-way	1DM	Yes	No
Frame Delay Measurement: Two-way	DMM-DMR	Yes	No

Common OAM Header Format



Ethernet Continuity Check (ETH-CC) [1/2]



- CC defined per EVC for one-way connectivity monitoring
- Proactive OAM

Ethernet Continuity Check (ETH-CC) [2/2]

- **7 choices for transmission period:**
  - 3.33 msec (protection switching),
  - 10 msec,
  - 100 msec (error performance monitoring),
  - 1 sec (fault management),
  - 10 sec, 1 min, 10 min.
- **Detects the following defects:**
  - Loss of Continuity
  - Unexpected MEG level, Mismerge, Unexpected MEP
  - Unexpected Period
- ***Loss of Continuity* is declared if no ETH-CC frame has been received for 3.5 transmission periods.**
- **Loss of Continuity can signal APS to initiate protection.**

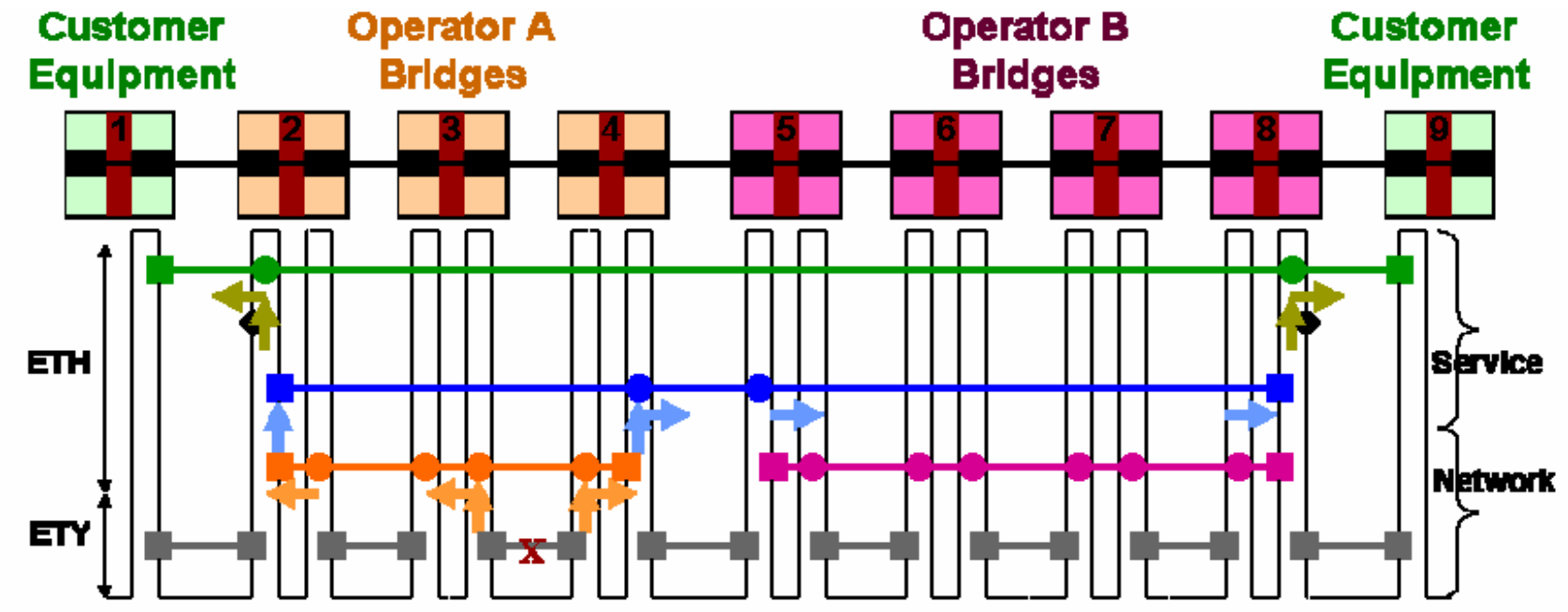
Ethernet Loopback (ETH-LB)

- **On-demand OAM**
- **Unicast ETH-LB**
  - Bidirectional connectivity of a MEP with a MIP or a peer MEP.
  - Diagnostics test between a pair of MEPs: BW throughput, bit errors.
- **Multicast ETH-LB**
  - Bidirectional connectivity of a MEP with its peer MEPs.
- **LBM frame (Unicast or Multicast Class 1 DA) & LBR frame (Unicast DA)**
- **Expects LBR in 5 seconds**
- **Assumption: The MAC address of the MIP/MEP to ping is known.**
  - Link Trace can be one way to discover the MAC address.

Ethernet Link Trace (ETH-LT)

- **Purpose**
  - To trace the path to another MEP or MIP in the same MEG.
  - Fault (e.g. link failure, device failure, loop) localization
- **All intermediate MIPs do the followings:**
  - respond back to the originating MEP,
  - decrement TTL value by one, and forward until the Target MEP/MIP is reached.
  - Only the MIPs that lie between the originating MEP and the Target must response.
- **On-demand OAM**
- **LTM frame (Multicast Class 2 DA) & LTR frame (Unicast DA)**

Ethernet Alarm Indication Signal (ETH-AIS)[1/2]



- Used to suppress alarms at the client layer following detection of defect conditions at the server layer.
- Upon detecting a defect condition, the MEP start transmitting periodic AIS frames at a configured client MEG level.

Ethernet Alarm Indication Signal (ETH-AIS)[2/2]

- **Period = 1 sec or 1 min (The client layer may consist of multiple MEGs: up to 4094, as a MEP is per VLAN).**
- **Not for the spanning tree protocol environments.**
- **Conditions for AIS**
  - Signal fail conditions (including LoC, Unexpected MEG Level, Mismerge, Unexpected MEP) when ETH-CC is enabled.
  - AIS condition or LCK condition when ETH-CC is disabled.
- **AIS frame (Multicast Class 1 or Unicast DA)**

Ethernet Remote Defect Indication (ETH-RDI)

- **To communicate to peer MEPs that a defect condition occurred.**
- **ETH-CC 기능이 enabled된 경우에만 사용됨**
- **1 bit notification**
- **CCM frame을 이용**
- **Applications:**
  - Single-ended fault management
  - Contribution to far-end performance monitoring

Ethernet Locked Signal (ETH-LCK)

- Notify intentional administrative or diagnostic actions at MEP to its immediate client MEPs.
- Ex) When a MEP sends LBM frames, the MEP also generates LCK frames at the client MEG Level in opposite direction. The receiving MEP also generate LCK.
- Period: 1 sec or 1 min
- LCK frame (Multicast Class 1 DA or Unicast DA)

Ethernet Test (ETH-TST)

- One-way on-demand in-service or out-of-service diagnostics test: BW throughput, frame loss, bit errors, etc.
- For out-out-service test, a MEP transmits LCK frames.
- MIP is transparent to ETH-TST.
- TST frame (Unicast DA or Multicast Class 1 DA)

Ethernet Automatic Protection Switching (ETH-APS)

- To control protection switching operations
- APS frame (Multicast Class 1 DA or Unicast DA)
- Will be explained later

Ethernet Maintenance Communication Channel (ETH-MCC)

- To perform remote maintenance to peer MEP.
- ETH-MCC provides a maintenance communication channel between a pair of MEPs.
- MCC frame for both request and reply (Unicast DA or Multicast Class 1 DA for a point-to-point VLAN)

Ethernet Experimental OAM (ETH-EXP)

- **Confined within an administrative domain on a temporary basis.**

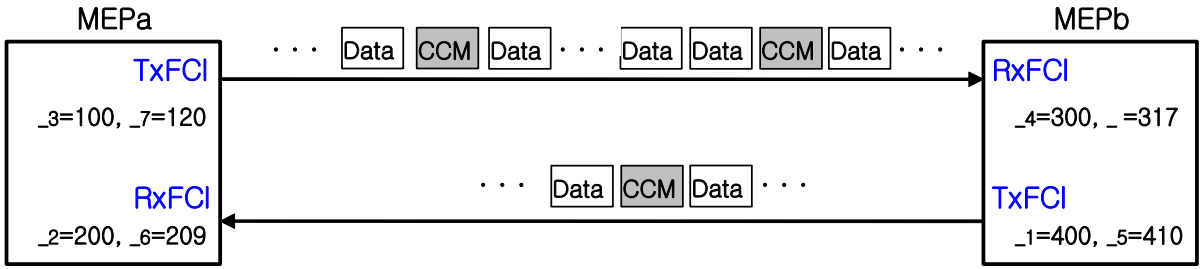
Ethernet Vender Specific OAM (ETH-VSP)

- **Applied to the equipments from a specific vendor only.**

Frame Loss Measurement (ETH-LM)

- **Two local counters for each peer MEP:**
  - TxFCl: Counter for in-profile data frames transmitted towards peer MEP
  - RxFCl: Counter for data frames received from peer MEP
- **Dual-ended ETH-LM**
  - Proactive OAM
  - CCM frame
  - TxFCf: Value of TxFCl at the time of CCM frame transmission
  - RxFCb: Value of RxFCl at the time of the last CCM frame reception
  - TxFCb: Value of TxFCf in the last received CCM frame
  - Frame Loss_far = |TxFCb[tc] – TxFCb[tp]| – |RxFCb[tc] – RxFCb[tp]|
  - Frame Loss_near = |TxFCf[tc] – TxFCf[tp]| – |RxFCl[tc] – RxFCl[tp]|
- **Single-ended ETH-LM**
  - On-demand OAM
  - LMM frame (Unicast DA or Multicast Class 1 DA for multipoint measurements) & LMR frame (Unicast DA)

Frame Loss Calculation – Example



MEPa sends at time 3:

TxFCf = $TxFCl_3$ = 100
RxFCb = $RxFCl_2$ = 200
TxFCb = $TxFCf_1$ = 400
(RxFCl = $RxFCl_4$ = 300)

MEPb sends at time 5:

TxFCf = $TxFCl_5$ = 410
RxFCb = $RxFCl_4$ = 300
TxFCb = $TxFCf_3$ = 100
(RxFCl = $RxFCl_6$ = 209)

MEPa sends at time 7:

TxFCf = $TxFCl_7$ = 120
RxFCb = $RxFCl_6$ = 209
TxFCb = $TxFCf_5$ = 410
(RxFCl = $RxFCl_8$ = 317)

MEPb calculates:

Frame Loss_far = |410−400| − |209−200| = 1
Frame Loss_near = |120−100| − |317−300| = 3

Frame Delay Measurement (ETH-DM)

- **On-demand OAM for measuring Frame Delay (FD) and Frame Delay Variation (FDV)**
- **One-way ETH-DM**
  - Clock synchronization required, otherwise FDV can be performed.
  - FD = RxTimef – TxTimeStampf
  - 1DM frame (Unicast DA or Multicast Class 1 DA for multipoint measurement)
- **Two-way ETH-DM**
  - DMM frame (Unicast DA or Multicast Class 1 DA for multipoint measurement) & DMR frame (Unicast DA)
  - One timestamp in DMM & DMR
    - FD = RxTimeb – TxTimeStampf
  - Two additional timestamps in DMR
    - FD = (RxTimeb – TxTimeStampf) – (TxTimeStampb – RxTimeStampf)

Issues for Next Version of Y.1731

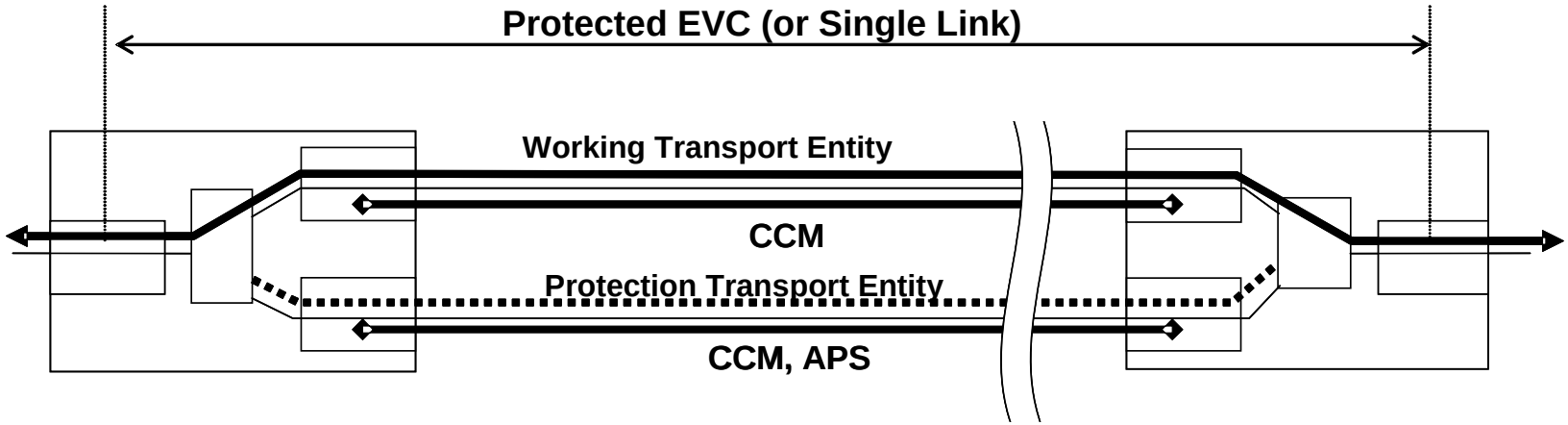
- **Performance monitoring for multipoint connectivity**

Ethernet Linear Protection

Protection Types & Protection Switching Architecture

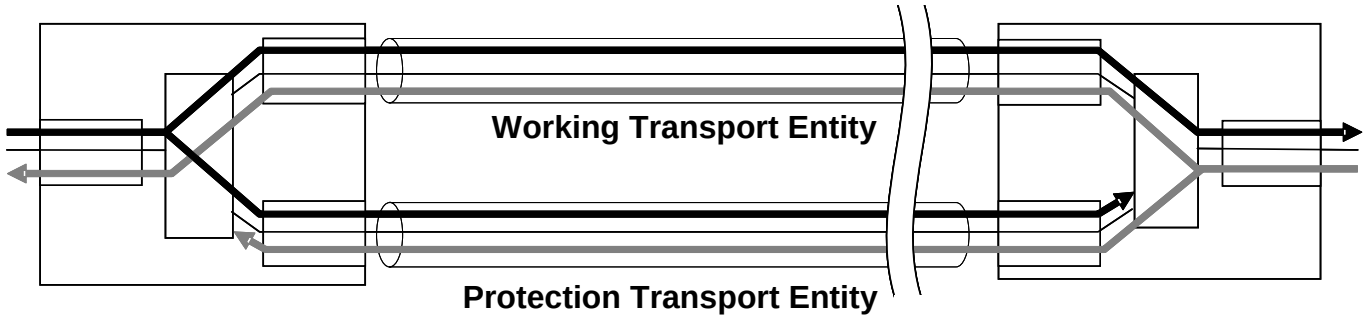
- 1+1 bidirectional protection
- 1+1 unidirectional protection
- 1:1 bidirectional protection

Switching Architecture

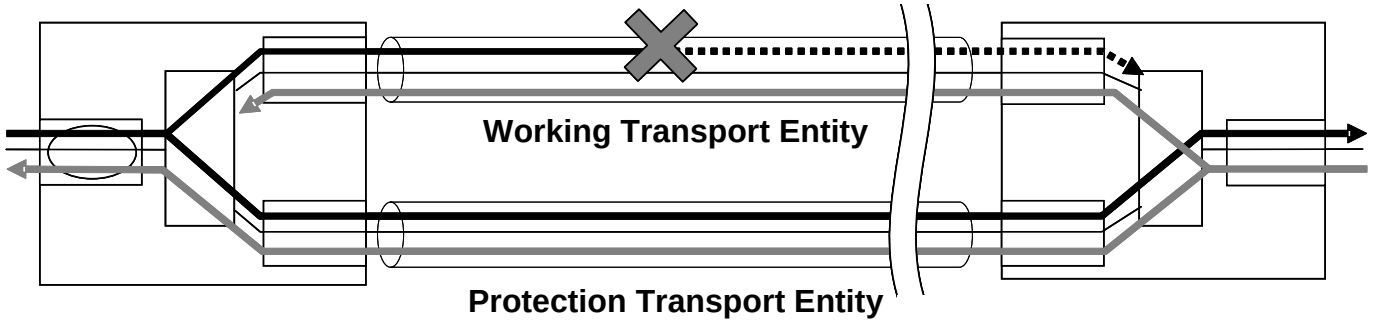


1+1 Bidirectional Protection Switching Architecture

No defect

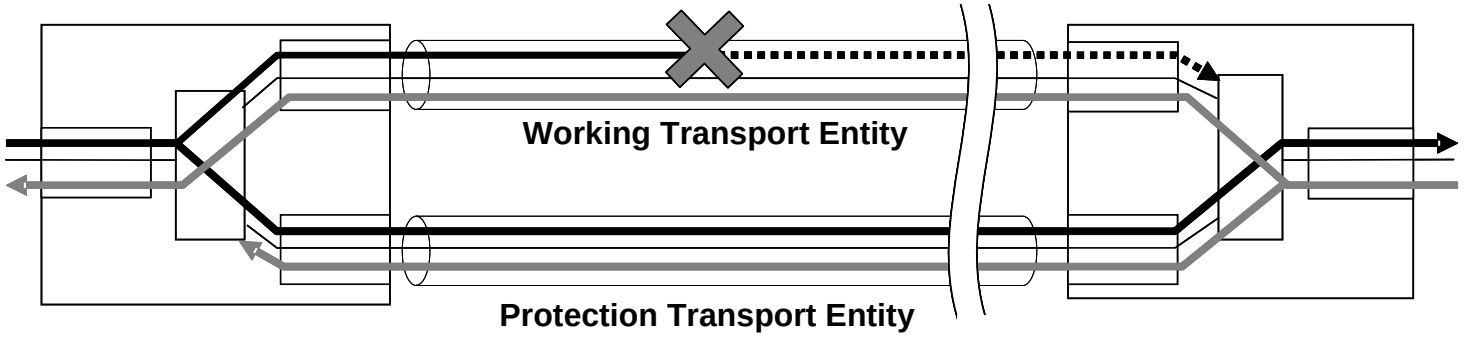


Signal Fail on Working (East bound)

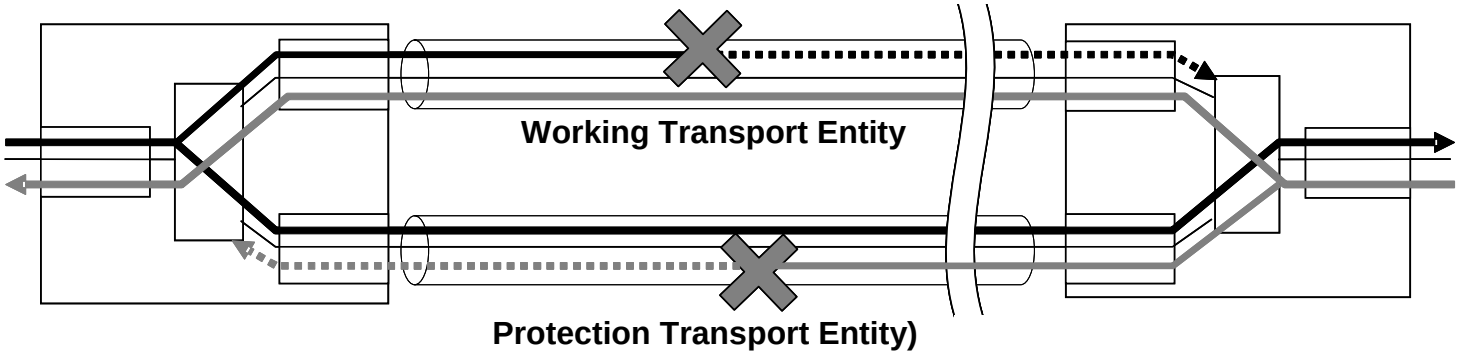


1+1 Unidirectional Protection Switching Architecture

Signal Fail on Working (East bound)

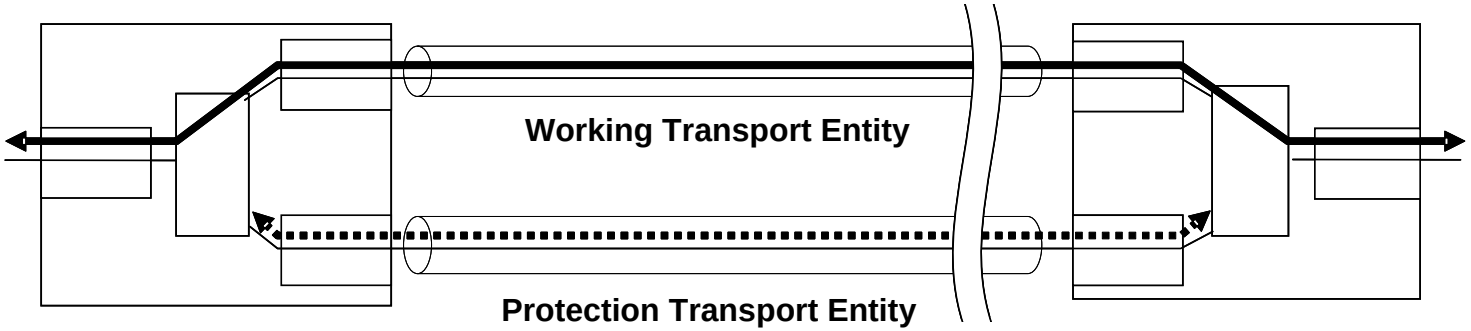


Signal Fail on Working (West bound)

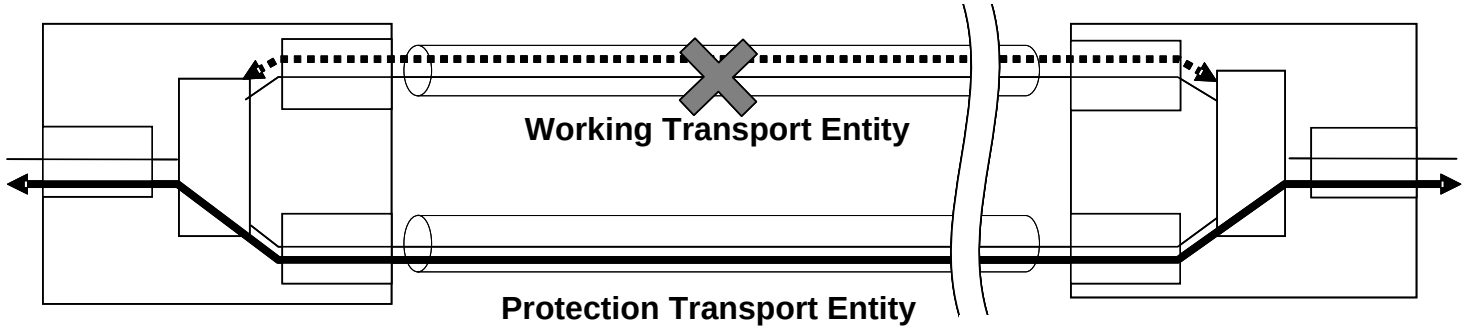


1:1 Bidirectional Protection Switching Architecture

No defect



Signal Fail on Working



Comparison

	1+1 Unidirectional	1+1 Bidirectional	1:1 Bidirectional
Pro	■Fast recovery ■No APS needed, nor return path ■Can protect two failures in opposite directions on different entities		■Support extra traffic ■Protection capacity can be shared by best effort traffic in normal condition
Con	■Source node should support multicast ■Sink node should delete packet from protection transport entity	■Source node should support multicast ■Sink node delete packet from protection transport entity ■Return path and APS needed ■Protocol overhead	■Return path and APS needed ■Protocol overhead ■Slower than 1+1

■ 1:1 unidirectional implementation gets too complicated without any significant benefits.

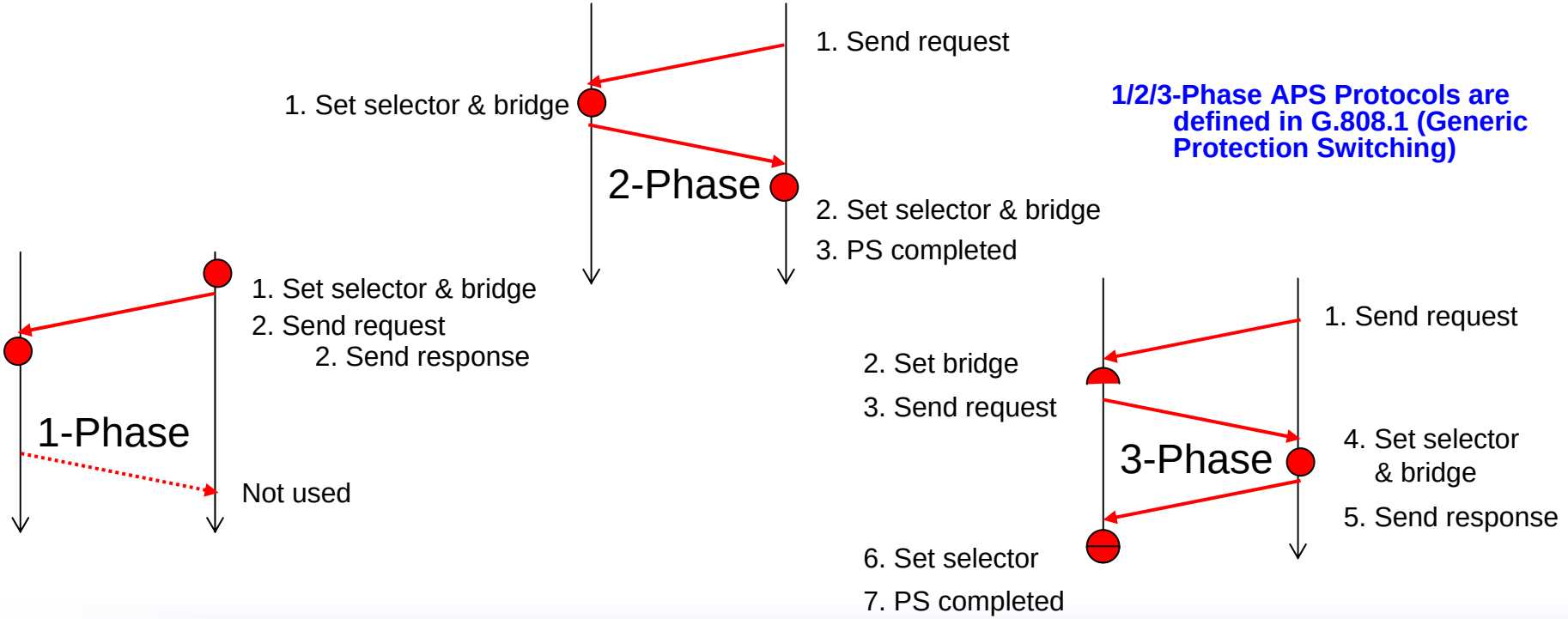
Protection Configuration for Coordination

- **No APS Channel needed or APS Channel needed**
- **1+1 or 1:1**
- **Unidirectional or Bidirectional**
- **Non-revertive or Revertive**
  - Second glitch
  - More optimized path for working transport entity

1-Phase APS Protocol

Simplest APS protocol

- Faster switching time than 2-Phase/3-Phase APS
- But unnecessary temporal interruption may happen.
  - 2-Phase and 3-Phase APS can avoid this interruption.
  - Duration of a temporal interruption is at most RTT which is shorter than the switching time for SF in 2-Phase APS.

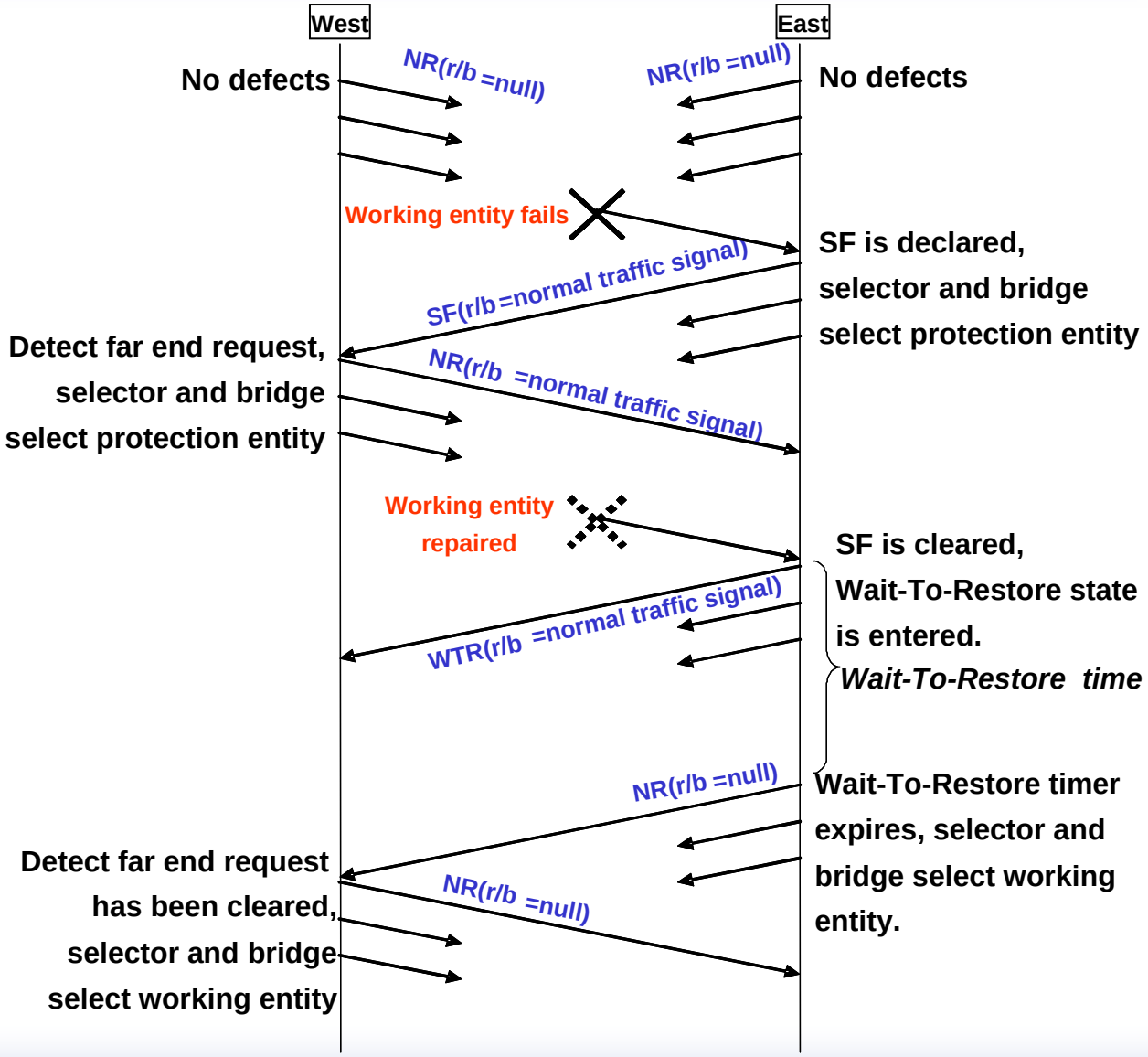


1/2/3-Phase APS Protocols are defined in G.808.1 (Generic Protection Switching)

Operation Example – Protection part

1:1 bidirectional protection in revertive mode

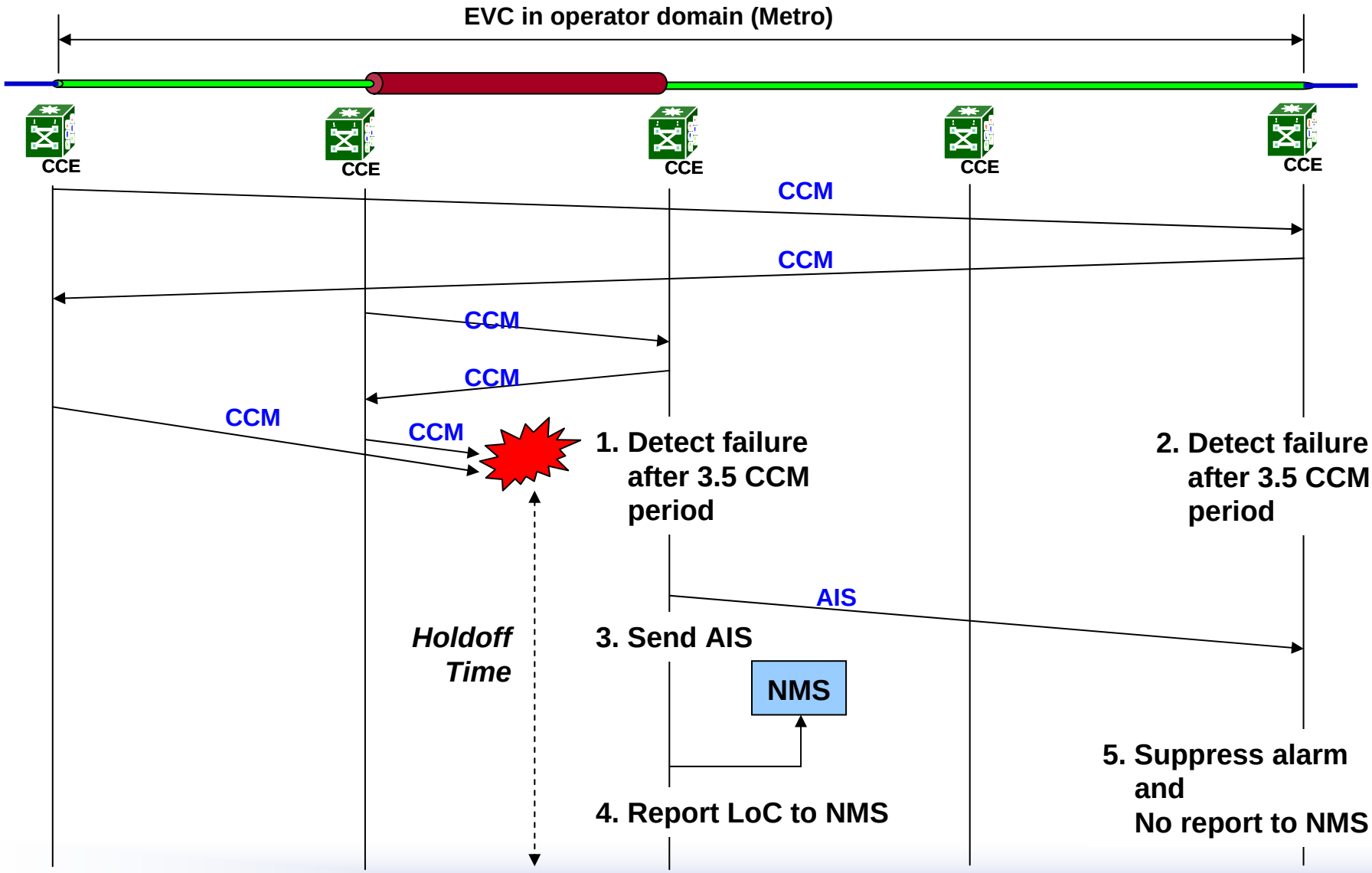
1. **The protected domain is operating without any defect.**
2. **Signal Fail occurs in the west to east direction.**
3. **The defect is repaired.**



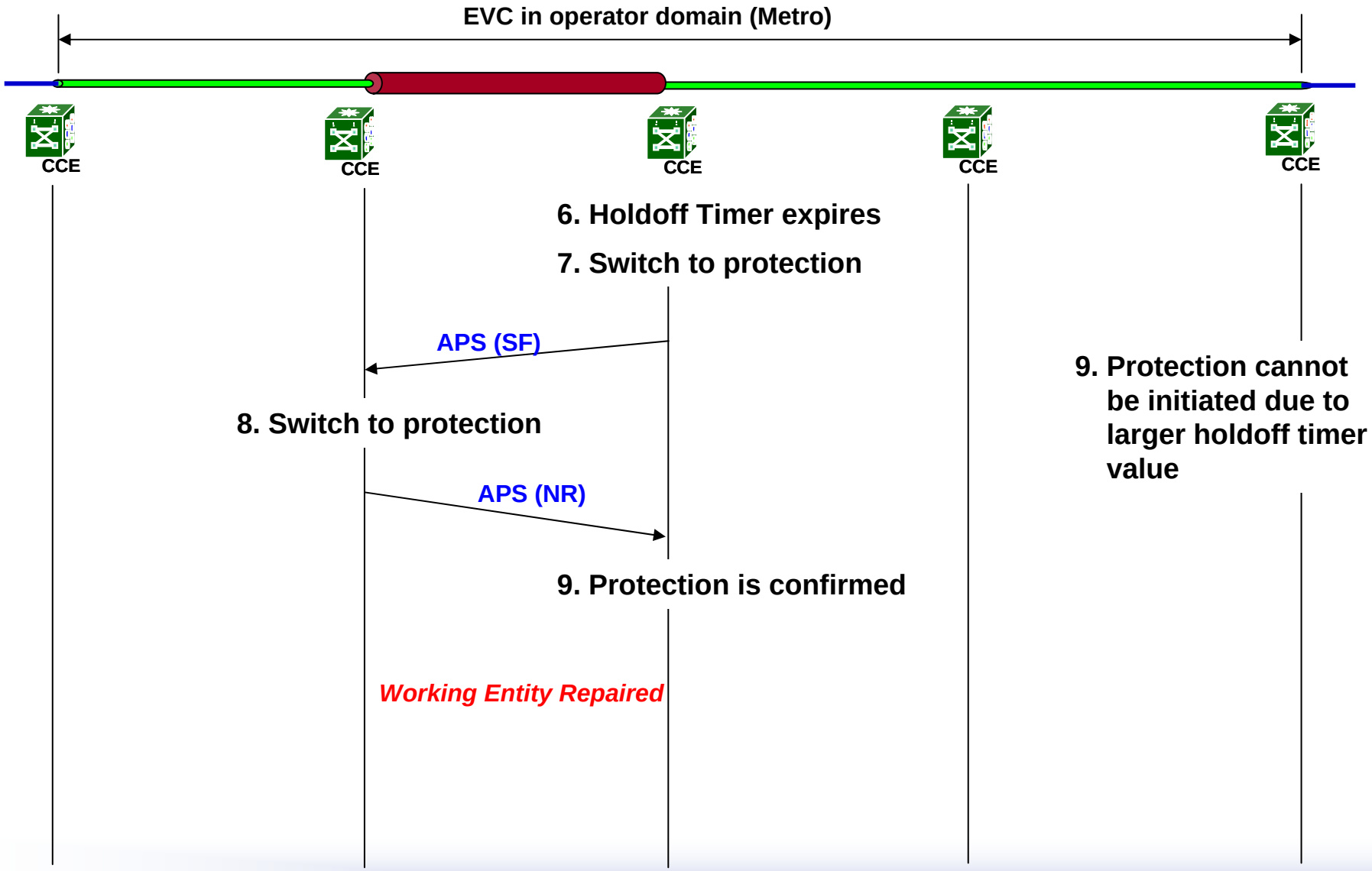
Multi-Level Protection

- **Client layer protection is required when server layer protection is not activated.**
- **Signal Fail on each layer protection is monitored by CCM mechanism.**
- **Server layer node transmits AIS to client layer nodes when Loss of Continuity is detected.**
- **In order to prevent duplicated protection, Client layer protection should have longer hold-off timer than server's.**
  - E.g., Hold off time for Single Link=0msec, EVC in operator domain=100msec, EVC in service provider domain=200msec

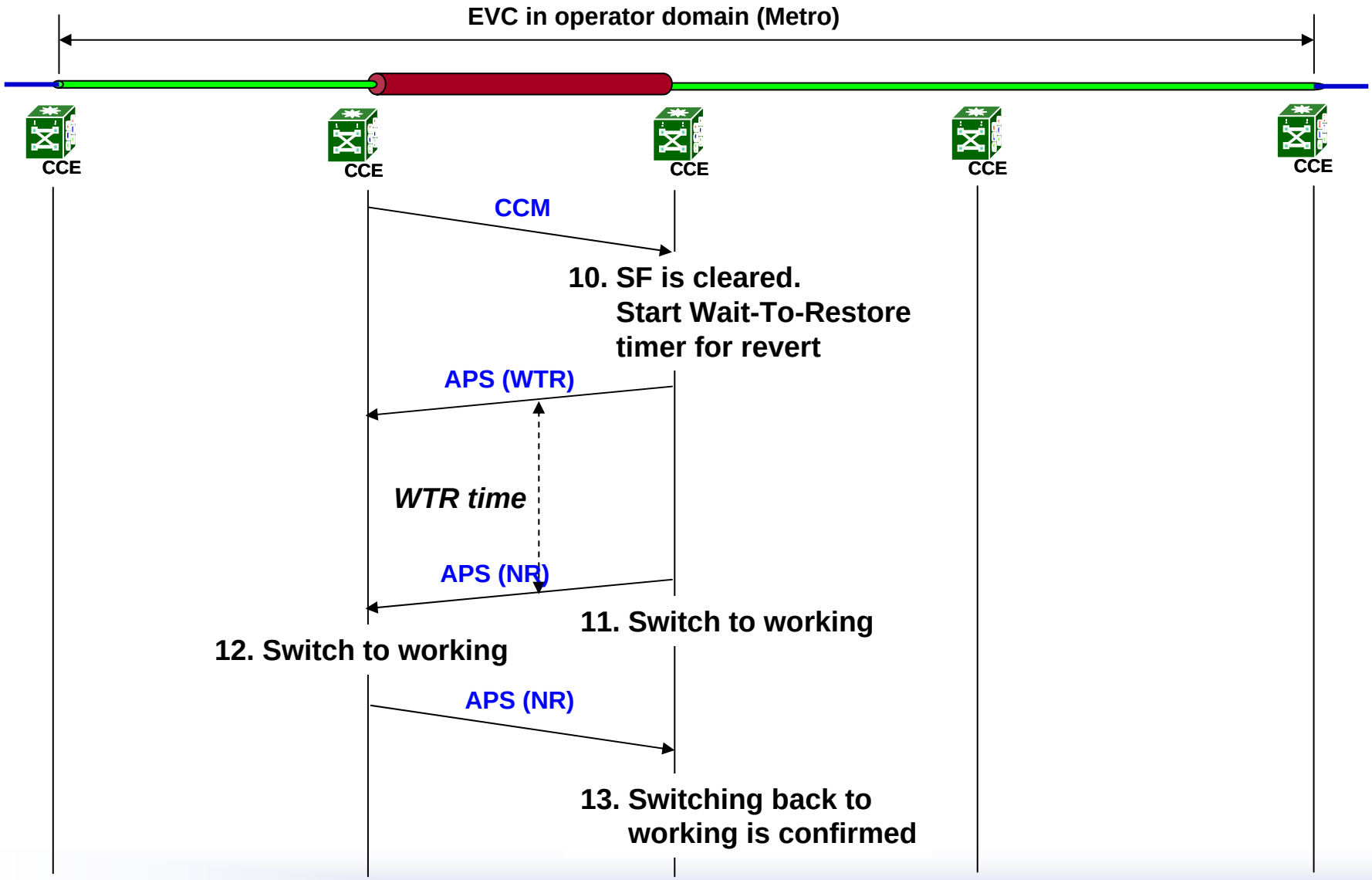
Operation Example – Whole picture (1/3)



Operation Example – Whole picture (2/3)



Operation Example – Whole picture (3/3)



Conclusions

- Packet Transport Layer Network
- Carrier Ethernet Service
- Ethernet OAM as an end-to-end Service OAM
- Ethernet OAM includes additional OAM capabilities not in original Ethernet specs
- Ethernet OAM is a MUST for providing “carrier-class” Ethernet services
- Ethernet Linear Protection
- The same functions and mechanisms as Ethernet OAM/P for other packet transport layer networks.