Carrier Ethernet

Student Questions

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These slides and audio/video recordings of this class lecture are at:

http://www.cse.wustl.edu/~jain/cse570-21/

Overview

1. Enterprise vs Carrier Ethernet
2. UNI vs Peer-to-Peer Signaling
3. Metro Ethernet
4. Ethernet Provider Bridge (PB)
5. Provider Backbone Network (PBB)
6. Connection Oriented Ethernet

Note: Although these technologies were originally developed for carriers, they are now used inside multi-tenant data centers (clouds)

Student Questions

Enterprise vs. Carrier Ethernet

Enterprise	Carrier
❑ Distance: up to 2km	❑ Up to 100 km
❑ Scale:	
➢ Few K MAC addresses	❑ Millions of MAC Addresses
➢ 4096 VLANs	❑ Millions of VLANs Q-in-Q
❑ Protection: Rapid Spanning tree	❑ Shortest Path Routing
❑ Path determined by spanning tree	❑ Traffic engineered path
❑ Simple service	❑ SLA
❑ Priority ⇒ Aggregate QoS	❑ Need per-flow QoS
❑ No performance/Error monitoring (OAM)	❑ Need performance/BER

Student Questions

❑ In the video you noted that STP should be replaced by RSTP.

RSTP=Rapid Spanning Tree protocol. Converges an order of magnitude faster (after a failure). Backward compatible.

❑ Could we say AT&T also is a enterprise? What I mean is that AT&T is a carrier but also is a enterprise.

AT&T's needs as a carrier are very different from their needs as an enterprise.
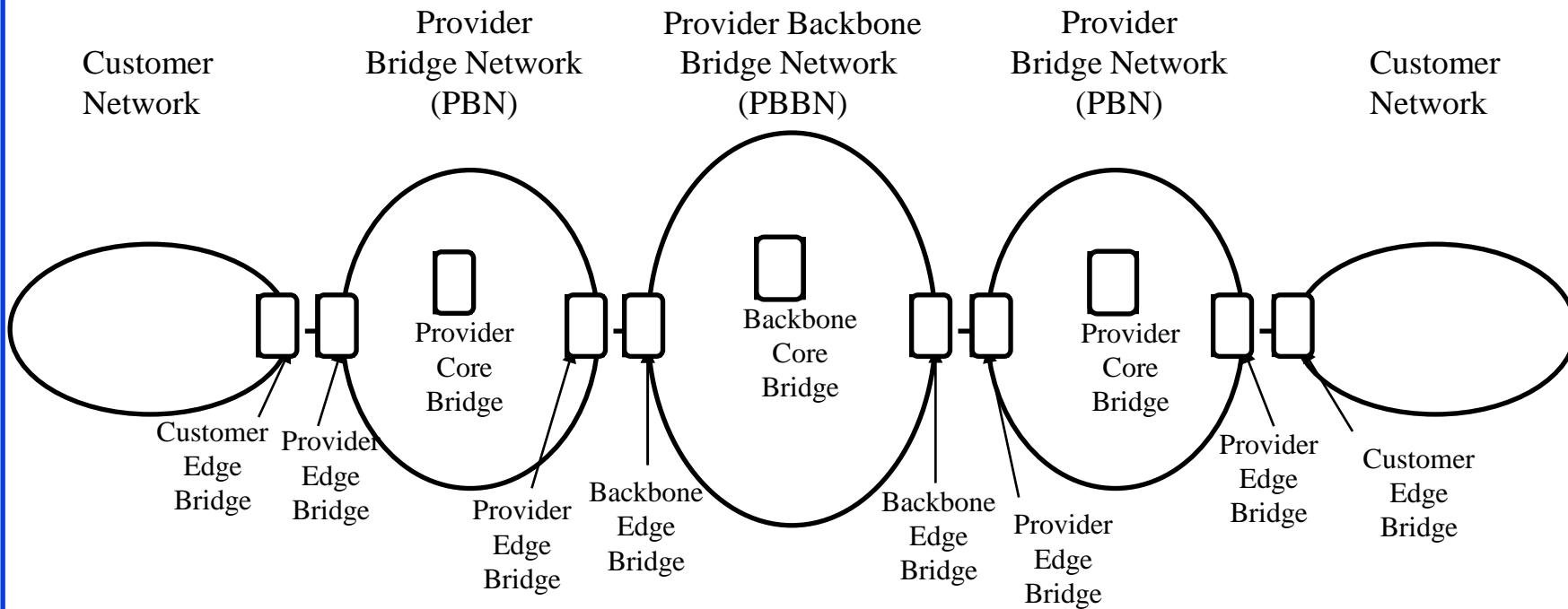
Carriers vs. Enterprise

We need to exchange topology for optimal routing.

Sorry, We can't tell you anything about our internal network.

Student Questions

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Network Hierarchy

Customer Network — Provider Bridge Network (PBN) — Provider Backbone Bridge Network (PBBN) — Provider Bridge Network (PBN) — Customer Network

Provider Core Bridge · Backbone Core Bridge · Provider Core Bridge

Customer Edge Bridge · Provider Edge Bridge · Provider Edge Bridge · Backbone Edge Bridge · Backbone Edge Bridge · Provider Edge Bridge · Provider Edge Bridge · Customer Edge Bridge

Student Questions

❑ If a global carrier such as China Unicom has no its own facilities in a specific country, let's say US, but people can use it's internet service in US as usual, how should we define this carrier? Tier 1 or Tier 2?
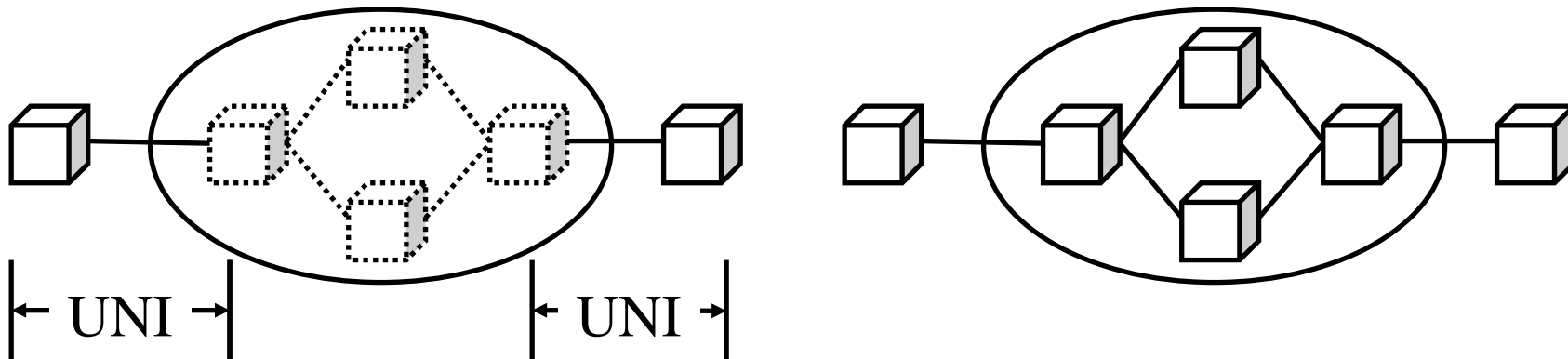
China Telecom could be a Tier 1 if it connects many Tier 2 carriers. It does not have to be global.

A tier 2 can offer service by collaborating with another Tier 2 and using the collaborator's facilities. But it will still be called Tier 2.

Issue: UNI vs Peer-to-Peer Signaling

- ❑ Two Business Models:
  - ➢ Carrier: Overlay or cloud
    - ❑ Network is a black-box
    - ❑ User-to-network interface (UNI)
  - ➢ Enterprise: Peer-to-Peer
    - ❑ Complete exchange of information

UNI   UNI

UNI vs. ENNI

❑ **User to Network Interface (UNI)**:

  ➢ Separates responsibilities between the user and the provider. (Troubleshooting, failures etc).

  ➢ Like the wired phone box outside your home.

  ➢ Only one customer's traffic.

❑ **External Network to Network Interface (ENNI)**:

  ➢ Separates responsibilities between two providers.

  ➢ Many customer's traffic passes through an ENNI

  ➢ Tier 2 *operators* sell services to Tier 3 service providers.

Customer — UNI — Provider 1 (Tier 3) — ENNI — Provider 2 (Tier 2)

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❑ Can ENNI connect two providers with the same tier level?

Yes.

Operator Virtual Connection (OVC)

❑ Between UNI and ENNI or between two ENNIs.

❑ For wholesale service providers

❑ Two types: Point-to-Point and Multipoint-to-Multipoint

❑ Untagged or single tagged frames at NNI. Q-in-Q at ENNI

❑ UNIs may be 10 to 100 Mbps. ENNIs at 1 to 10 Gbps.
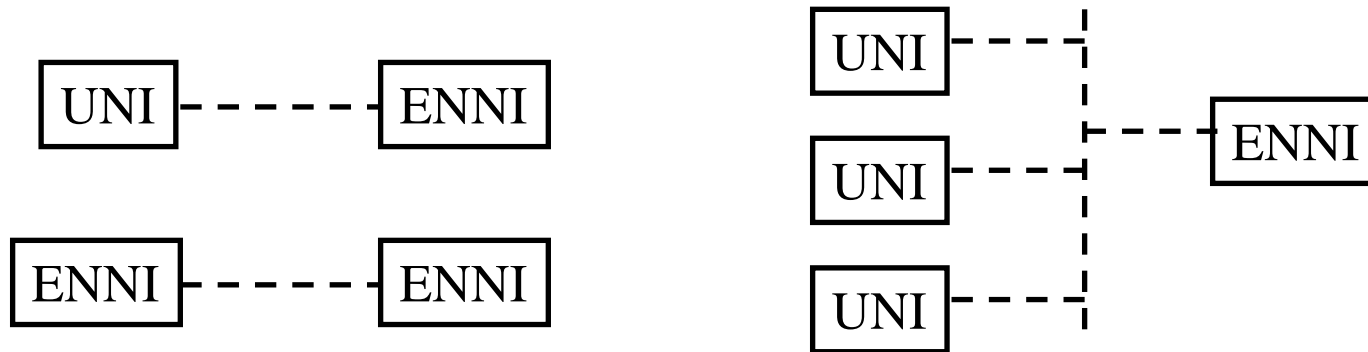
Student Questions

❑ What is Q-in-Q?
802.1Q inside another 802.1Q packet. See slide 6-19 and 6-20.

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Metro Access Ethernet Private Line

- **Access Ethernet Private Line (Access-EPL):**
    - Port-based service for Internet access
      Like the service at your home.
    - Ends at your access provider, where many other Access-EPLs may end
    - Access provider has only one interface
      Shared by many Access-EPLs $\Rightarrow$ Different from p2p EPL.
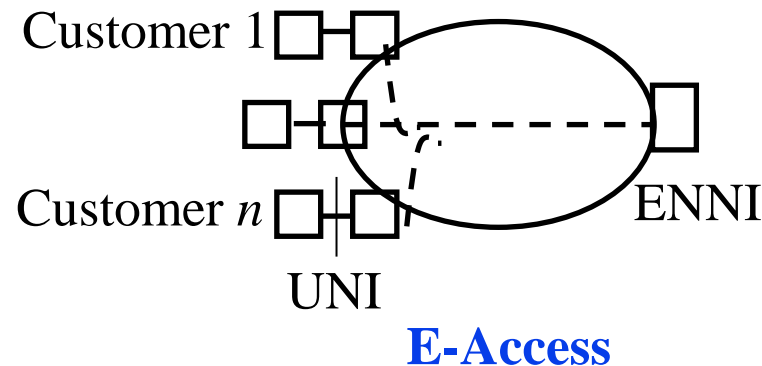
Customer 1

Customer n

UNI

ENNI

E-Access

End-to-End Metro Ethernet Connection

❑ An EC may go through multiple service providers
   ⇒ Multiple OVCs can be concatenated to create an EC
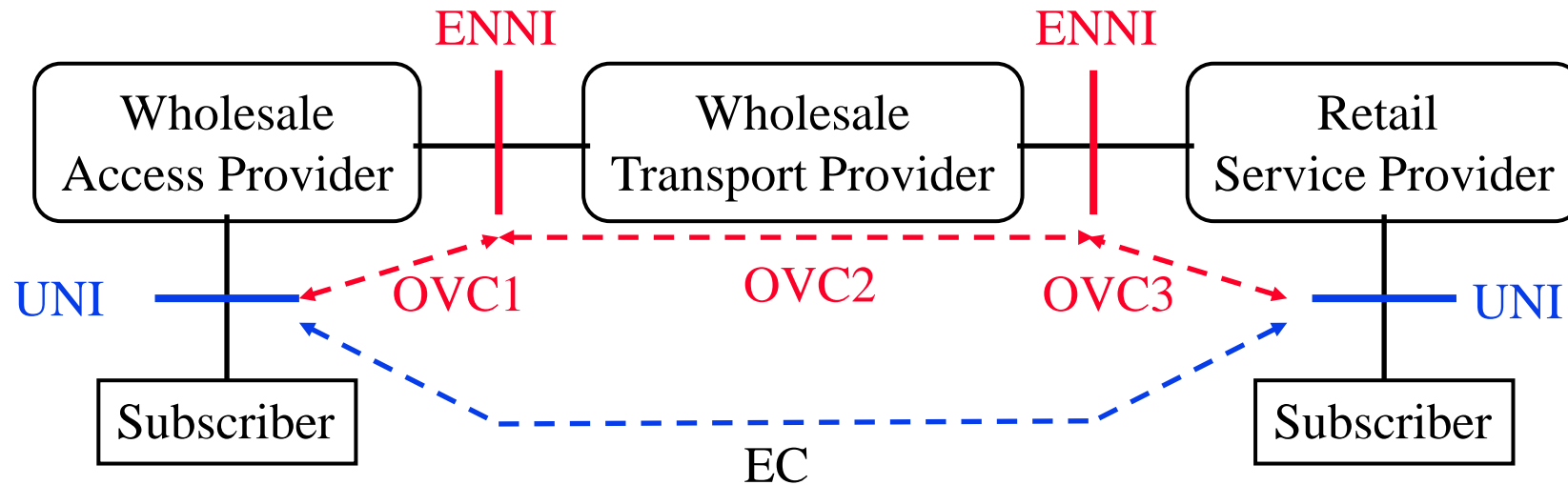
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Ethernet Virtual Connections (EVCs)

- **Port-based ECs**: Forwarding not based on VLANs. Frames delivered to remote UNI/ENNI for P2P or Based on destination address for P2MP

- **VLAN-based ECs**: Forwarding based on VLAN tag.
  - ⇒ Multiple Virtual UNIs
  - ⇒ Ethernet *Virtual* Connection (*EVC*)

  More cost-effective for Enterprise customers

- Types of EVCs:
  1. Ethernet Virtual Private Line (EVPL)
  2. Ethernet Virtual Private Tree (EVP-Tree)
  3. Ethernet Virtual Private LAN (EVPLAN)
  4. Access Ethernet Virtual Private Line (Access EVPL)

- Note: Service providers always share an ENNI for multiple connections ⇒ OVCs are always virtual
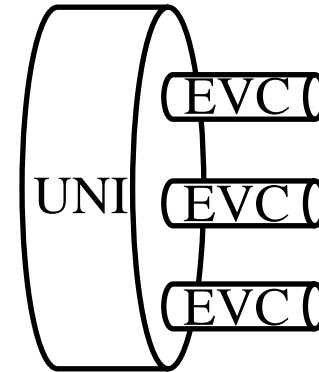
Student Questions
- So in a VLAN-based EC, the final forwarding to the destination is done by the VLAN switch connected to the UNI, whereas in a port-based EC it is directly Point-2-Point via the UNI?

Yes. Port=Physical, VLAN=Virtual.

- For the test, I need to confirm that "OVC are always virtual and EVCs' are not" ?

Both OVC and EVCs are virtual.

Metro Ethernet Service Attributes

❑ Bandwidth Profiles: Limits on data dates
  ➢ Ingress Profile: Incoming data rate
  ➢ Egress Profile: Outgoing data rate
❑ Per UNI, Per EVC or OVC, or
  Per EVC/OVC per Class of Service (CoS)
❑ CoS is indicated by the 3-bits in the priority field or
  4-bit Differentiated Services Code Point (DSCP)
❑ Rate specified by 5 parameters
  1. Committed Information Rate (CIR)
  2. Committed Burst Size (CBS)
  3. *Excess* Information rate (EIR)
  4. Excess Burst Size (EBS)
  5. Color Mode (CM): Customer does/does not
     mark drop eligibility indicator (DEI)

Data

CBS

EBS   CIR

Dropped

Mark   EIR
DEI

Forwarded

Example

- A user with CIR=10 Mbps, CBS=2 MB, EIR=2 Mbps, EBS=1MB, sends a 10 MB file at 20 Mbps. What percent of packets will be dropped? What percent will be marked?
- CBS = 2 MB = 16 Mb, EBS = 1 MB = 8 Mb, File size = 80 Mb
- File time = 80 Mb/20 Mbps = 4 s
- 1st Bucket fill rate = 20-10 = 10 Mbps, 1st Bucket fill time = 16/10 = 1.6s Total output from 1st bucket = 4*10 Mbps + 16 Mb = 56 Mb (committed) = 70%
- 1st Bucket Overflow time = 4-1.6 = 2.4s 1st bucket Overflow amount = 2.4 s*(20-10) Mbps = 24 Mb
- 2nd bucket fill Rate = 10-2 = 8 Mbps 2nd bucket fill time = Size/Rate = 8 Mb/8 Mbps = 1 s Total output from 2nd bucket = 0*1.6 + 2*(4 - 1.6) + 8 = 12.8 Mb (Marked) = 16%
- 2nd Bucket overflow time = 4 - 1.6 - 1 = 1.4s 2nd bucket overflow amount = (10-2)*1.4 = 11.2 Mb (Dropped) = 14%
- Check: Total = 56+12.8+11.2 = 80 Mb

File

CBS

CIR

EBS

Dropped

EIR

Mark

DEI

Forwarded

Rate   File

20
18
16
14
12
10
8
6
4
2

Overflow from 1st

Overflow from 2nd

Time

0 0.8 1.6 2.4 3.2 4.0
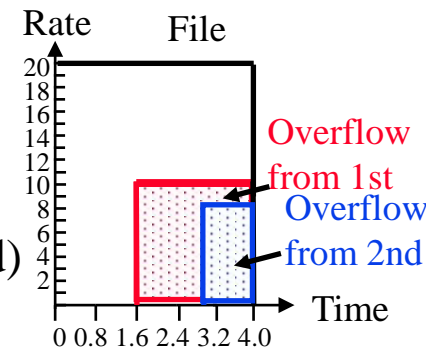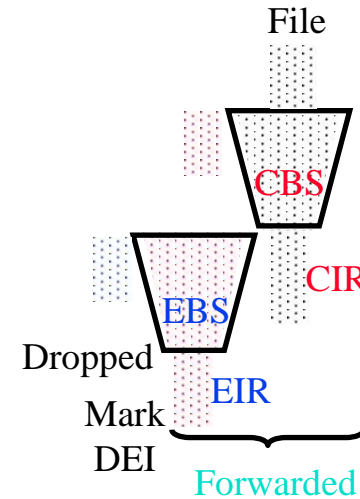
Student Questions

- What is the marked data means?

Marked $\Rightarrow$ DEI set.

- For 2nd bucket fill rate: 10 - 2 = 8. Where is the 10 come from? Is it the 1st bucket overflow rate?

Yes. 20-10=10

- Could you please explain this slide in detail again?

Sure.

- Is there a tabular way of doing this calculation? It seems Mb, MB and Mbps were used interchangeably.

No. B and b were used very carefully. You should do the same.

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Homework 6

❑ A user with CIR=25 Mbps, CBS=2 MB, EIR=2 Mbps, EBS=1MB, sends a 15 MB file at 30 Mbps.
What percent of packets will be dropped?
What percent will be marked?

Metro Ethernet OAM

❑ Operation, Administration and Maintenance (OAM)

❑ Defined in IEEE 802.1ag, IEEE 802.1ah, and ITU Y.1731

❑ Maintenance End Points (MEPs)

❑ Maintenance Intermediate Points (MIPs)

❑ Maintenance Entity Group (MEG): Level of Administration
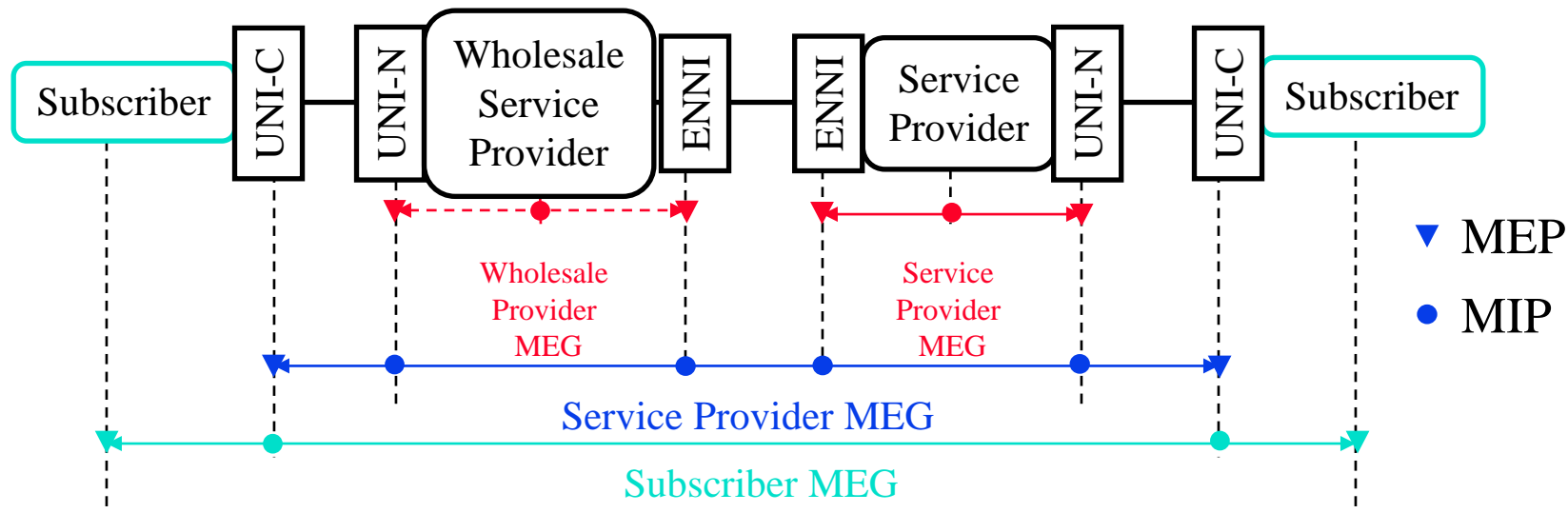
Student Questions

Metro Ethernet OAM (Cont)

- Performance Monitoring: Measure throughput and latency
- Connectivity Fault Management: Monitor downtime
  - Service Fault Management
  - Link Fault Management
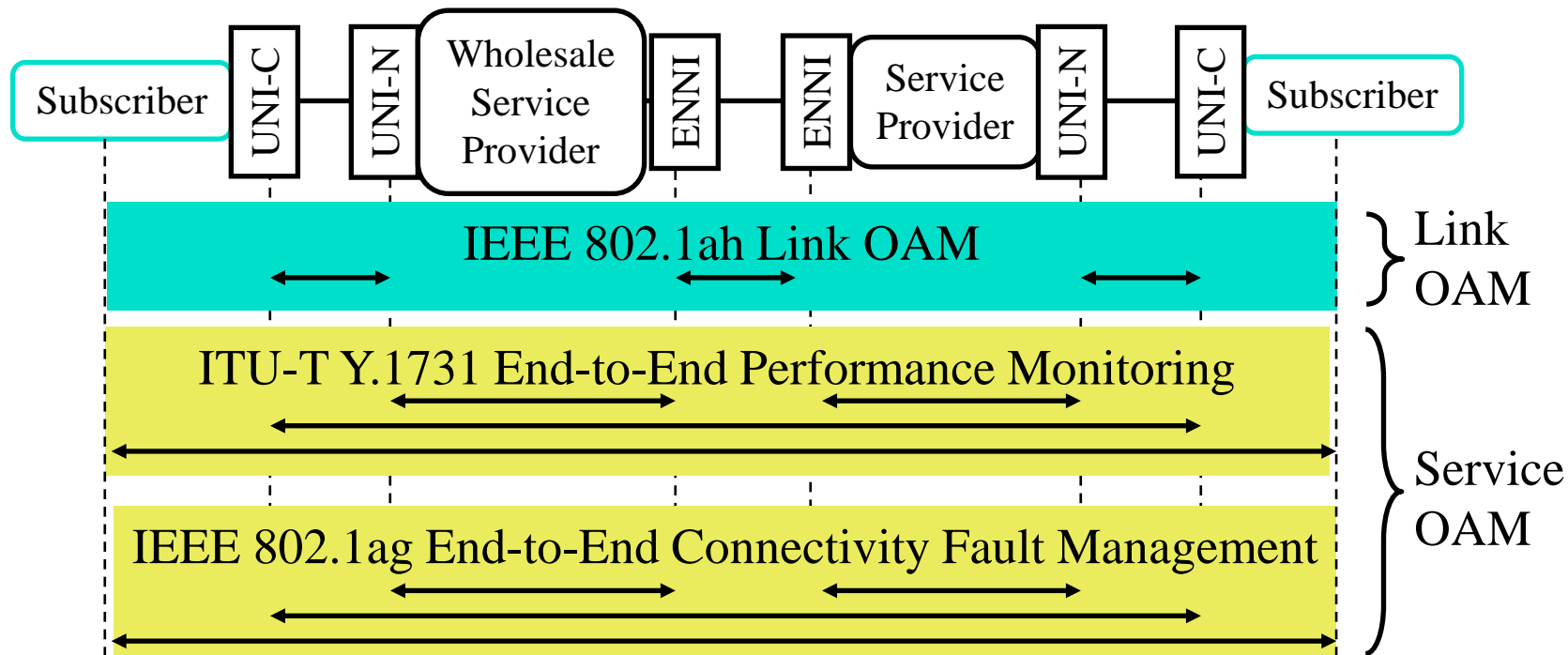
Student Questions

- Link OAM is L1? Service OAM is L2 and L3?

Yes.

Metro Ethernet OAM Messages

- Continuity Check Message (CCM) in both directions (Similar to IP Ping)
- Link Trace Message (LTM): Locates fault. Link Trace Response (LTR) is returned by each end point and intermediate point (similar to IP trace route)
- Fault, Configuration, Accounting, Performance, Security (FCAPS)
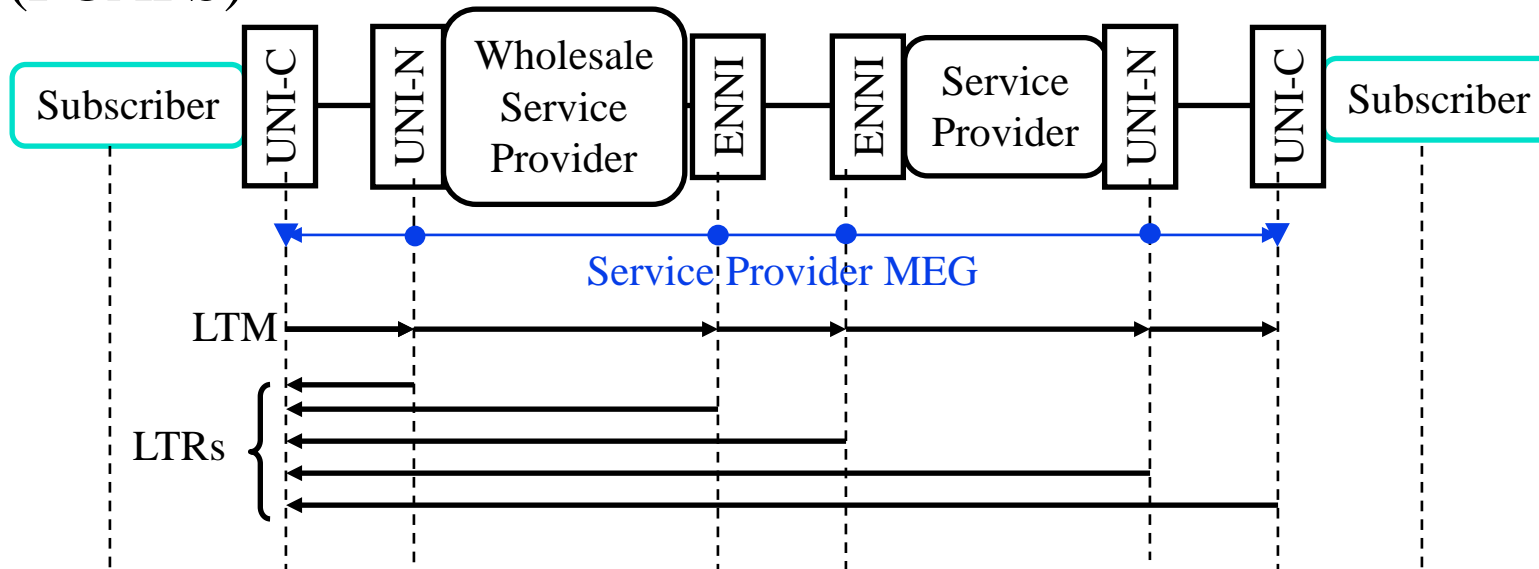
Student Questions

- Is C in FCAPS for configuration or capacity?

C=Configuration

Metro Ethernet Use Cases

1. Head office to Satellite offices and/or Internet
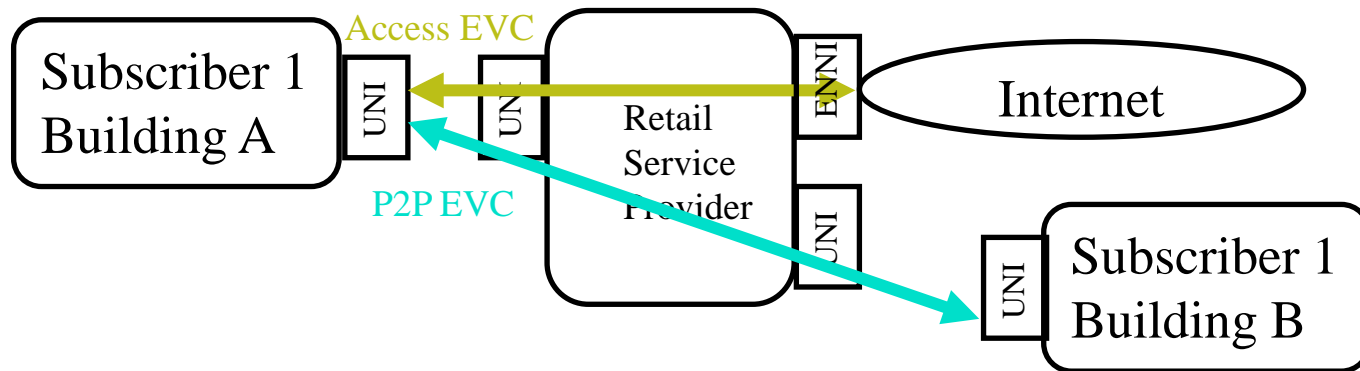
2. Customers to Cloud Service Provider
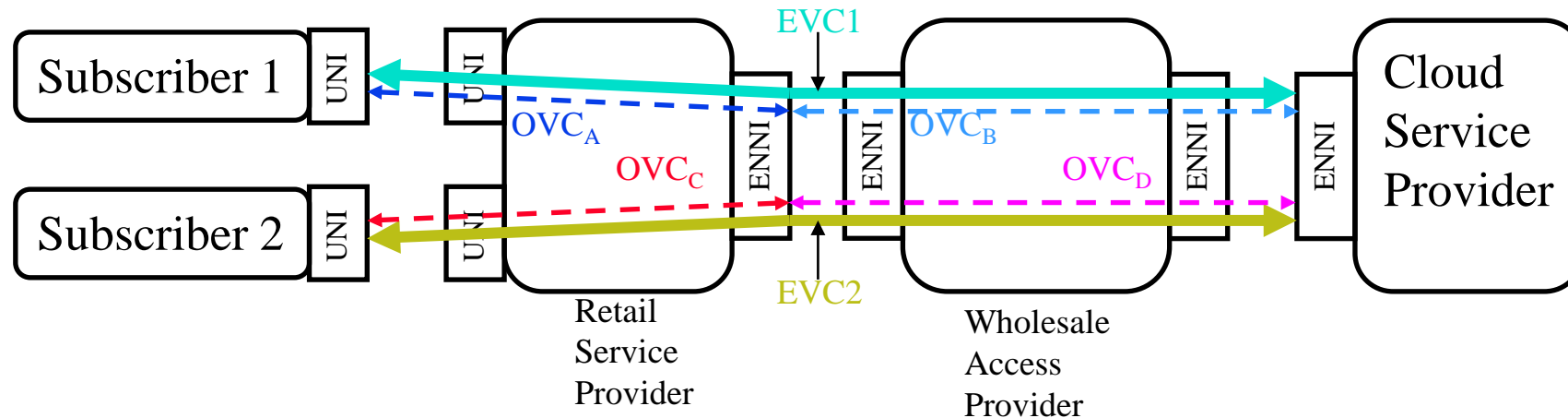
Student Questions

Ethernet Provider Bridge (PB)
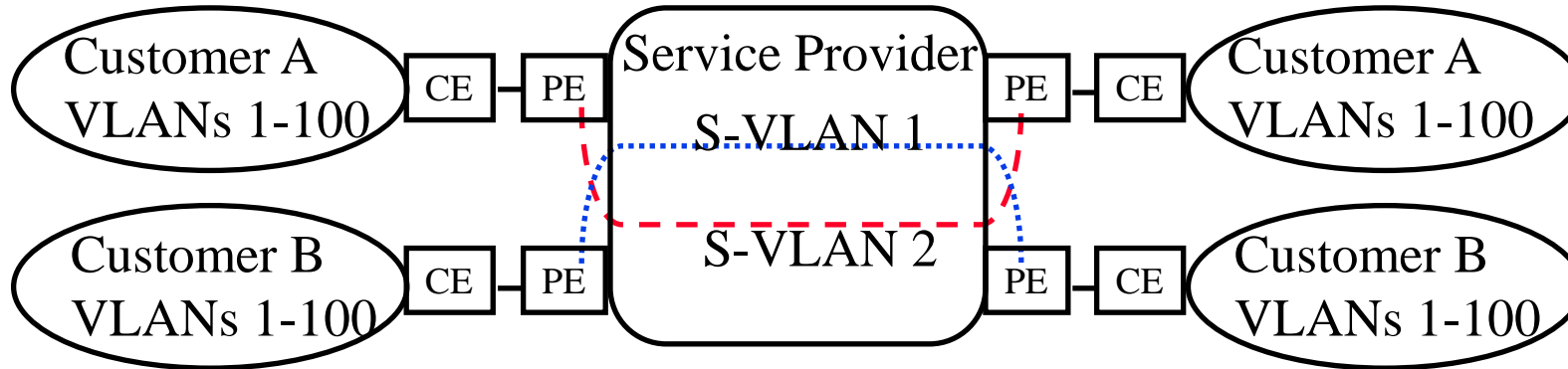
- ❑ IEEE 802.1ad-2005 incorporated in IEEE 802.1Q-2011
- ❑ Problem: Multiple customers may have the same VLAN ID. How to keep them separate?
- ❑ Solutions:
  1. VLAN translation: Change customer VLANs to provider VLANs and back
  2. VLAN Encapsulation: Encapsulate customer frames

Provider Bridge (Cont)

❑ Q-in-Q Encapsulation: Provider inserts a service VLAN tag VLAN translation Changes VLANs using a table

❑ Allows 4K customers to be serviced. Total 16M VLANs

❑ 8 Traffic Classes using Differentiated Services Code Points (DSCP) for Assured Forwarding

		S-Tag					
C-DA	C-SA	Type 88A8	S-VID	Type 8100	C-VID	Type	Payload
48b	48b	16b	16b	16b	16b	16b	

Priority	CFI	S-VLAN ID
3b	1b	12b

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Provider Backbone Network (PBB)

- ❑ Problem: Number of MAC addresses passing through backbone bridges is too large for all core bridge to remember
  Broadcast and flooded (unknown address) frames give unwanted traffic and security issues

- ❑ Solution: IEEE 802.1ah-2008 incorporated in 802.1Q-2011

- ❑ Add new source/destination MAC addresses pointing to ingress backbone bridge and egress backbone bridge
  ⇒Core bridges only know edge bridge addresses

Student Questions

MAC-in-MAC Frame Format

❑ Backbone edge bridges (BEB) forward to other BEB's and learn customer MAC addresses ⇒ Backbone *core* bridges (BCB) do not learn customer MACs

❑ B-DA = Destination backbone bridge address Determined by Customer Destination Address

❑ Backbone VLANs delimit the broadcast domains in the backbone

```
Edge          Edge
     Core
Edge   Core   Edge
```
Backbone

B-DA	B-SA	Type 88A8	B-VID	Type 88E7	Flags	I-SID	C-DA	C-SA	Type 88A8	S-VID	Type 8100	C-VID	Type	Payload
48b	48b	16b	16b	16b	8b	24b	48b	48b	16b	16b	16b	16b	16b	

I-Tag
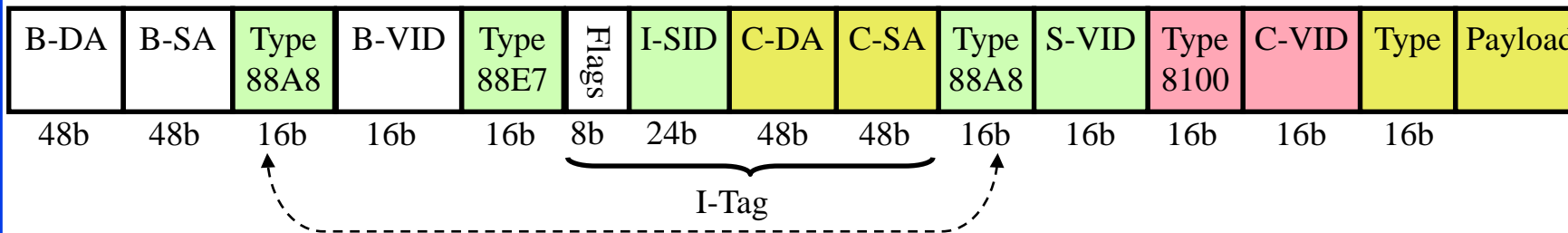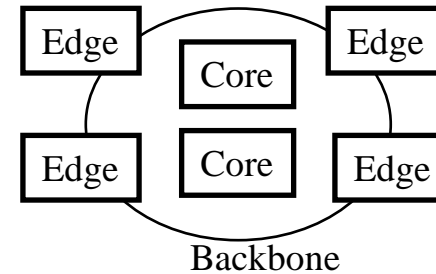
❑ Core switches forward based on Backbone Destination Bridge Address and Backbone-VLAN ID (60 bits) Similar to 802.1ad Q-in-Q. Therefore, same EtherType.

Student Questions

❑ It shows B-VID is 16 bits on the figure. Why it is saying that Backbone VLAN ID is 60 bits?

MAC in MAC adds 48+48+16+16+16+8 +32=184 b = 23 bytes to the frame.

❑ if we have 4 Tags, the outer one will always have an ID of 88A8? and only the inner one will have 8100? in between we might have 887E or another 88A8? When I see 88E7, does it mean that this packet is being routed through PBB and I should expect I-Tag afterwards? Note: 88A8 is defined in IEEE as Service VLAN Tag (S-TAG) or Backbone VLAN Tag (B-TAG), so it can indicate both!

Yes. Both B-Tag and S-Tag. B-Tag if outer, S-Tah if inner.

❑ B-VID is 16 bits, and backbone VLAN ID is 60bits? can you please explain the difference? How can BEB learn customer MAC address if its encapsulated inside service provider VLAN?

Learning happens in the edge not in the core.

❑ Why are there two 88A8 Tags? Can you show what the core looks at and what it ignores?

Everyone looks at the outermost tag.

❑ Tags such as B-DA, I-SID, etc. are all added by the backbone edge bridges on top of the customer's packet (payload) that comes in?

Yes.

PBB Service Instance

❑ 24-bit Service instance ID (I-SID) indicates a specific flow

➢ All frames on a specific port, or

➢ All frames on a specific port with a specific *service* VLAN, or

➢ All frames on a specific port with a specific service VLAN and a specific *customer* VLAN

SID	Definition	B-VLAN
1	Port 1	1
20	Port 2, S-VLAN=10	3
33	Port 2, S-VLAN=20	6
401	Port 2, S-VLAN=30, C-VLAN=100	4
502	Port 3, S-VLAN=40, C-VLAN=200	4

Port 1 — B-VLAN=1

Port 2 — B-VLAN=3

B-VLAN=6

Port 3 — B-VLAN=4

Service Instance Mapping
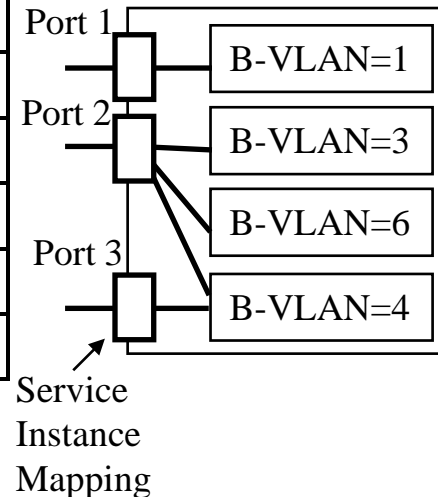
Student Questions

❑ What is B-VLAN

Backbone VLAN

❑ 88E7 indicates that I-tag is following, but what problem it solves? what is the point of using ports is it for multicast?? load balancing? grouping? what is it for?

Service tag is used to provide classes of service.

❑ Do PBB still assigned service instance ID dynamically when a new flow is established, or it is completely managed administratively like PBB-TE?

Carrier business is a lot of money. Everything has to be managed administratively.

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MAC-in-MAC (Cont)
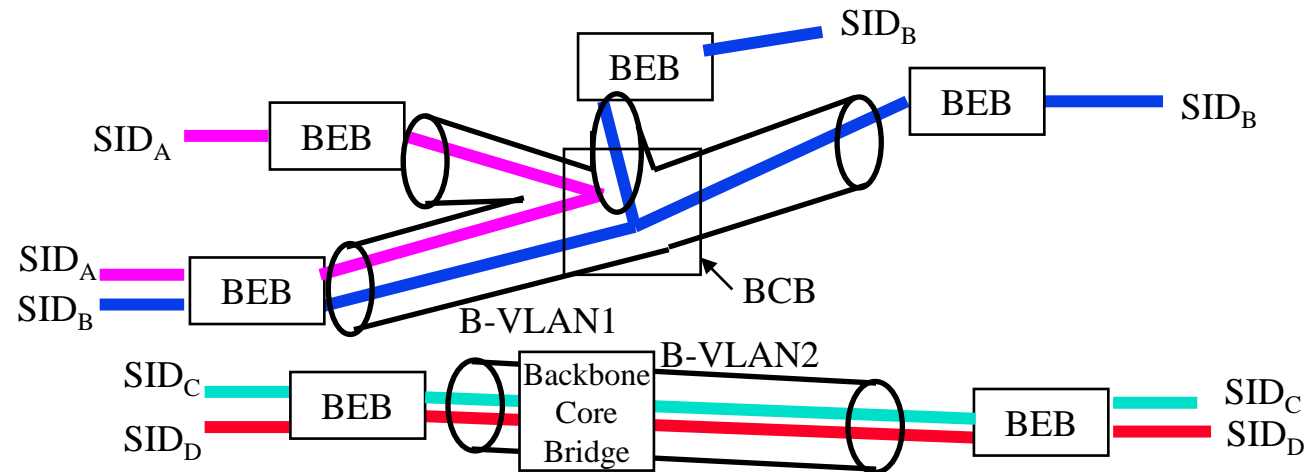
❑ Each Backbone VLANs (B-VLAN) can carry multiple services

❑ 24-bit SID $\Rightarrow 2^{24}$ Service Instances in the backbone

❑ I-Tag format: I-Tag not looked at in the core.
Includes C-DA+C-SA.
UCA=1 $\Rightarrow$ Use customer addresses (used in CFM in the Edge)

Priority Code Point (I-PCP)	Drop Eligibility Indicator (I-DEI)	Use Customer Address (UCA)	Reserved 1	Reserved 2	Service Instance ID (I-SID)	Customer Destination Address (C-DA)	Customer Source Address (C-SA)
3b	1b	1b	1b	2b	24b	48b	48b

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Connection Oriented Ethernet

❑ Connectionless: Path determined at forwarding
  ⇒ Varying QoS

❑ Connection Oriented: Path determined at provisioning

  ➢ Path provisioned by management ⇒ Deterministic QoS

    ❑ No spanning tree, No MAC address learning,

    ❑ Frames forwarded based on VLAN Ids and Backbone bridges addresses

    ❑ Path not determined by customer MAC addresses and other customer fields ⇒ More Secure

  ➢ Reserved bandwidth per EVC

  ➢ Pre-provisioned Protection path ⇒ Better availability

```
[CE]━━━[PE]  (  Working Path        )  [PE]━━━[CE]
                 Protection Path
```

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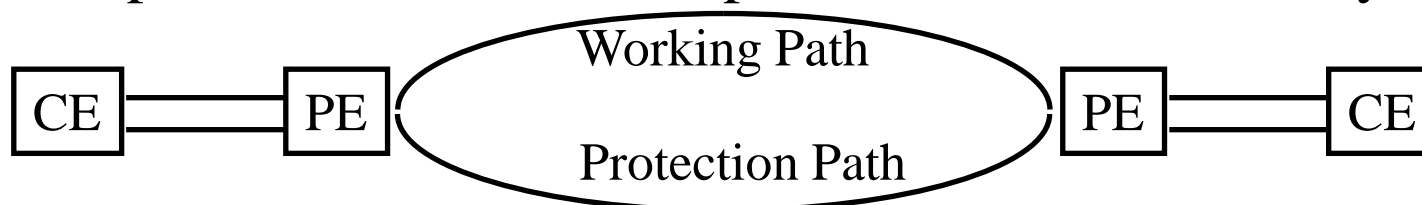
VLAN Cross-Connect

- Cross-connect $\Rightarrow$ Circuit oriented
- Connection Oriented Ethernet with Q-in-Q
- Forward frames based on VLAN ID and Input port
  $\Rightarrow$ No MAC Learning

Input Port	VLAN ID	Output Port
1	200	7
2	201	5
3	20	5
3	21	6
4	100	7
4	101	8
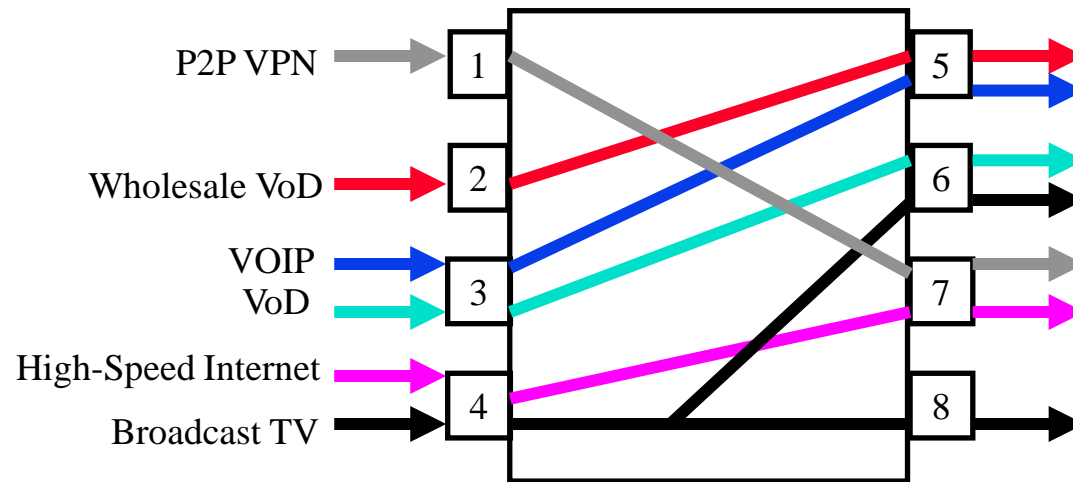
Student Questions

PBB-TE

- Provider Backbone Bridges with Traffic Engineering (PBB-TE)
- IEEE 802.1Qay-2009 incorporated in 802.1Q-2011
- Provides connection oriented P2P (E-*Line*) Ethernet service
- For PBB-TE traffic VLANs:
  - Turn off MAC learning
  - Discard frames with unknown address and broadcasts.
    $\Rightarrow$ No flooding
  - Disable Spanning Tree Protocol.
  - Add protection path switching for each direction of the trunk
- Switch forwarding tables are administratively populated using management
- Same frame format as with MAC-in-MAC. No change.

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PBB-TE QoS

- Guarantees QoS $\Rightarrow$ No need for MPLS or SONET/SDH
- UNI traffic is classified by Port, Service VLAN ID, Customer VLAN ID, priority, Unicast/Multicast
- UNI ports are *policed* $\Rightarrow$ Excess traffic is dropped
  No policing at NNI ports. Only remarking, if necessary.
- Traffic may be marked and remarked at both UNI and NNI

Subscriber — UNI-C — UNI-N — Wholesale Service Provider — ENNI — ENNI — Service Provider — UNI-N — UNI-C — Subscriber

Classification, Policing, Marking

Scheduling, Remarking

Shaping
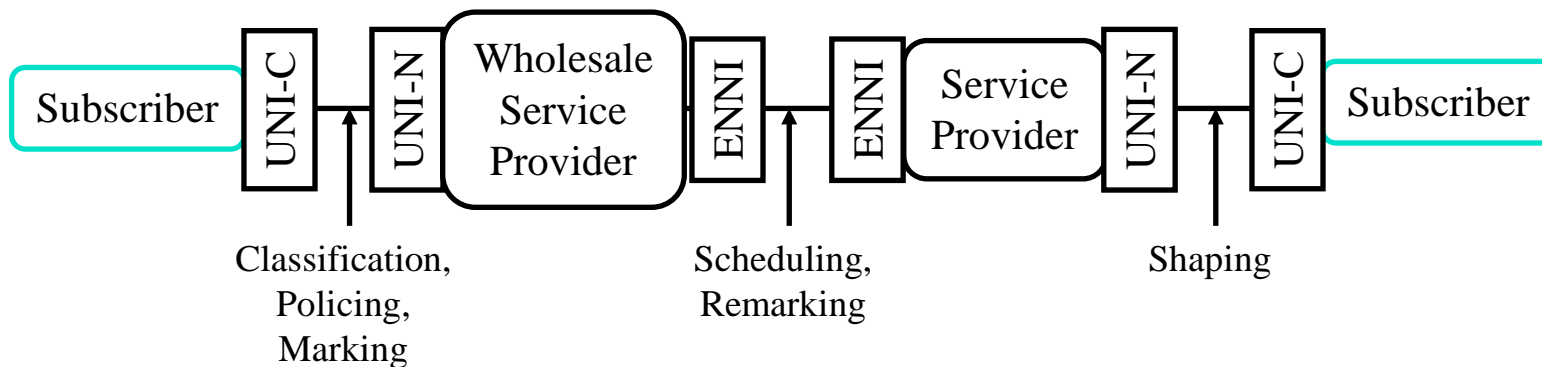
Student Questions
- So do Carriers use MPLS in practice? Or do they not need to since we can use PBB-TE instead?

Everything in networking stays once it is in there. So they use both.

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Ethernet Tagged Frame Format Evolution

- Original Ethernet

C-DA	C-SA	Type	Payload

- IEEE 802.1Q VLAN

C-DA	C-SA	Type 8100	C-VID	Type	Payload

- IEEE 802.1ad PB

C-DA	C-SA	Type 88A8	S-VID	Type 8100	C-VID	Type	Payload
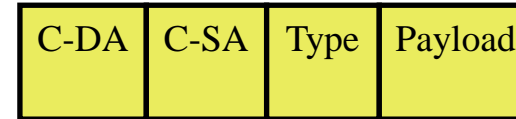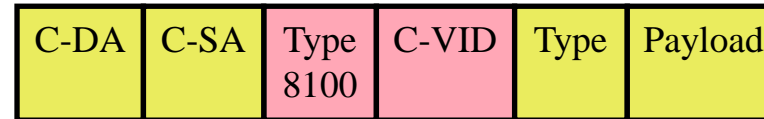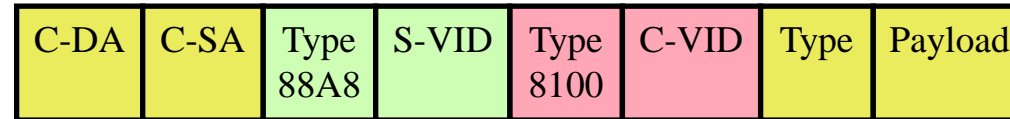
- IEEE 802.1ah PBB or 802.1Qay PBB-TE

B-DA	B-SA	Type 88A8	B-VID	Type 88E7	I-SID	C-DA	C-SA	Type 88A8	S-VID	Type 8100	C-VID	Type	Payload
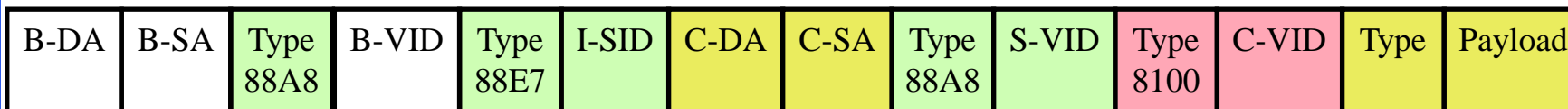
Tag Type	Value
Customer VLAN	8100
Service VLAN or Backbone VLAN	88A8
Backbone Service Instance	88E7

Student Questions

- 88E7 is either regular PBB or PBB-TE? what field has the PBB-TE QoS info?

Service Tag

Comparison of Technologies

	Basic Ethernet	MPLS	PB	PBB-TE
Resilience	No	Protection Fast Reroute	SPB/LAG	Protection Fast Reroute
Security	No	Circuit Based	VLAN	Circuit Based
Multicast	Yes	Inefficient	Yes	No. P2P only
QoS	Priority	Diffserve	Diffserve+ Guaranteed	Diffserve+ Guaranteed
Legacy Services	No	Yes (PWE3)	No	No
Traffic Engineering	No	Yes	No	Yes
Scalability	Limited	Complex	Q-in-Q	Q-in-Q+ Mac-in-MAC
Cost	Low	High	Medium	Medium
OAM	No	Some	Yes	Yes

Student Questions

❑ Which of these technologies is the most common?
MPLS, PBB-TE
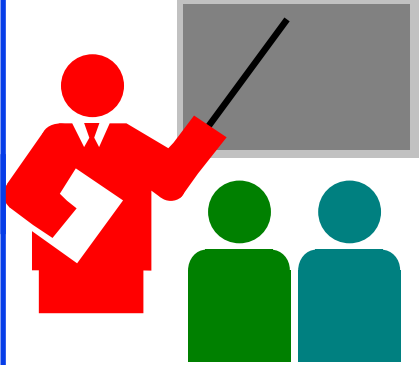
Summary

1. Carriers use User-to-Network Interface (UNI) signaling rather than peer-to-peer signaling

2. Metro Ethernet allows E-Line, E-Access, E-Tree, and E-LAN services

3. Q-in-Q allows service providers to carry customer VLAN tags in their Ethernet Frames

4. MAC-in-MAC extension allows very large Ethernet networks spanning over several backbone carriers

5. PBB-TE extension allows connection oriented Ethernet with QoS guarantees and protection

Student Questions

Reading List

❑ Fujitsu, "Carrier Ethernet Essentials," http://www.fujitsu.com/downloads/TEL/fnc/whitepapers/CarrierEthernetEssentials.pdf

❑ R. Santitoro, "Metro Ethernet Services – A Technical Overview," The Metro Ethernet Forum, 2003, V2.7, https://www.mef.net/Assets/White_Papers/Metro-Ethernet-Services.pdf

Student Questions

References

- G. Santana, "Datacenter Virtualization Fundamentals," Cisco Press, 2014, ISBN: 1587143240 (Safari Book)

- H. Saboowala, M. Abid, S. Modali, "Designing Networks and Services for the Cloud: Delivering business-grade cloud applications and services," Cisco Press 2013, ISBN:1587142945 (Safari Book)

Student Questions

Wikipedia Links

- http://en.wikipedia.org/wiki/Carrier_Ethernet
- http://en.wikipedia.org/wiki/Connection-oriented_Ethernet
- http://en.wikipedia.org/wiki/Ethernet_Private_Line
- http://en.wikipedia.org/wiki/Ethernet_Virtual_Private_Line
- http://en.wikipedia.org/wiki/IEEE_802.1ad
- http://en.wikipedia.org/wiki/IEEE_802.1ag
- http://en.wikipedia.org/wiki/IEEE_802.1ah-2008
- http://en.wikipedia.org/wiki/Metro_Ethernet
- http://en.wikipedia.org/wiki/Metro_Ethernet_Forum
- http://en.wikipedia.org/wiki/Network-to-network_interface
- http://en.wikipedia.org/wiki/Operations,_administration_and_management
- http://en.wikipedia.org/wiki/Provider_Backbone_Bridge_Traffic_Engineering
- http://en.wikipedia.org/wiki/Traffic_policing
- http://en.wikipedia.org/wiki/Traffic_shaping
- http://en.wikipedia.org/wiki/User%E2%80%93network_interface
- http://en.wikipedia.org/wiki/Virtual_Private_LAN_Service

Student Questions

Acronyms

- B-VID   Backbone VLAN Identifier
- BER   Bit Error Rate
- C-VID   Customer VLAN Identifier
- CBS   Committed Burst Size
- CCM   Continuity Check Message
- CE   Customer Edge
- CFI   Canonical Form Indicator
- CFM   Connectivity Fault Management
- CIR   Committed Information Rate
- CM   Color Mode
- CoS   Class of Service
- DA   Destination Address
- DEI   Drop Eligibility Indicator
- DSCP   Differentiated Services Code Points
- EBS   Excess Burst Size
- EC   Ethernet Connection

Student Questions

Acronyms (Cont)

- EIR — Excess Information rate
- ENNI — External Network to Network Interface
- EPL — Ethernet Private Line
- EVC — Ethernet Virtual Connection
- EVP-Access — Ethernet Virtual Private Access
- EVP-LAN — Ethernet Virtual Private Local Area Network
- EVP-Line — Ethernet Virtual Private Line
- EVP-Tree — Ethernet Virtual Private Tree
- EVPL — Ethernet Virtual Private Line
- I-SID — Instance Service ID
- ID — Identifier
- IEEE — Institution of Electrical and Electronic Engineers
- IETF — Internet Engineering Task Force
- IP — Internet Protocols
- ITU — International Telecommunications Union

Student Questions

Acronyms (Cont)

- LAN   Local Area Network
- LTM   Link Trace Message
- LTR   Link Trace Response
- MAC   Media Access Control
- MEG   Maintenance Entity Group
- MEP   Maintenance End Points
- MIP   Maintenance Intermediate Points
- MP   Multi-Point
- MPLS   Multi-Protocol Label Switching
- NNI   Network-to-Network Interface
- OAM   Operation, Administration and Maintenance
- OC   Optical Carrier
- OIF   Optical Interoperability Forum
- OVC   Operator Virtual Connection

Student Questions

Acronyms (Cont)

- PB   Provider Bridge
- PBB-TE   Provider Backbone Bridge with Traffic Engineering
- PBB   Provider Backbone Bridge
- PBBE   Provider BackBone Edge
- PBBN   Provider Backbone Network
- PBEB   Provider backbone edge bridges
- PBN   Provider Bridging network
- PBX   Private Branch Exchange
- PCP   Priority Code Point
- PDH   Plesiochronous Digital Hierarchy
- PE   Provider Edge
- PW   Pseudo-Wire
- PWE3   Pseudo-Wire Emulation Edge-to-Edge
- QoS   Quality of Service
- S-VID   Service (Provider) VLAN ID
- SA   Source Address
- SDH   Synchronous Digital Hierarchy

Student Questions

Acronyms (Cont)

- SID   Service Identifier
- SLA   Service Level Agreement
- SONET   Synchronous optical network
- TE   Traffic Engineering
- TV   Television
- UCA   Use Customer Address (flag)
- UNI   User to Network Interface
- VID   VLAN Identifier
- VLAN   Virtual Local Area Network
- VoD   Video on Demand
- VoIP   Voice over IP
- VPN   Virtual Private Network

Student Questions

Scan This to Download These Slides

http://www.cse.wustl.edu/~jain/cse570-21/m_06cee.htm

Raj Jain

http://rajjain.com

Student Questions

❑ Can you please make the slides for this module available on the course webpage?

Some network issues have prevented me from uploading anything to the website last week.

❑ Also the reading list from past-years slides do not show the specific chapters of the books for this module?

Use the index or ToC in the book. Or search feature in Safari books.

❑ Do we have a reading list for this module? its mentioned in the video but not added in the slides!

There are two books in the reading list. See slide 6-32 when the pdf is available.

❑ Can you please upload the slides?

Related Modules

CSE567M: Computer Systems Analysis (Spring 2013),

https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof

CSE473S: Introduction to Computer Networks (Fall 2011),

https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcgy5e_10TiDw

Wireless and Mobile Networking (Spring 2016),

https://www.youtube.com/playlist?list=PLjGG94etKypKeb0nzyN9tSs_HCd5c4wXF

CSE571S: Network Security (Fall 2011),

https://www.youtube.com/playlist?list=PLjGG94etKypKvzfVtutHcPFJXumyyg93u

Video Podcasts of Prof. Raj Jain's Lectures,

https://www.youtube.com/user/ProfRajJain/playlists

Student Questions