

# Carrier Ethernet



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

<http://www.cse.wustl.edu/~jain/cse570-23/>

**Student Questions**



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 initially developed for carriers, they are now used inside multi-tenant data centers (clouds)

## Student Questions

# Enterprise vs. Carrier Ethernet

Enterprise	Carrier
<input type="checkbox"/> Distance: up to 2km	<input type="checkbox"/> Up to 100 km
<input type="checkbox"/> Scale:	<input type="checkbox"/> Millions of MAC Addresses
➤ Few K MAC addresses	<input type="checkbox"/> Millions of VLANs
➤ 4096 VLANs	Q-in-Q
<input type="checkbox"/> Protection: <b>Rapid</b> Spanning tree	<input type="checkbox"/> Shortest Path Routing
<input type="checkbox"/> Path determined by spanning tree	<input type="checkbox"/> Traffic-engineered path
<input type="checkbox"/> Simple service	<input type="checkbox"/> SLA
<input type="checkbox"/> Priority ⇒ Aggregate QoS	<input type="checkbox"/> Need per-flow QoS
<input type="checkbox"/> No performance/Error monitoring (OAM)	<input type="checkbox"/> 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 an enterprise? What I mean is that AT&T is a carrier but also is an enterprise.

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

- Could you please explain how RSTP is faster?

*Rather than trying to find root in all directions, as in STP, RSTP tries to reaffirm its known direction as superior. If it is, then the neighbor will tell all its neighbors.*

# Carriers vs. Enterprise

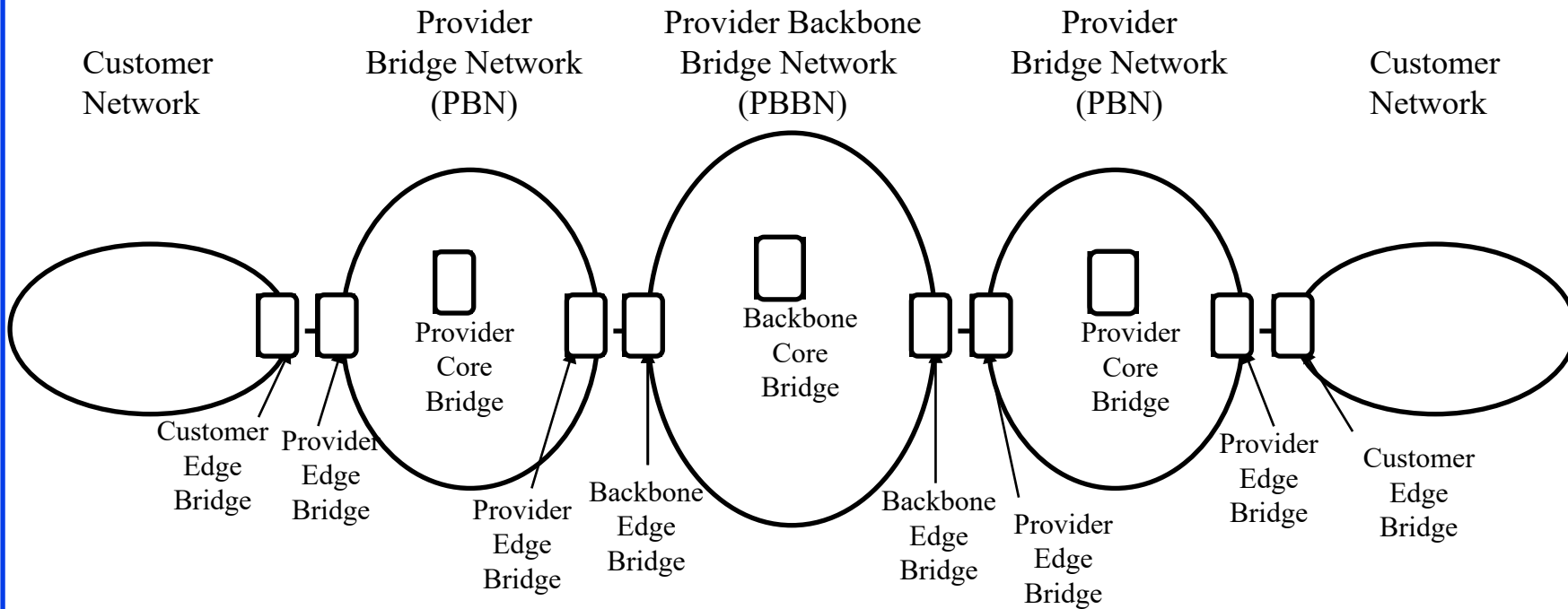
We need to exchange topology for optimal routing.

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



## Student Questions

# Network Hierarchy



## Student Questions

- ❑ If a global carrier such as China Unicom has no its own facilities in a specific country, let's say the US, but people can use it's internet service in the 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.*

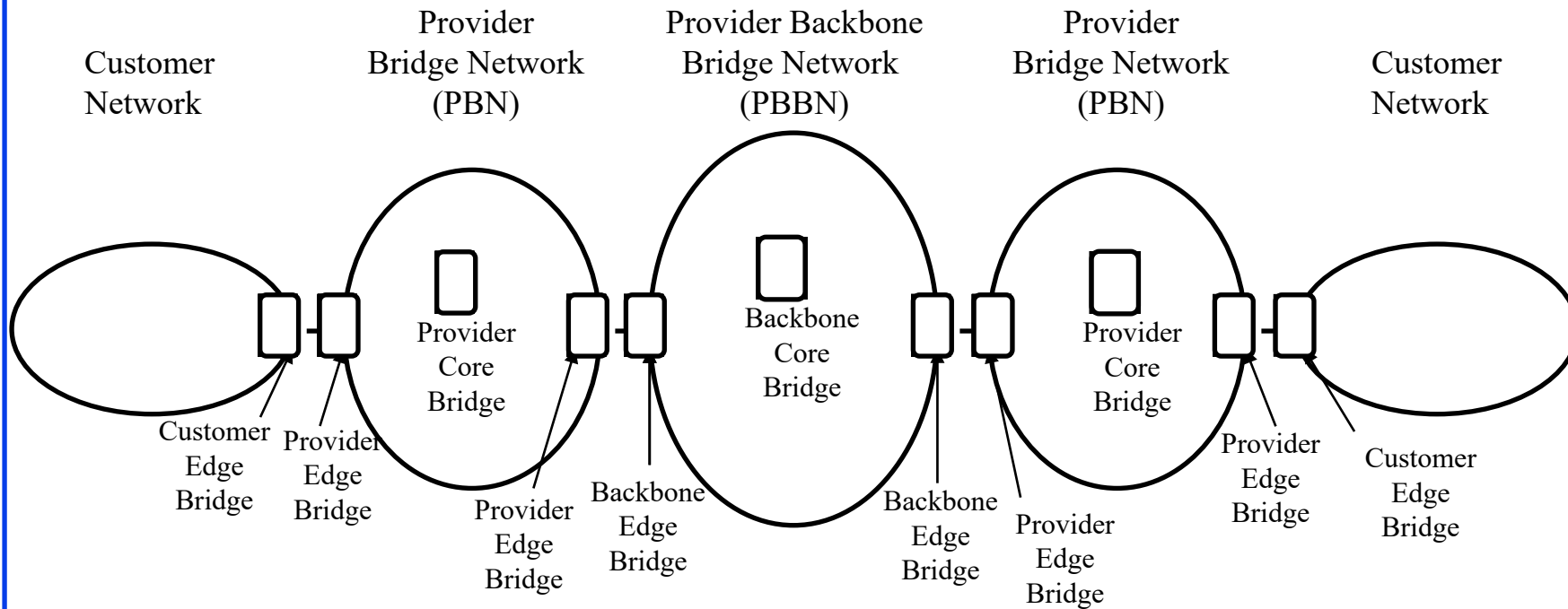
*A tier 2 can offer service by collaborating with another Tier 2 and using the collaborator's facilities. But it will still be called Tier 2.*

- ❑ You call out the tiers in the video, but reference the classroom screen. Is the PBN tier 1 and the PBBN tier 2?

*Lower Tiers are towards the edges. OBBN is Tier 1 and PBN is Tier 2.*



# Network Hierarchy



## Student Questions

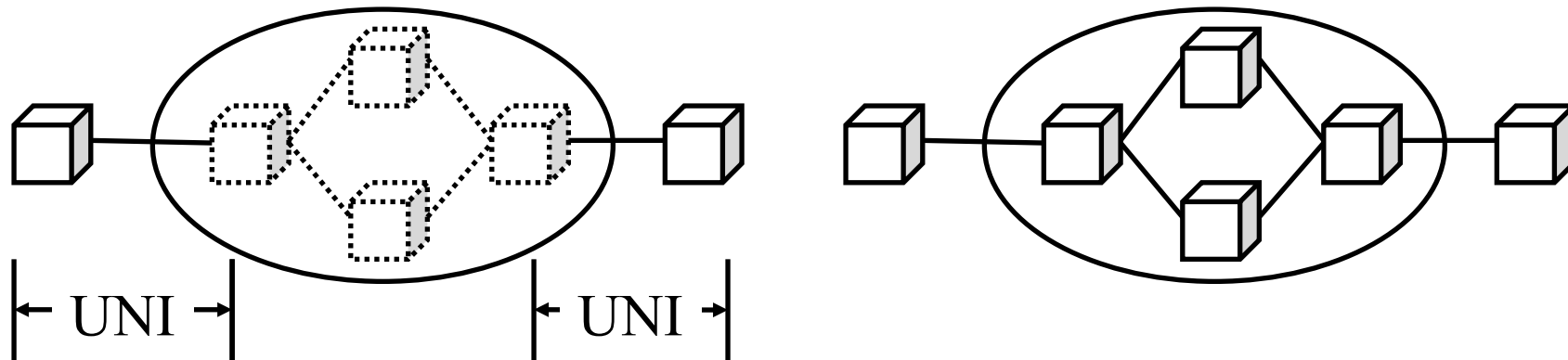
- ❑ Is it possible for bridges in PBN or PBBN to check every packet passing through the network and conditionally drop packets if the target address of that packet is not on the rule table specified by the remote controller?

*Rules table contains several rules about what to do with packets not in the table and when to drop a packet.*

# 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
  - A complete exchange of information



## Student Questions

- About UNI vs. peer-to-peer, is there any difference in L3 level and up?

*UNI can be L2, L2.5, or L3, depending on the service provided by the carrier. Higher layers are not visible to the carrier.*

- Can you please highlight the difference between these two figures?

*Left is the user view of the carrier network. Right is the view for network owners (enterprise or carrier)*

- What do the dashed lines imply?

*Only visible to users within the network.*

- OIF is deleted from the slide. Is it omitted from the test?

*If it is in the video, it is not omitted from the test.*

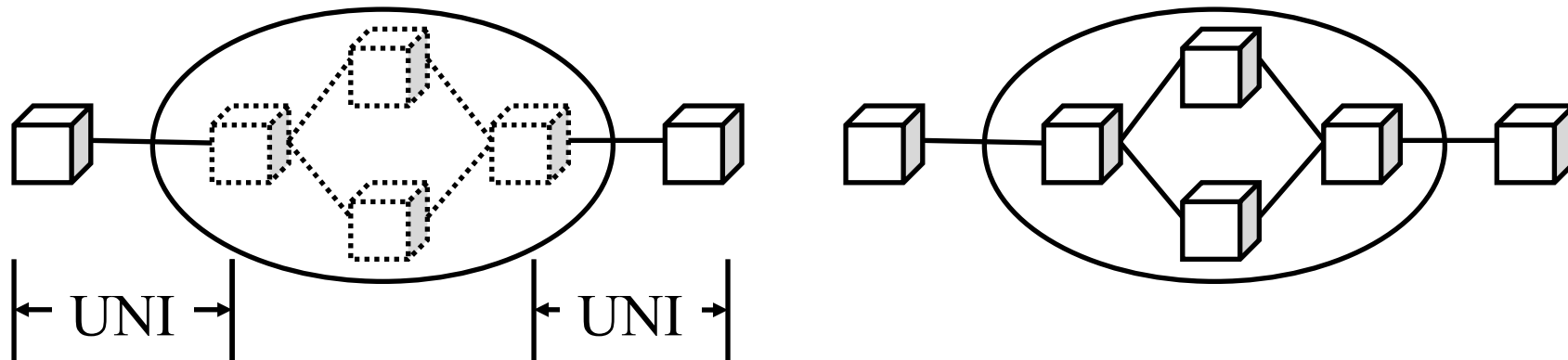
- Isn't it bad "security-wise" for an enterprise to share all network info with other enterprises?

*Yes. No one shares the info with others. Peer-to-peer is used inside the enterprise. BGP is used between enterprises but does not disclose the internal network.*

- In P2P, what type of info is shared?  
*OSPF is a P2P routing protocol.*

# 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
    - ❑ A complete exchange of information



## Student Questions

- ❑ What is the relationship between peer-to-peer and ENNI? Is it the same?  
*No. ENNI is an “interface,” and P2P is a protocol. Interface=Door. Protocol=Language. For Ethernet, RJ45 is the interface.*

- ❑ In this example, is P2P the model being used within the Enterprise network? Could P2P be theoretically used to connect enterprises?

*P2P requires trust, and so it is used only inside an enterprise.*

- ❑ What are the benefits of choosing UNI or Peer to Peer Signaling?

*It is not a choice. UNI provides privacy to Carriers. They don't disclose their internal structure.*



# 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 customers traffic passes through an ENNI
- Tier 2 *operators* sell services to Tier 3 service providers.



## Student Questions

- ❑ Can ENNI connect two providers with the same tier level? *Yes.*
- ❑ The UNI example you gave was for wired phones. Is there an equivalent between a provider and a cellphone?

*Yes, the interface between the cell phone and the tower is an example of a UNI.*

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

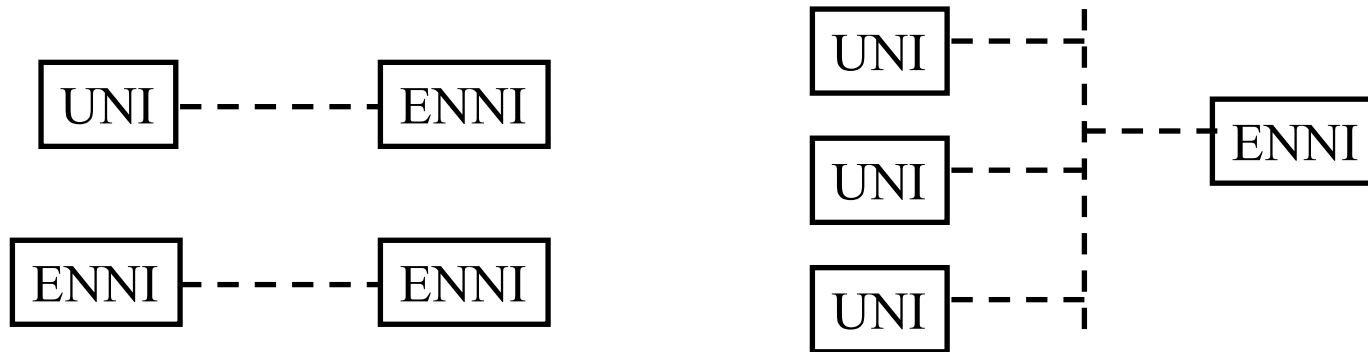
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# Operator Virtual Connection (OVC)

- ❑ 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 slides 6.19 and 6.20.*

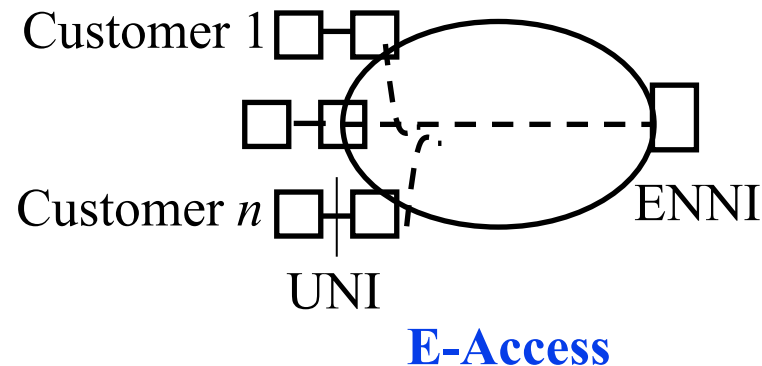
- ❖ Is a point-to-point connection between a UNI and ENNI a realistic setup? It seems that in practice, you would always have multiple users connected to a provider.

*The right-side picture shows multiple users connected to a single ENNI.*

# 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 ⇒ Different from p2p EPL.



**E-Access**

## Student Questions

- Is this true for all services to the home? Or is it an extra cost?

*Most home services from carriers are EPL. Cable operator's network service may not be EPL.*

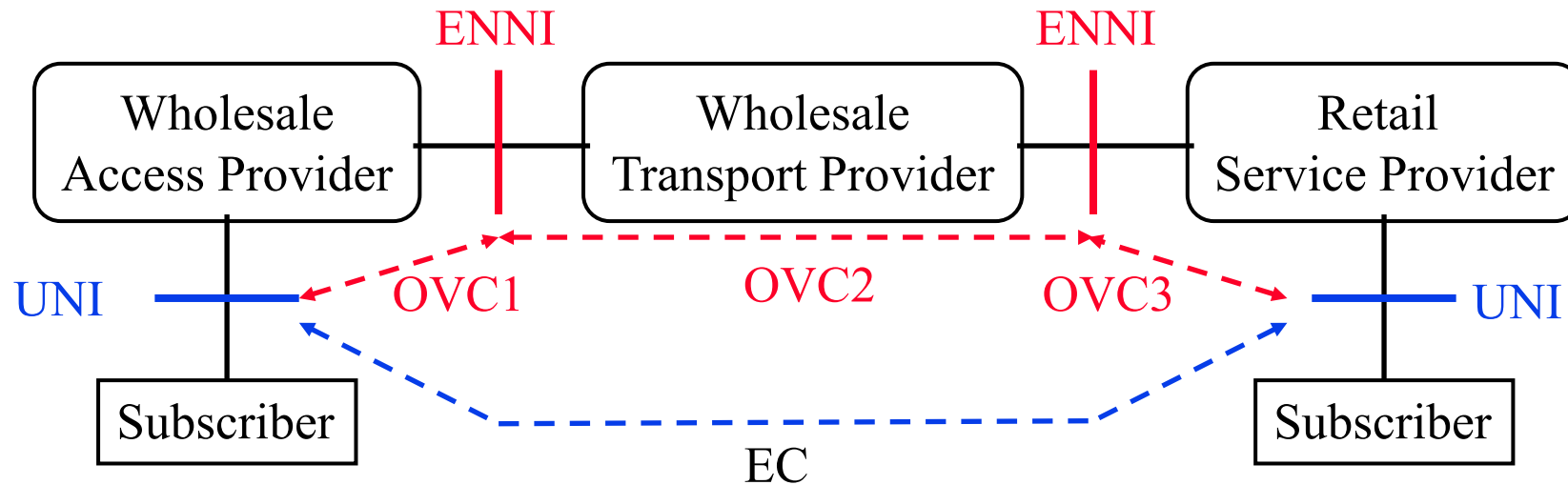
- Which tier provides Access-EPL?  
*Generally, Tier-3. However, some carriers offer Tier 2 and Tier 3 or Tier 1, 2, and 3. They are called by their lowest tier number.*

- What does the word "E-Access" refer to?

*Ethernet access.*

# End-to-End Metro Ethernet Connection

- An EC may go through multiple service providers  
⇒ Multiple OVCs can be concatenated to create an EC



## Student Questions

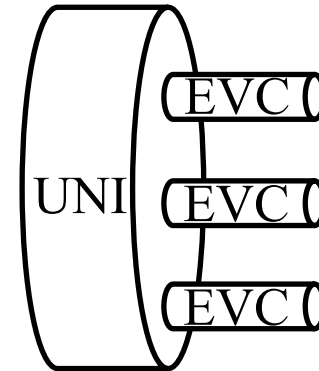
- What is the difference between wholesale and retail?  
*Wholesale=Large quantities*  
*Retail=Small quantities*  
*Example: Mint, Tello, and Red Pocket offer mobile phone service using AT&T infrastructure.*

- What network advantages does OVC have over real fiber (aside from cost)?  
*All advantages of sharing. Less maintenance and cost.*

- Is EC just a name for the path comprised of OVCs?

# Ethernet Virtual Connections (EVCs)

- ❑ **Port-based ECs:** Forwarding not based on VLANs. Frames delivered to remote UNI/ENNI for P2P or Based on the 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, do I need to confirm that “OVCs are always virtual and EVCs' are not”?

*Both OVC and EVCs are virtual.*

- ❑ What are the use cases for each of the types of EVCs?

*The line to connect a building  
Tree to connect multiple nearby buildings*

*LAN to connect many nearby buildings*

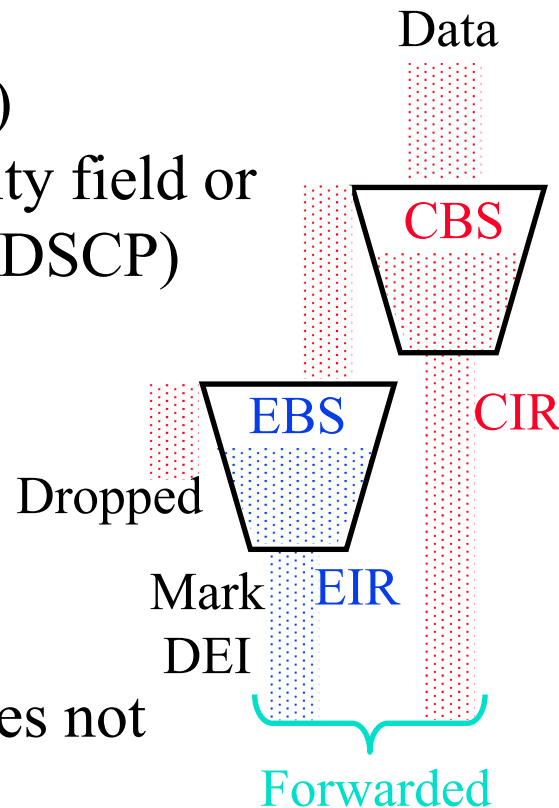
*EVPL from an access provider.*

*Ref:*

<https://wiki.mef.net/display/CESG/Carrier+Ethernet>

# Metro Ethernet Service Attributes

- ❑ Bandwidth Profiles: Limits on data rates
  - 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)
- ❑ The rate specified by five 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)

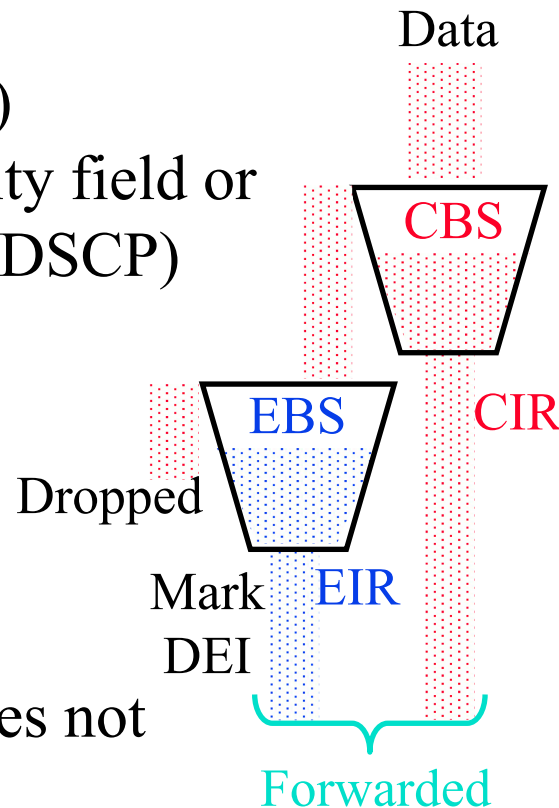


## Student Questions

- ❑ What is the packet-dropping policy?  
Random, drop the packet first packet or drop the last packet?  
*Generally, “Drop Tail” ≡ Last arriving packet is dropped. RED=Random Early Drop has been suggested but not used in carrier networks.*
- ❑ Does the color mode depend on the customer service agreement or the type of data/priority?  
*Customer Service Agreement. The type of data is not visible to the carrier. The agreement may include priority in Ethernet level service or class of service byte in IP level services.*
- ❑ Is this DEI the same field that is in the VLAN tag?  
*Yes.*
- ❑ Is there a difference between QoS and CM?  
*CM is a part of the “Class of Service.”  
QoS=Quality of Service.*
- ❑ For those packets marked with DEI, will they be dropped in the future?  
*Yes, anytime there is congestion anywhere, DEI-marked packets are dropped first.*

# Metro Ethernet Service Attributes

- ❑ Bandwidth Profiles: Limits on data rates
  - Ingress Profile: Incoming data rate
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- ❑ CoS is indicated by the 3-bits in the priority field or 4-bit Differentiated Services Code Point (DSCP)
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  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)



## Student Questions

- ❑ What are the practical differences between using the 3-bit priority field and the 4-bit Differentiated Services Code Point (DSCP) to indicate Class of Service (CoS)?

*Priority is now an old concept.*

*DSCP provides classes of service.*

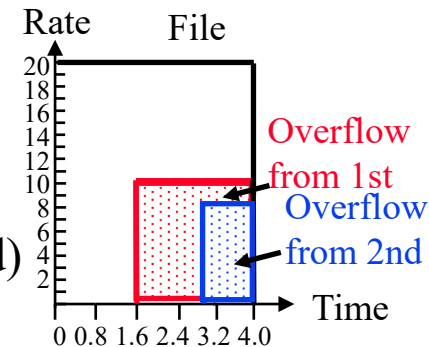
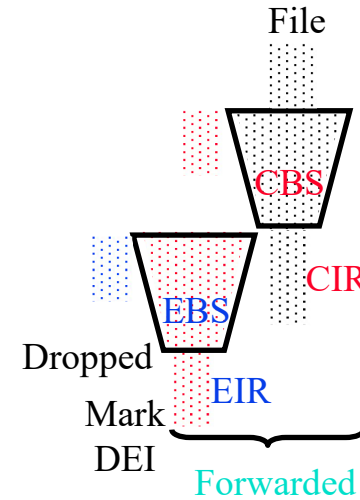
- ❑ Is this setup meant for streaming? If not, is the data in the overflow bin the most recently uploaded? Is it safe to label it DEI?

*DEI is helpful for video streaming.*

*Carriers strictly monitor the incoming rate, even for non-streaming services.*

# 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
- ❑ 1<sup>st</sup> Bucket fill rate = 20-10 = 10 Mbps, 1<sup>st</sup> Bucket fill time = 16/10 = 1.6s  
Total output from 1<sup>st</sup> bucket = 4\*10 Mbps + 16 Mb = 56 Mb (committed) = 70%
- ❑ 1<sup>st</sup> Bucket Overflow time = 4-1.6 = 2.4s  
1<sup>st</sup> bucket Overflow amount = 2.4 s\*(20-10) Mbps = 24 Mb
- ❑ 2<sup>nd</sup> bucket fill Rate = 10-2 = 8 Mbps  
2<sup>nd</sup> bucket fill time = Size/Rate = 8 Mb/8 Mbps = 1 s  
Total output from 2<sup>nd</sup> bucket = 0\*1.6 + 2\*(4 - 1.6) + 8 = 12.8 Mb (Marked) = 16%
- ❑ 2<sup>nd</sup> Bucket overflow time = 4 - 1.6 - 1 = 1.4s  
2<sup>nd</sup> bucket overflow amount = (10-2)\*1.4 = 11.2 Mb (Dropped) = 14%
- ❑ Check: Total = 56+12.8+11.2 = 80 Mb



## Student Questions

- ❑ What does the marked data mean?  
*Marked ⇒ DEI set.*
- ❑ For the 2<sup>nd</sup> bucket, the fill rate is 10 - 2 = 8. Where is the ten come from? Is it the 1<sup>st</sup> 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. It would be best if you did the same.*



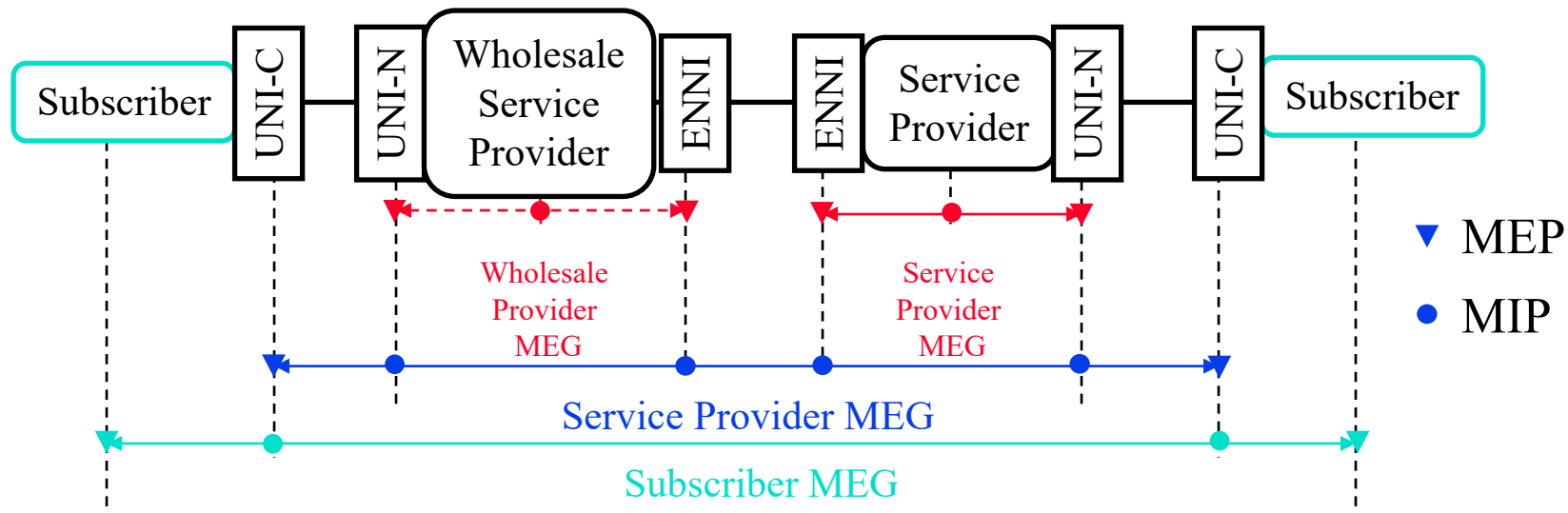
## Homework 6

- 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?

### Student Questions

# Metro Ethernet OAM

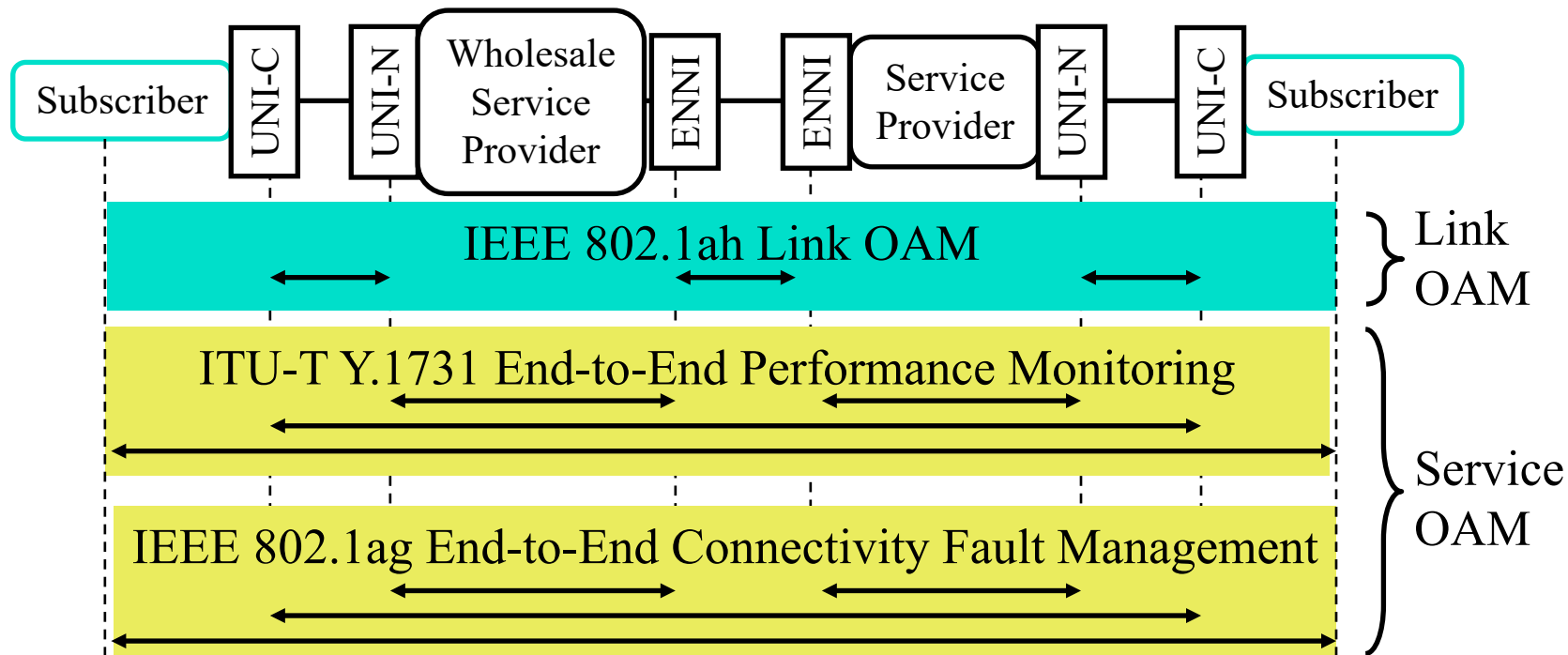
- ❑ Operation, Administration, and Maintenance (OAM)
- ❑ Defined in IEEE 802.1ag, IEEE 802.1ah, and ITU Y.1731
- ❑ Maintenance End Points (MEPs)
- ❑ Maintenance Intermediate Points (MIPs)
- ❑ Maintenance Entity Group (MEG): Level of Administration



## 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

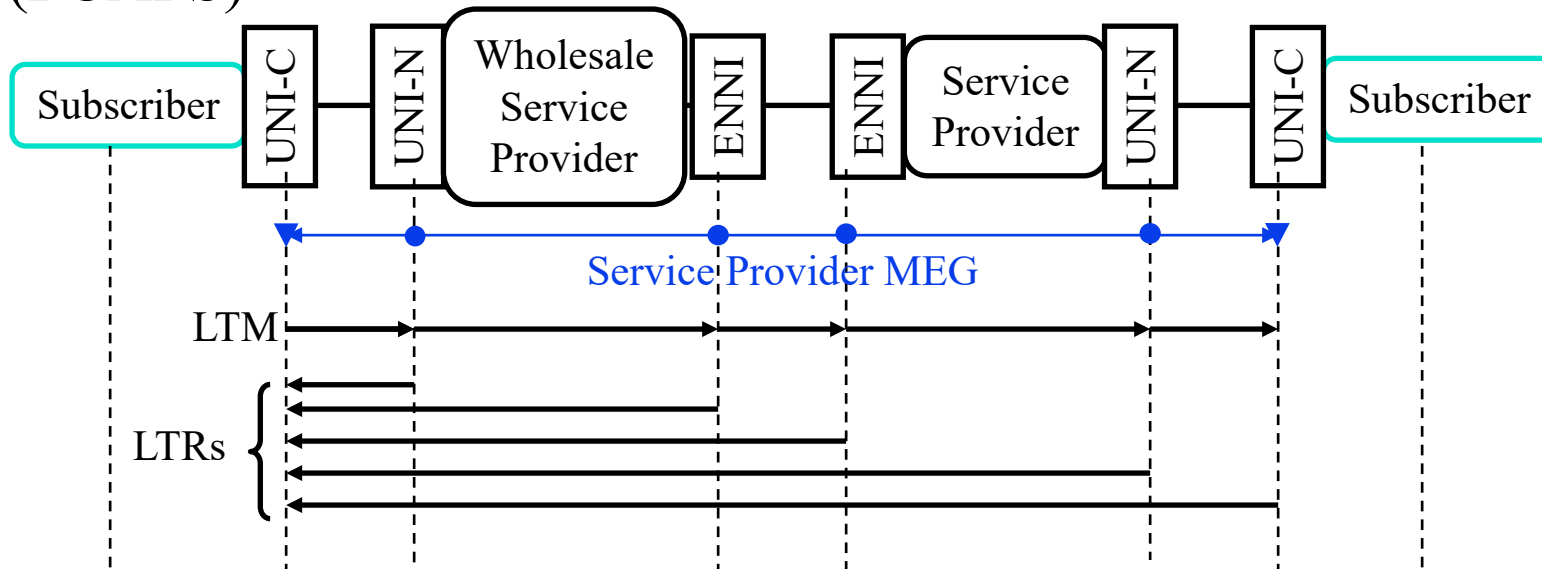
- ❑ Is Link OAM L1? Service OAM is L2 and L3? *Yes.*

- ❑ what is the difference between Link OAM and Service OAM? Is that one for the link and one for the whole service?

*A phone service may use many links. Each link needs a Link OAM. The phone service needs its OAM to ensure it is working.*

# 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 endpoint and intermediate point (similar to IP trace route)
- ❑ Fault, Configuration, Accounting, Performance, Security (FCAPS)

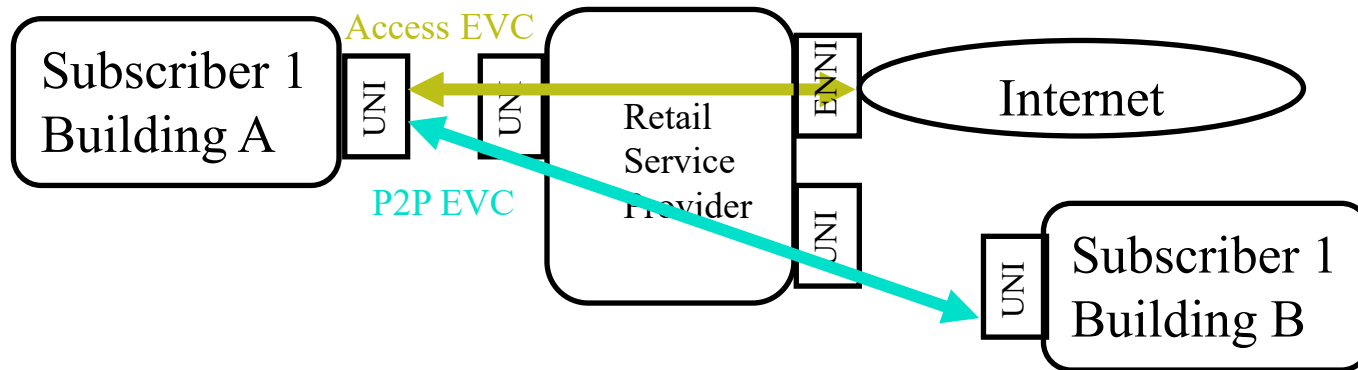


## Student Questions

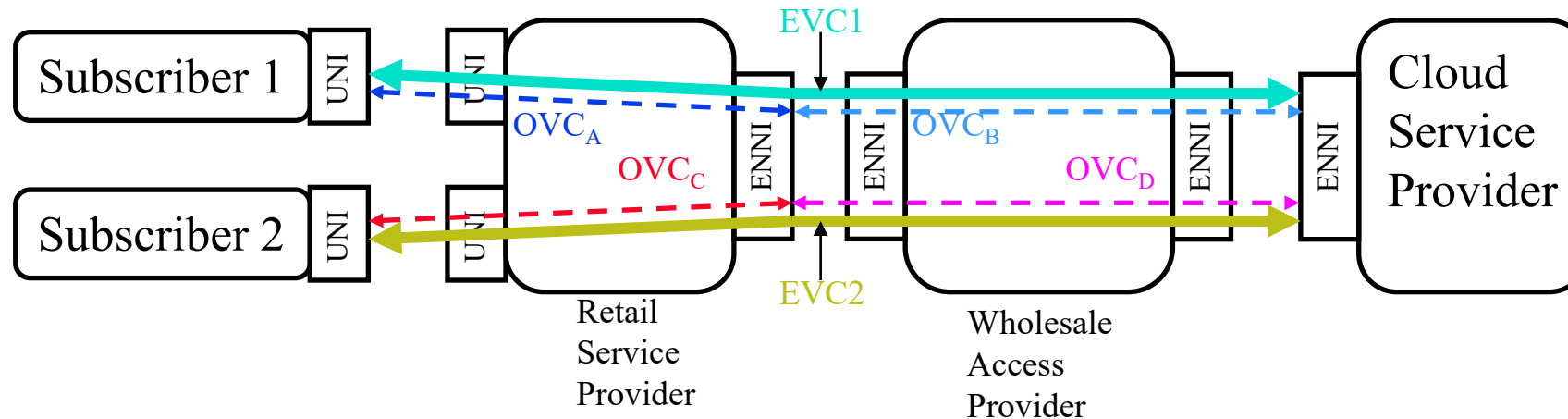
- ❑ Is C in FCAPS for configuration or capacity? *C=Configuration*

# Metro Ethernet Use Cases

## 1. Head office to Satellite offices and/or Internet



## 2. Customers to Cloud Service Provider



## Student Questions

- ❖ Are UNIs user-specific? Could you draw the UNIs on the bottom image's retail service provider as one?

*No, UNI is the standard interface for users. It needs to be customer-specific. It may be service-specific. For example, RS-45 is the hardware interface for Ethernet service. RJ11 for telephone service. Similarly, UNI is the hardware/ software interface for user-to-network communications.*

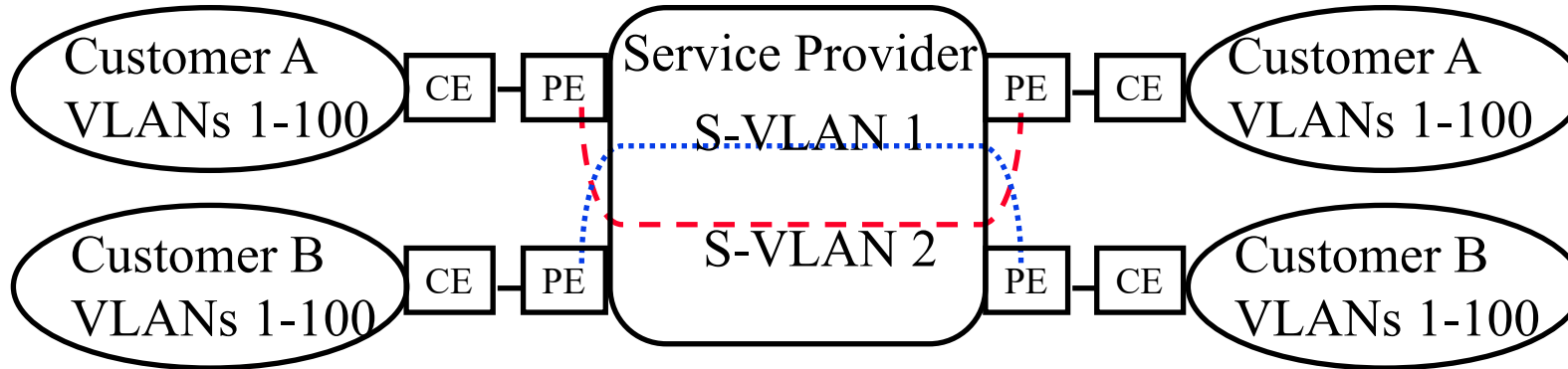


RJ11



RJ48

# Ethernet Provider Bridge (PB)



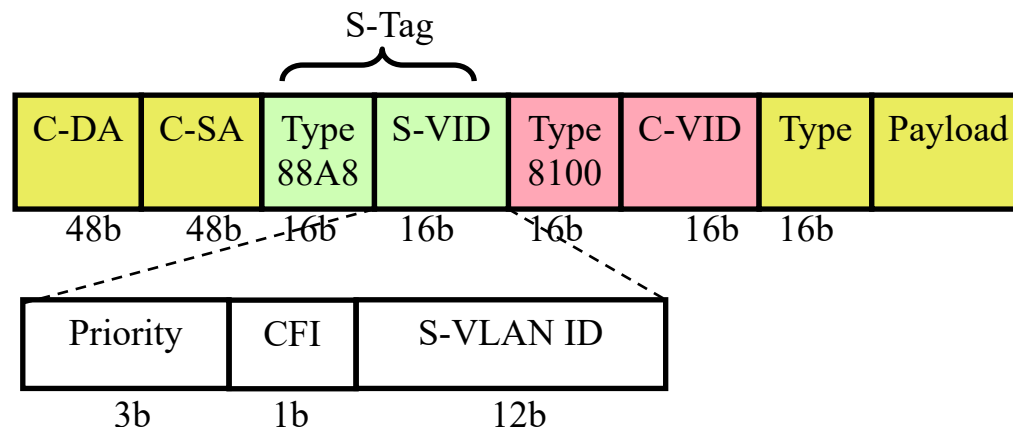
- ❑ IEEE 802.1ad-2005 incorporated in IEEE 802.1Q-2011
- ❑ Problem: Multiple customers may have the same VLAN ID. How do we keep them separate?
- ❑ Solutions:
  1. VLAN translation: Change customer VLANs to provider VLANs and back
  2. VLAN Encapsulation: Encapsulate customer frames

## Student Questions

- ❑ If the VLAN IDs are the same, what would their MAC addresses be? Also, the same?  
*No. MAC addresses are fixed and are not virtualized. Each device in the universe has a unique MAC address. The administrator assigns VLAN IDs, and could be identical.*
- ❑ Would you compare VLAN encapsulation to be similar to Labels in MPLS?  
*Yes. VLANs have been around longer. MPLS is related to IP also. Thus, VLANs are L2, while MPLS is L2.5.*

# 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



## Student Questions

- ❑ Is S-Tag the same as TPI (Tag Protocol Identifier) learned in 'Data Center Ethernet'?

*That was Q-Tag. This has precisely the same format but a different "Type" value.*

- ❑ Doesn't the data size of the packet decrease if S-Tag is additionally added?

*The packet size increases. Data size does not decrease. This is invisible to the user.*

- ❑ Is the priority of 0-7 from high to low or low to high?

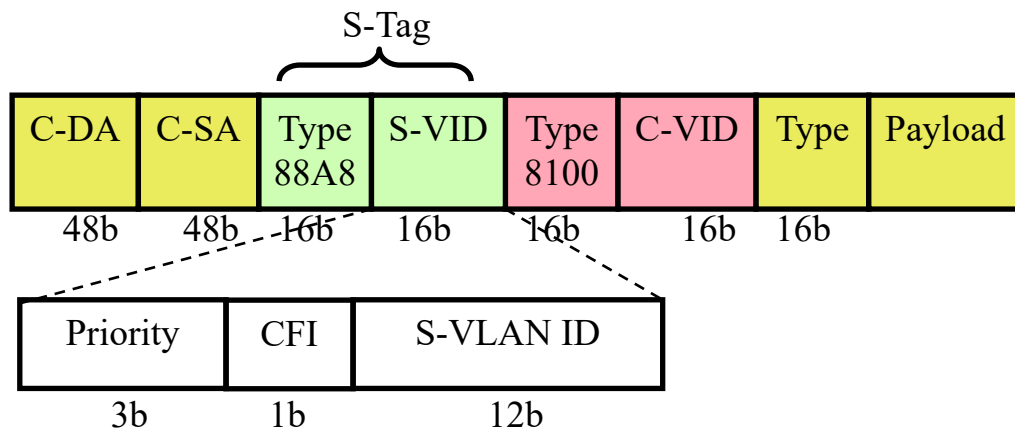
*7=Highest*

- ❑ In this slide, it says Q-in-Q encapsulation is "Provider inserts a service VLAN tag....Changes VLAN using a table", but the quiz says "customers can freely choose their own VLAN IDs," and the answer is "true." Is it correct?

*Yes, the answer is correct since the carriers did not touch customers' VLANs before this standard. The customer and provider divided the VLAN space into two parts – one part for the customer. Other for the provider.*

# Provider Bridge (Cont)

- ❑ Q-in-Q Encapsulation: Provider inserts a service VLAN tag
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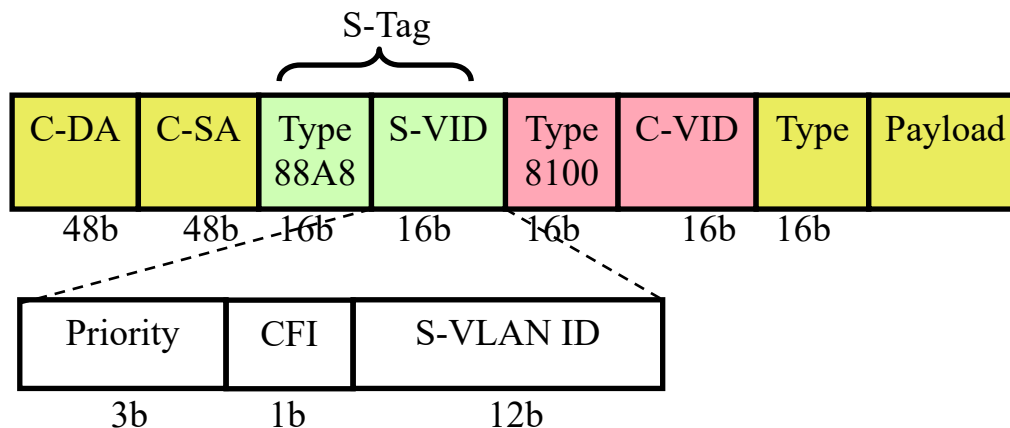
## Student Questions

- ❑ In the picture, which part is the VLAN tag?  
*Green and Pink*
  - ❑ What are the meanings of the colors in this picture? *To separate the fields.*
  - ❑ The green portion and the pink portion have the same contents. Is the pink portion also an S-tag? *Pink=V-Tag, Green=S-Tag*
  - ❑ Could you explain more about C-DA and C-SA? *Customer Source Address (C-DA) and Customer Source Address (C-SA)*
- 
- ❑ How do the traffic classes get determined again?  
*By the administrator of the serving network.*
  - ❑ How do customers choose their VLAN IDs?  
*The administrator assigns them based on the person's security domain.*



# Provider Bridge (Cont)

- ❑ Q-in-Q Encapsulation: Provider inserts a service VLAN tag  
VLAN translation Changes VLANs using a table
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- ❑ 8 Traffic Classes using Differentiated Services Code Points (DSCP) for Assured Forwarding



## Student Questions

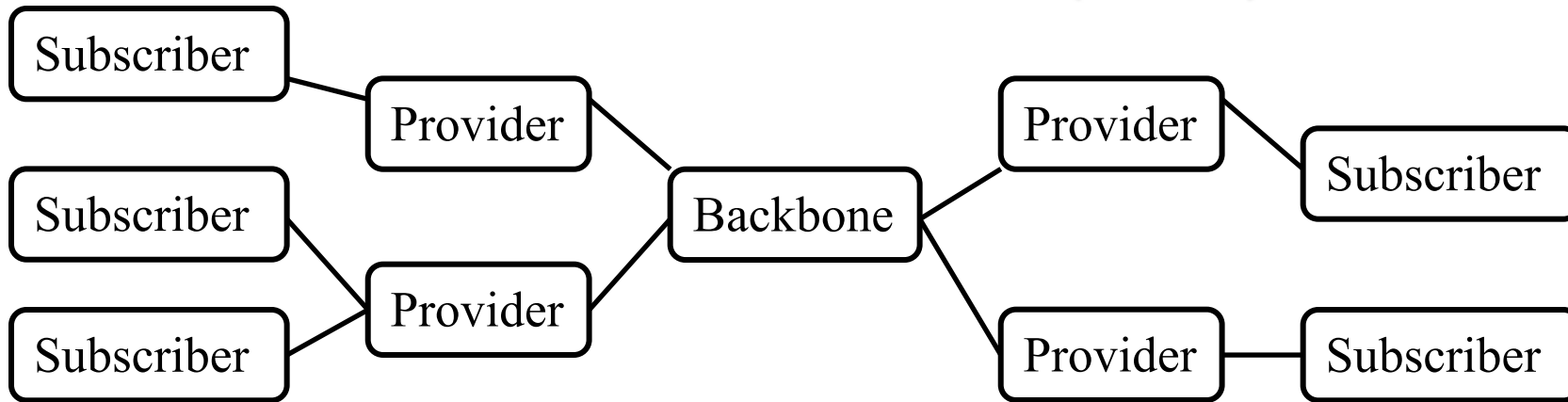
- ❑ What does the Q in Q-in-Q and Q-in-Q in general mean?

*802.1Q. This is the name of the first VLAN standard.*

- ❑ So, does this encapsulation method support more customer VLANs than the VLAN translation method?

*Of course. Each of the 4K customers can have their own 4K VLANs.*

# Provider Backbone Network (PBB)



- ❑ Problem: The number of MAC addresses passing through backbone bridges is too large for all core bridges 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 the ingress backbone bridge and egress backbone bridge  
⇒ Core bridges only know edge bridge addresses.

## Student Questions

- ❑ Even with IEEE 802.1ah-2008 incorporated in 802.1Q-2011 does this get flooded?

*Yes, broadcasts are sent to all to all nodes on all VLANs.*

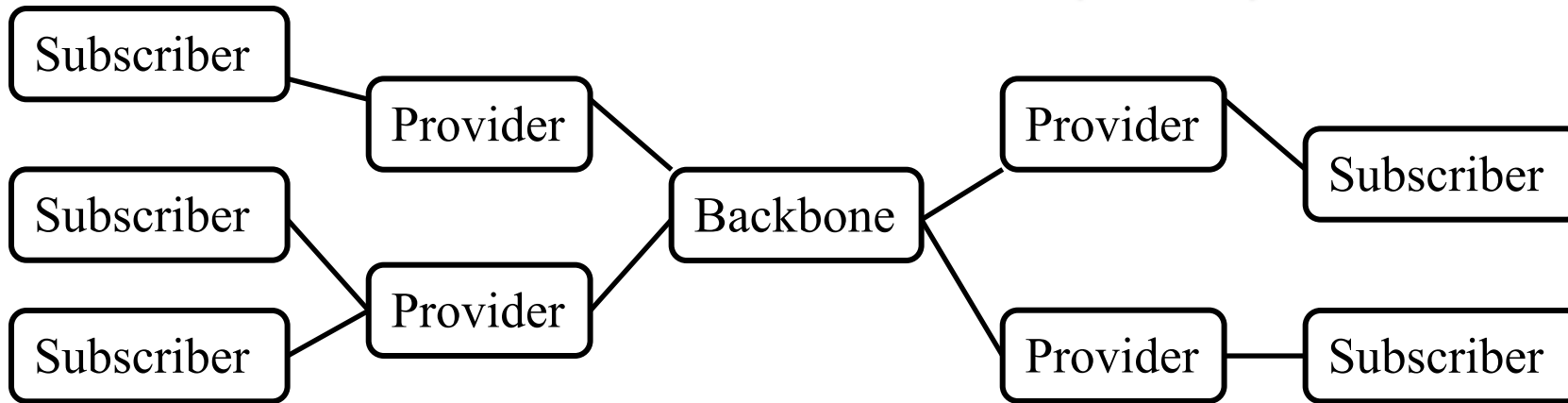
- ❑ How does a PBB enhance network performance?

*No need for translation.*

- ❑ Is this switching by edge bridge MAC addresses similar to MPLS switches only on a tag instead of an IP address?

*Yes. Bridges have nothing to do with IP addresses. They are pure L2 devices. With VLANs, they have to be selective about where your packets get sent.*

# Provider Backbone Network (PBB)



- ❑ Problem: The number of MAC addresses passing through backbone bridges is too large for all core bridges 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 the ingress backbone bridge and egress backbone bridge  
⇒ Core bridges only know edge bridge addresses.

## Student Questions

- ❖ How the MAC-in-MAC frame solve the issue of too many MAC addresses?

*Each MAC packet is encapsulated inside another MAC packet.*

*Backbone routing is based on the outer header which contains only the backbone edge MAC addresses.*

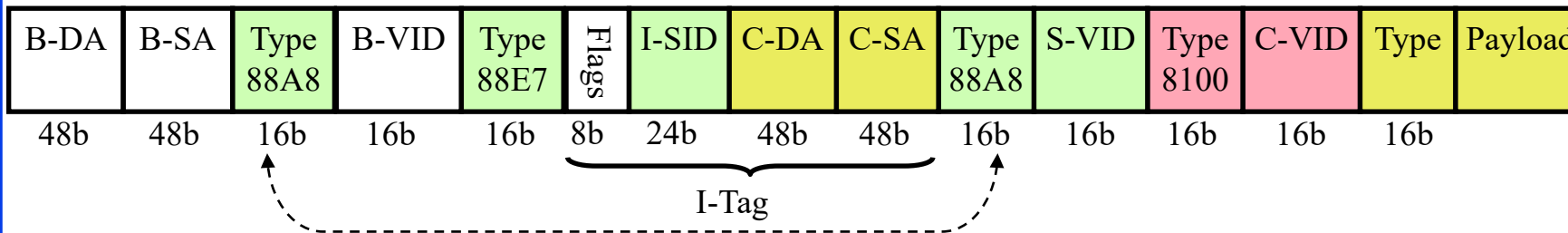
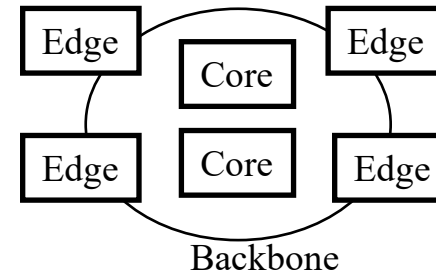


- ❖ Who owns the provider backbone network?

*Tier-1 carriers own the backbone network for many other Tier-1 and Tier-2 carriers.*

# MAC-in-MAC Frame Format

- ❑ Backbone edge bridges (BEB) forward to other BEBs 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



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

## Student Questions

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

*MAC in MAC adds*

$48+48+16+16+16+8+32=184\text{ b} = 23\text{ bytes to the frame.}$

- ❑ 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 this packet is being routed through PBB, and I should expect I-Tag afterward? Note: 88A8 is defined in IEEE as a Service VLAN Tag (S-TAG) or Backbone VLAN Tag (B-TAG), so it can indicate both!

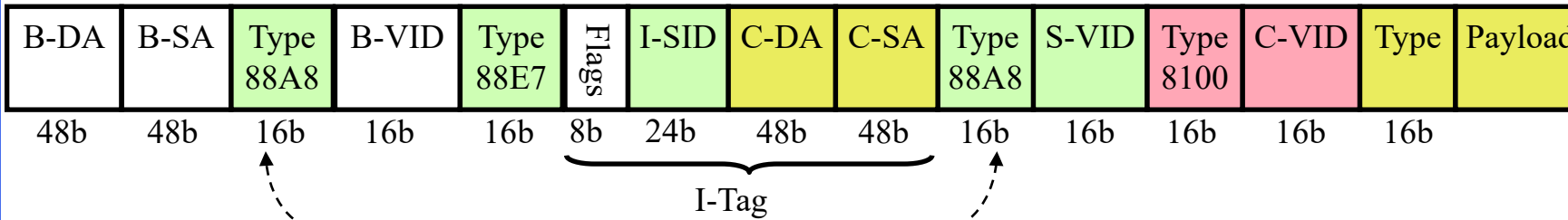
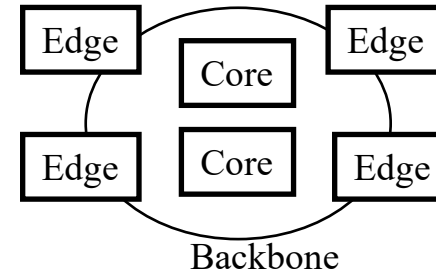
*Yes. Both B-Tag and S-Tag. B-Tag if outer, S-Tag if inner.*

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

*Learning happens at the edge, not at the core.*

# MAC-in-MAC Frame Format

- ❑ Backbone edge bridges (BEB) forward to other BEBs and learn customer MAC addresses  
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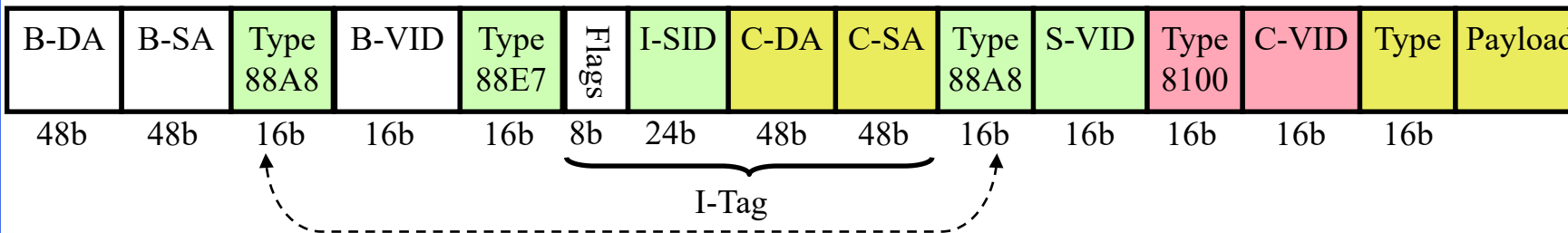
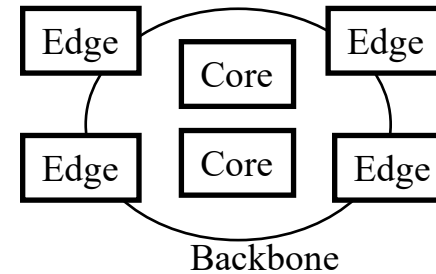
## Student Questions

- ❑ 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 the customer's packet (payload) that comes in.  
*Yes.*

- ❑ Are the BEB more capable than the BCB? Aren't they still having all the CE traffic the BCBs were getting? Or are there just more BEBs?  
*BEBs need more processing but are fewer in number than BCBs.*

# MAC-in-MAC Frame Format

- ❑ Backbone edge bridges (BEB) forward to other BEBs and learn customer MAC addresses  
⇒ Backbone *core* bridges (BCB) do not learn customer MACs
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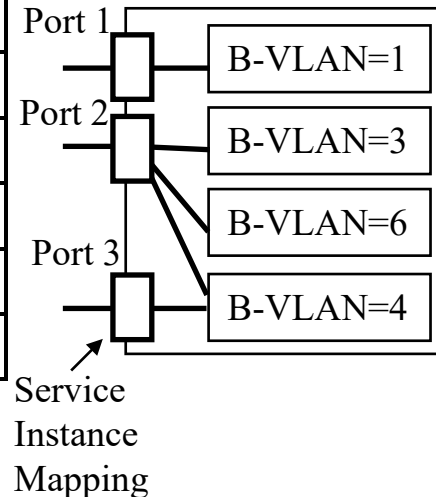
## Student Questions

- ❖ What is the I-Tag used for again?  
*I-Tag is used by the edge carriers to forward packets on its network. B-Tag is used by Backbone carriers. C-Tag is used by customers.*

# 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



## Student Questions

- ❑ What is B-VLAN? *Backbone VLAN*
- ❑ 88E7 indicates that I-tag is following, but what problem it solve? 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.*

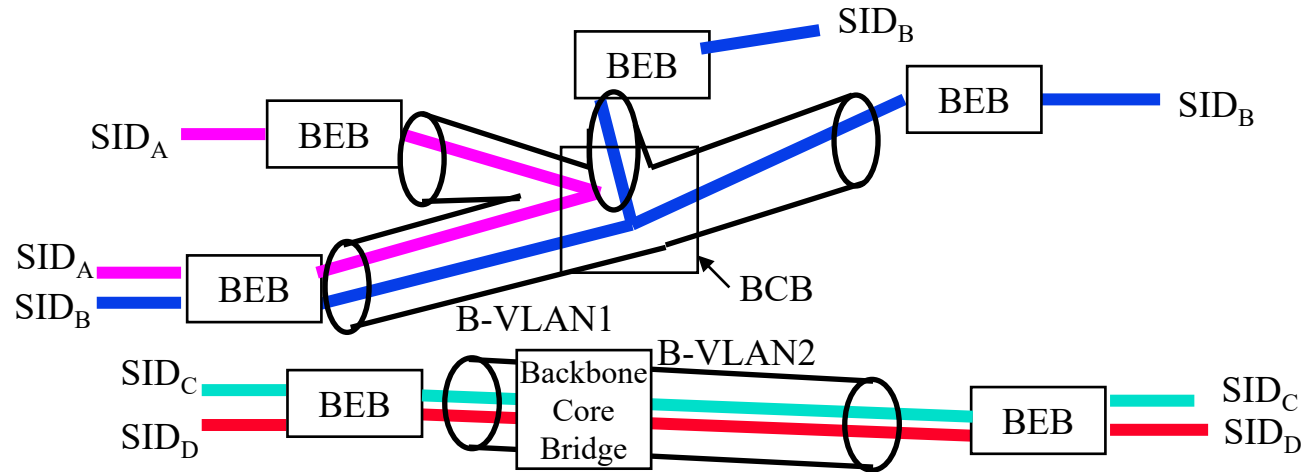
- ❑ Does PBB still assign service instance ID dynamically when a new flow is established, or is it wholly managed administratively like PBB-TE?

*The carrier business is much money. Everything has to be managed administratively.*

- ❑ Can you explain more about B-VLAN? How does it get numbered?

*B-VLAN numbering is decided by the carrier and the service purchased by the customer. Carrier offers several classes and types of service, similar to airline travel.*

# 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 is 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

## Student Questions

- ❑ What are more example services B-VLAN can carry?

*Long distance traffic*

*Bulk traffic*

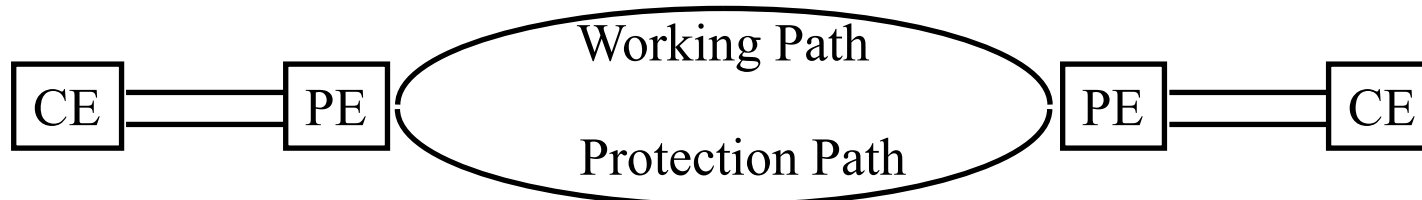
*Video Traffic*

*Data traffic*



# 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 bridge addresses
    - ❑ Path not determined by customer MAC addresses and other customer fields ⇒ More Secure
  - Reserved bandwidth per EVC
  - Pre-provisioned Protection path ⇒ Better availability

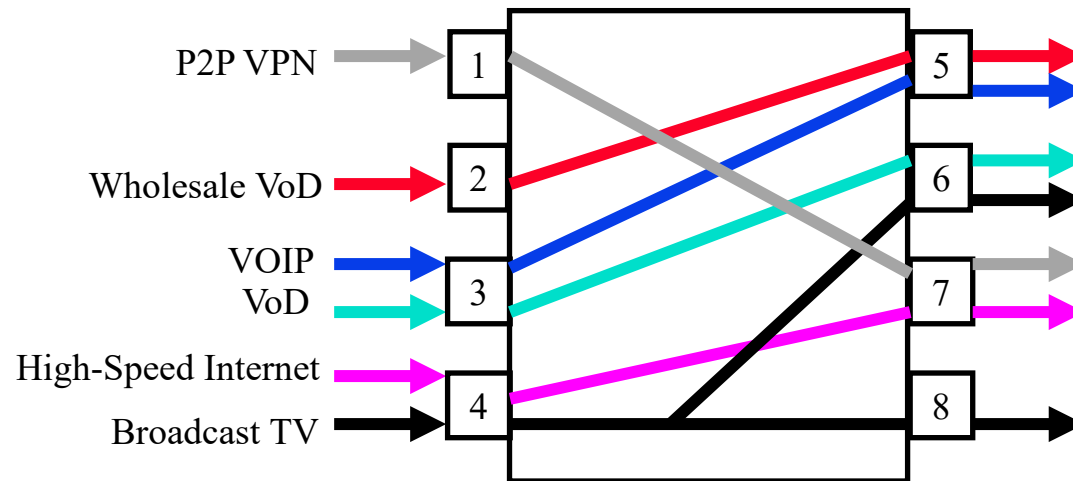


## Student Questions

# 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

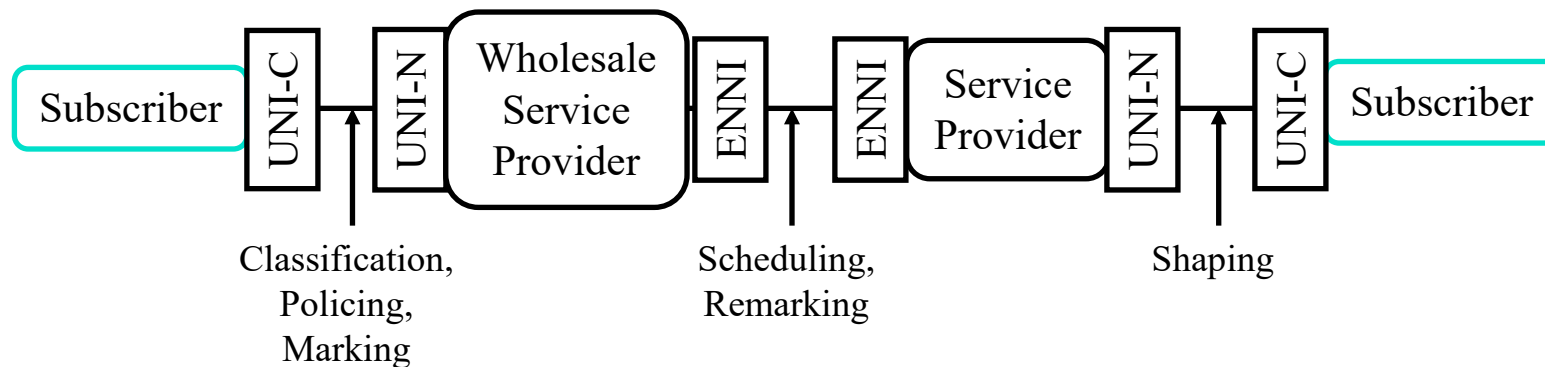
# PBB-TE

- ❑ 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 addresses and broadcasts.  
⇒ 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 MAC-in-MAC. No change.

## Student Questions

# 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



## Student Questions

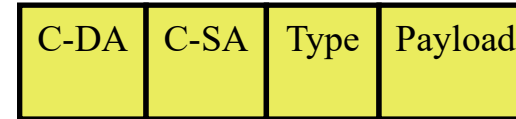
- ❑ So, do Carriers use MPLS in practice? Or do they not need to since we can use PBB-TE instead?

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

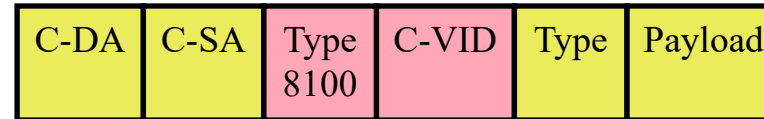
- ❑ Can carriers use PBB-TE?  
*Yes. PBB-TE is the IEEE's replacement for IETF's MPLS.*

# Ethernet Tagged Frame Format Evolution

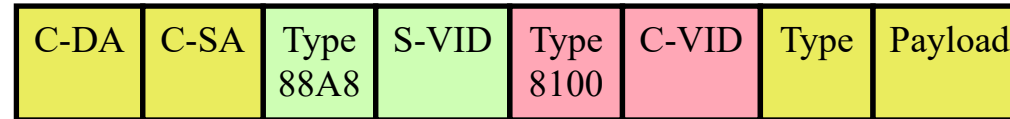
- Original Ethernet



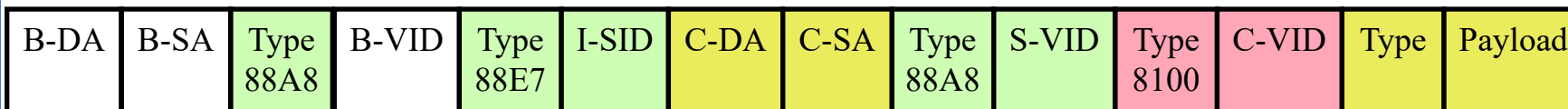
- IEEE 802.1Q VLAN



- IEEE 802.1ad PB



- IEEE 802.1ah PBB or 802.1Qay PBB-TE



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?

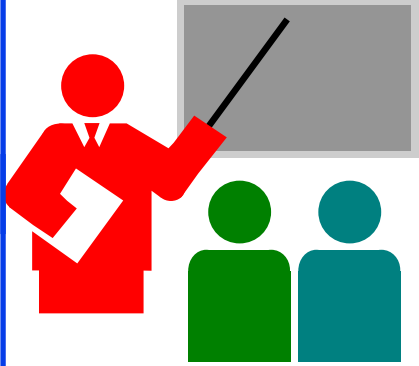
*Service Tag*

# Comparison of Technologies

	<b>Basic Ethernet</b>	<b>MPLS</b>	<b>PB</b>	<b>PBB-TE</b>
<b>Resilience</b>	No	Protection Fast Reroute	SPB/LAG	Protection Fast Reroute
<b>Security</b>	No	Circuit Based	VLAN	Circuit Based
<b>Multicast</b>	Yes	Inefficient	Yes	No. P2P only
<b>QoS</b>	Priority	Diffserve	Diffserve+ Guaranteed	Diffserve+ Guaranteed
<b>Legacy Services</b>	No	Yes (PWE3)	No	No
<b>Traffic Engineering</b>	No	Yes	No	Yes
<b>Scalability</b>	Limited	Complex	Q-in-Q	Q-in-Q+ Mac-in-MAC
<b>Cost</b>	Low	High	Medium	Medium
<b>OAM</b>	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.tacs.eu/Analyses/Ethernet/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/Carrier_Ethernet)
- ❑ [http://en.wikipedia.org/wiki/Connection-oriented\\_Ethernet](http://en.wikipedia.org/wiki/Connection-oriented_Ethernet)
- ❑ [http://en.wikipedia.org/wiki/Ethernet\\_Private\\_Line](http://en.wikipedia.org/wiki/Ethernet_Private_Line)
- ❑ [http://en.wikipedia.org/wiki/Ethernet\\_Virtual\\_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_802.1ad)
- ❑ [http://en.wikipedia.org/wiki/IEEE\\_802.1ag](http://en.wikipedia.org/wiki/IEEE_802.1ag)
- ❑ [http://en.wikipedia.org/wiki/IEEE\\_802.1ah-2008](http://en.wikipedia.org/wiki/IEEE_802.1ah-2008)
- ❑ [http://en.wikipedia.org/wiki/Metro\\_Ethernet](http://en.wikipedia.org/wiki/Metro_Ethernet)
- ❑ [http://en.wikipedia.org/wiki/Metro\\_Ethernet\\_Forum](http://en.wikipedia.org/wiki/Metro_Ethernet_Forum)
- ❑ [http://en.wikipedia.org/wiki/Network-to-network\\_interface](http://en.wikipedia.org/wiki/Network-to-network_interface)
- ❑ [http://en.wikipedia.org/wiki/Operations,\\_administration\\_and\\_management](http://en.wikipedia.org/wiki/Operations,_administration_and_management)
- ❑ [http://en.wikipedia.org/wiki/Provider\\_Backbone\\_Bridge\\_Traffic\\_Engineering](http://en.wikipedia.org/wiki/Provider_Backbone_Bridge_Traffic_Engineering)
- ❑ [http://en.wikipedia.org/wiki/Traffic\\_policing](http://en.wikipedia.org/wiki/Traffic_policing)
- ❑ [http://en.wikipedia.org/wiki/Traffic\\_shaping](http://en.wikipedia.org/wiki/Traffic_shaping)
- ❑ [http://en.wikipedia.org/wiki/User%E2%80%93network\\_interface](http://en.wikipedia.org/wiki/User%E2%80%93network_interface)
- ❑ [http://en.wikipedia.org/wiki/Virtual\\_Private\\_LAN\\_Service](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



Raj Jain

<http://rajjain.com>

[http://www.cse.wustl.edu/~jain/cse570-23/m\\_06cee.htm](http://www.cse.wustl.edu/~jain/cse570-23/m_06cee.htm)

## Student Questions

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

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

- Also, the reading list from last year's slides does 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? It's mentioned in the video but not added to the slides!

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

---



# Related Modules



CSE567M: Computer Systems Analysis (Spring 2013),

[https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n\\_1X0bWWNyZcof](https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof)

CSE473S: Introduction to Computer Networks (Fall 2011),

[https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcg5e\\_10TiDw](https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcg5e_10TiDw)



Wireless and Mobile Networking (Spring 2016),

[https://www.youtube.com/playlist?list=PLjGG94etKypKeb0nzyN9tSs\\_HCd5c4wXF](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