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

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 initially 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.

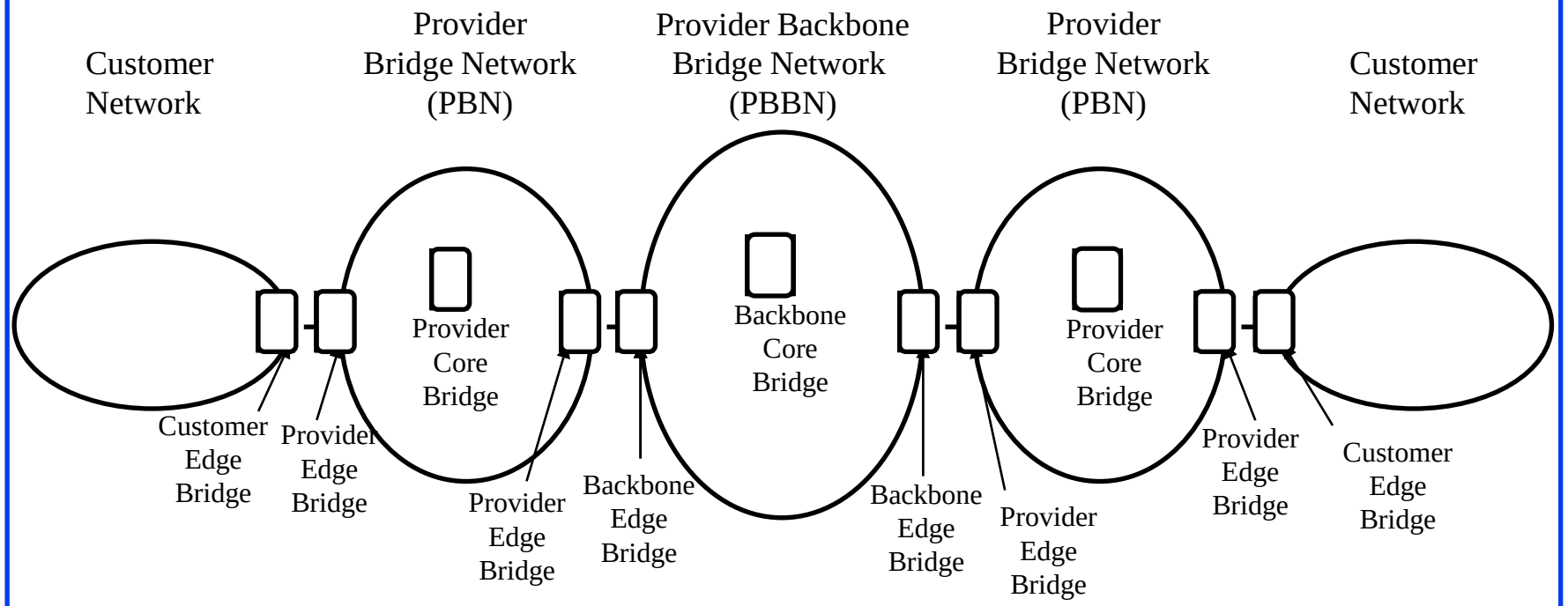
- Could we say AT&T also is an enterprise? What I mean is that AT&T is a carrier but also is an enterprise.

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

Carriers vs. Enterprise

Student Questions

Network Hierarchy



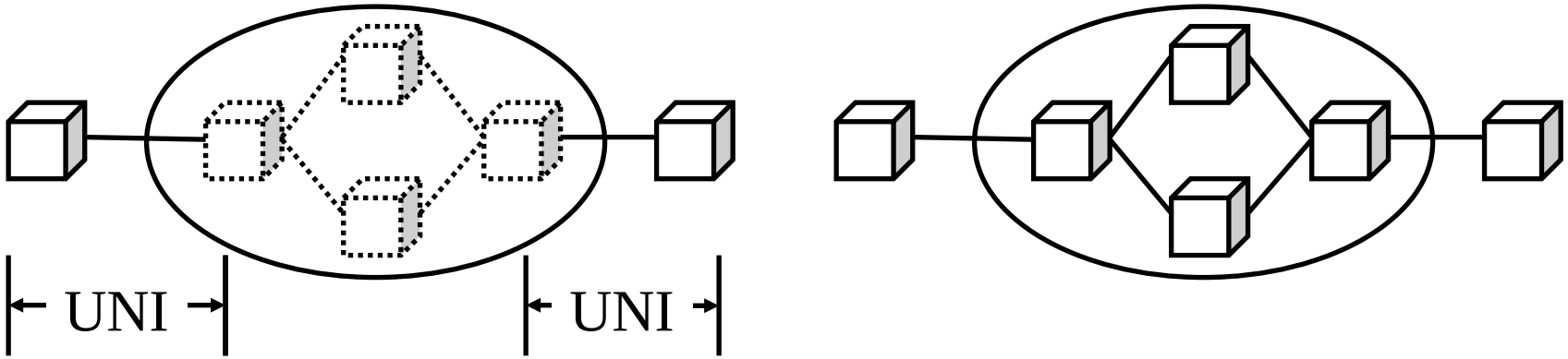
Student Questions

- 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.

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:
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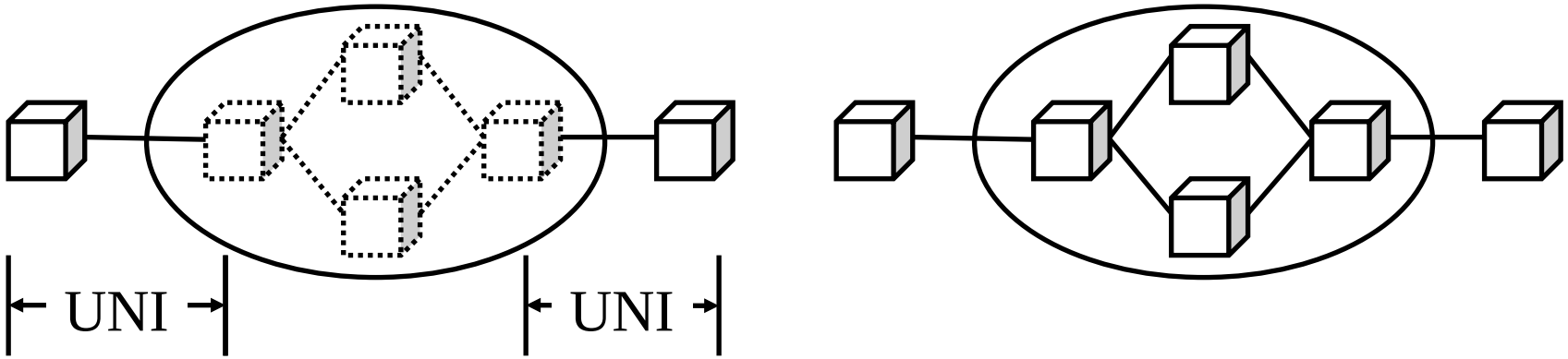


Student Questions

- 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.

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.

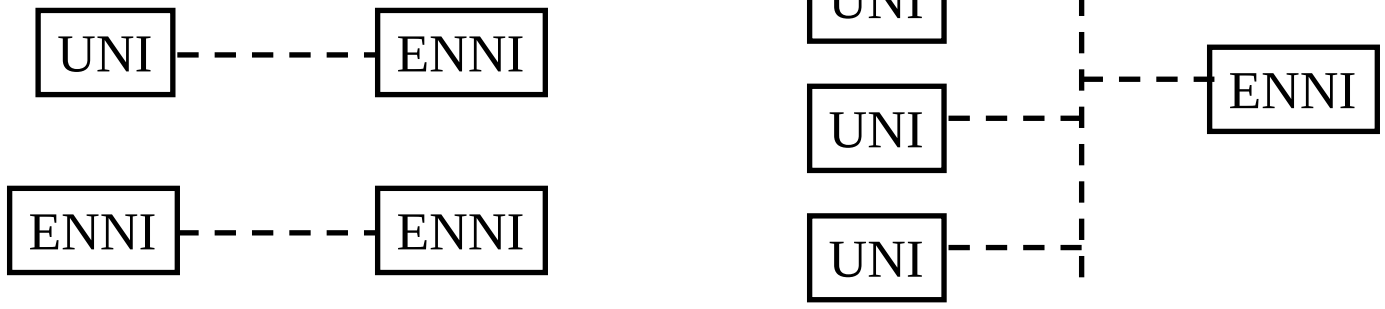
Student Questions

- Can ENNI connect two providers with the same tier level? *Yes.*

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

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.



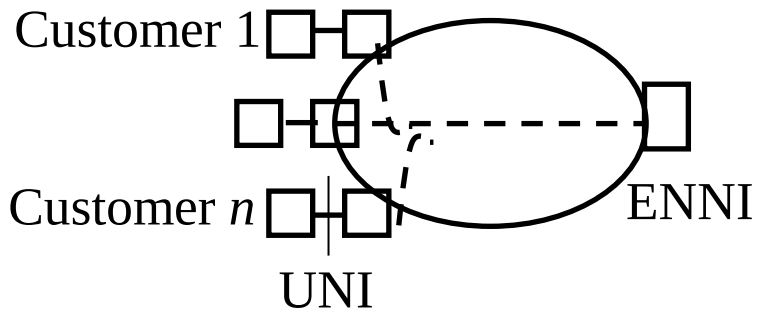
Student Questions

- What is Q-in-Q?

802.1Q inside another 802.1Q packet. See slides 6.19 and 6.20.

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?

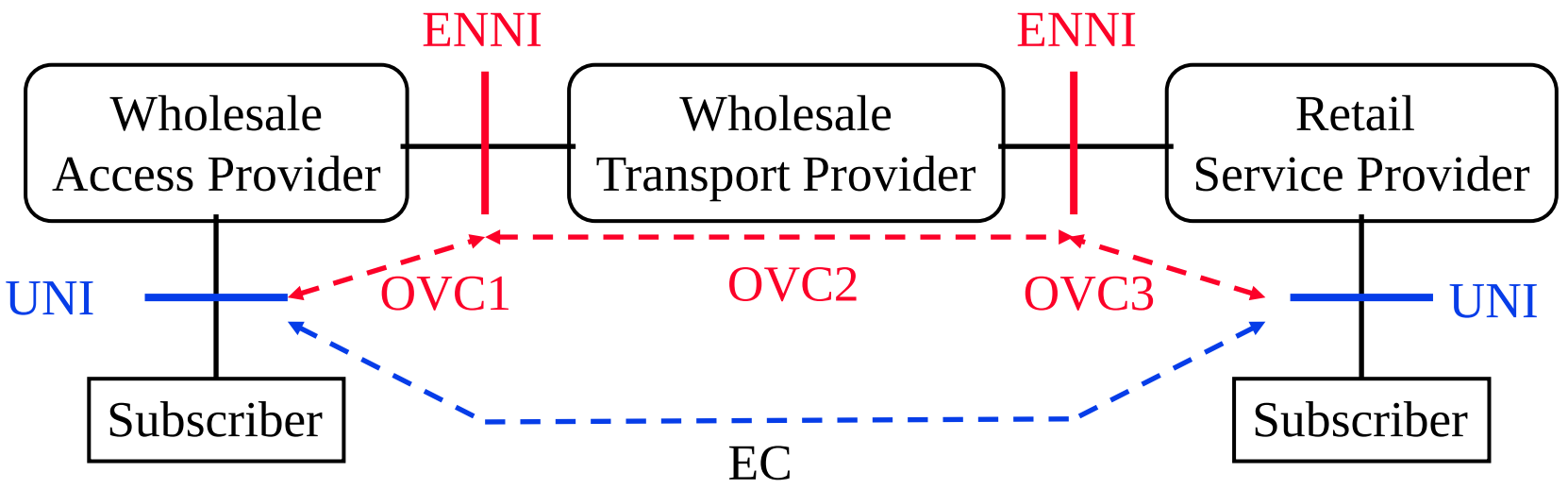
Most home services from carriers are EPL. Cable operator's network service may not be EPL.

- 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.

End-to-End Metro Ethernet Connection

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



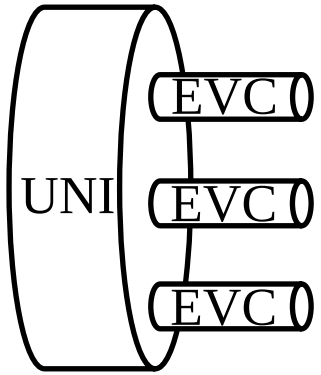
Student Questions

- 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.

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?

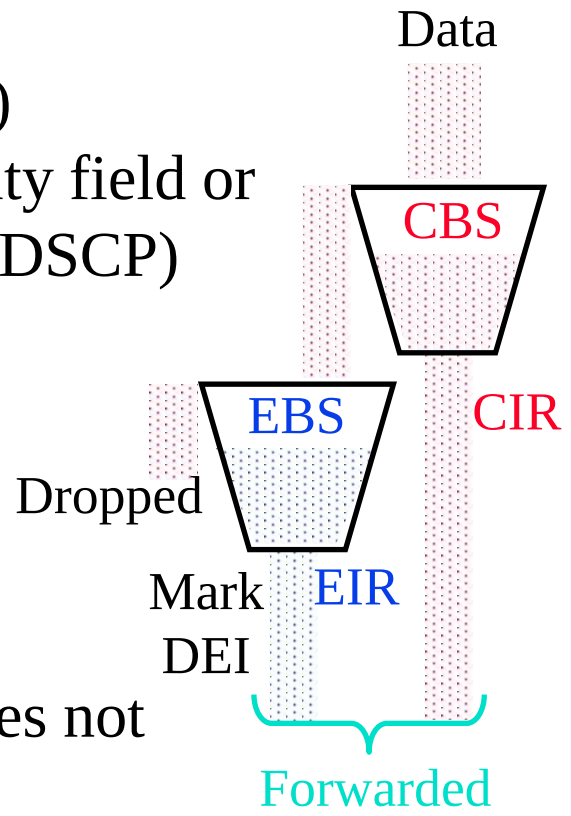
Yes. Port=Physical, VLAN=Virtual.

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

Both OVC and EVCs are virtual.

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)
- 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

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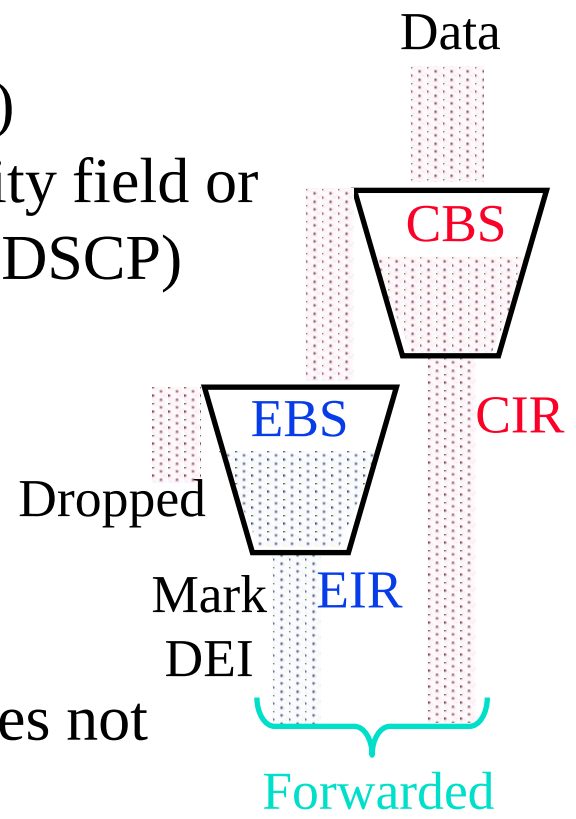
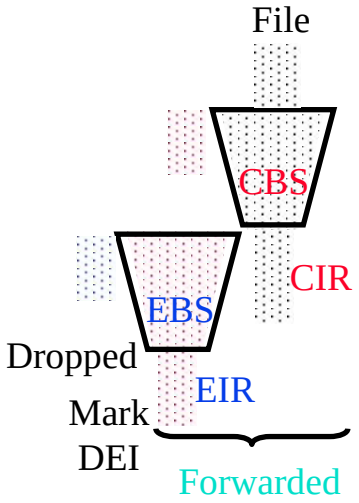
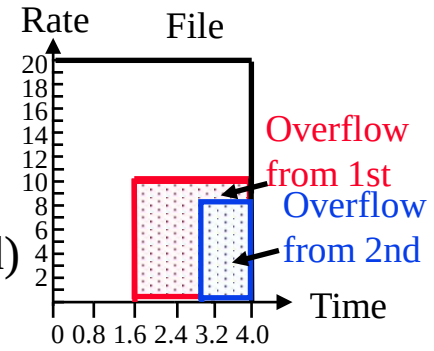


Student Questions

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





Student Questions

- What does the marked data mean?

Marked ⇒ DEI set.

- For the 2nd bucket, the fill rate is 10 – 2 = 8. Where is the ten 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. It would be best if you did the same.

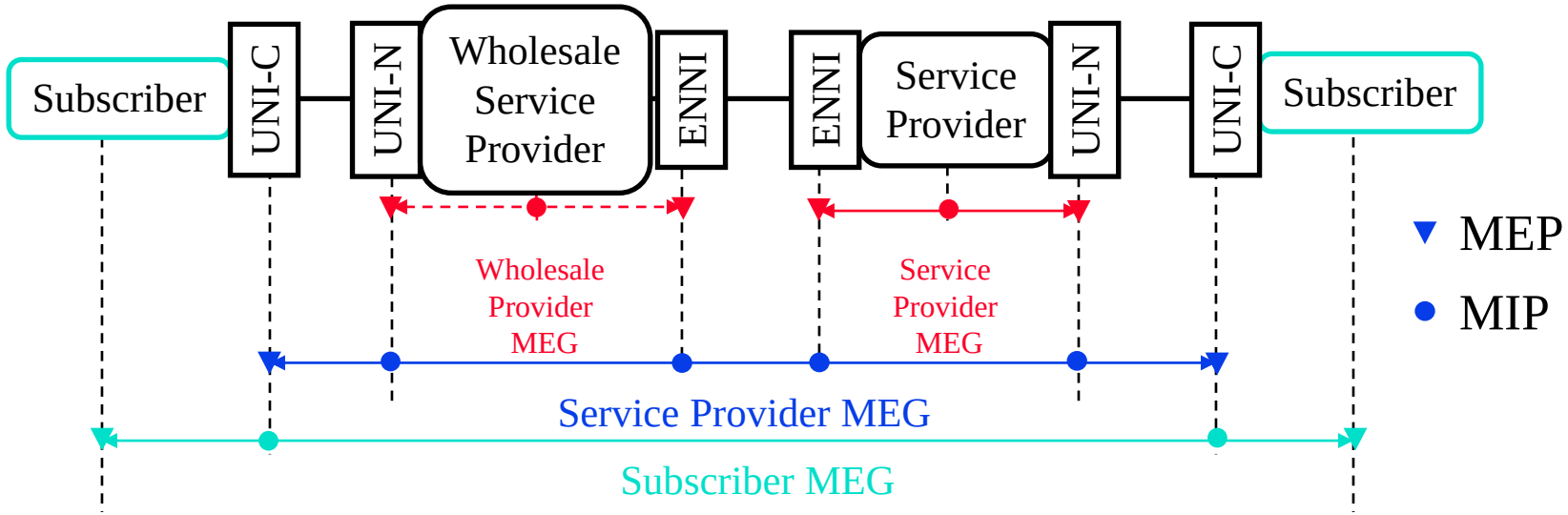
Homework 6

- 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

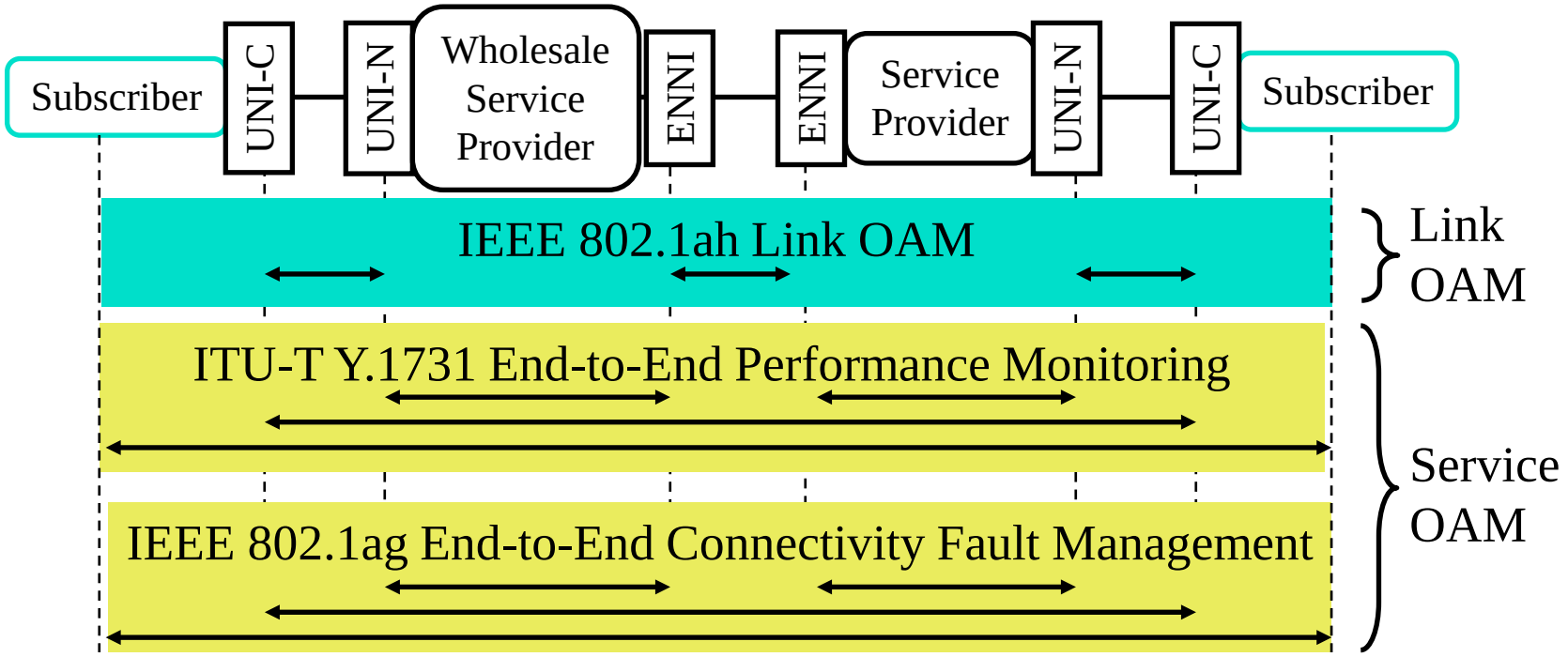
- Operation, Administration, and Maintenance (OAM)
- Defined in IEEE 802.1ag, IEEE 802.1ah, and ITU Y.1731
- Maintenance End Points (MEPs)
- Maintenance Intermediate Points (MIPs)
- Maintenance Entity Group (MEG): Level of Administration



Student Questions

Metro Ethernet OAM (Cont)

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

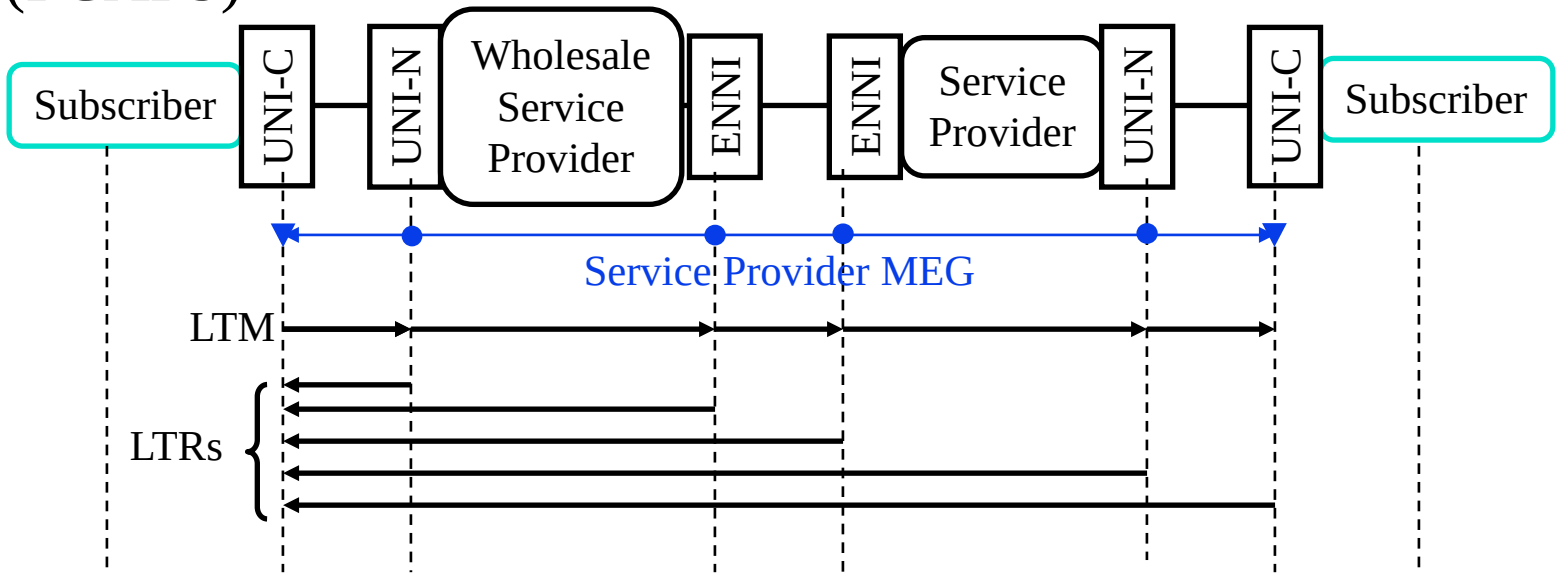


Student Questions

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

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)

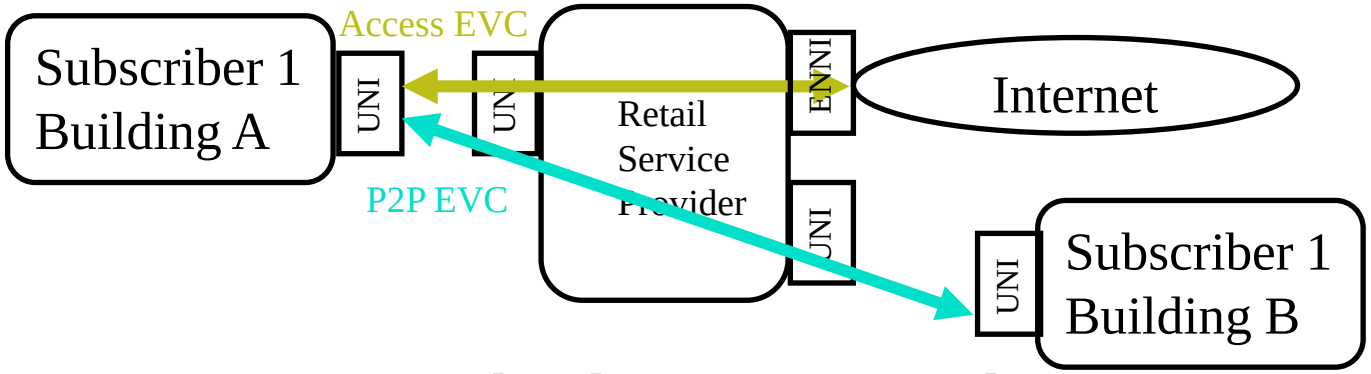


Student Questions

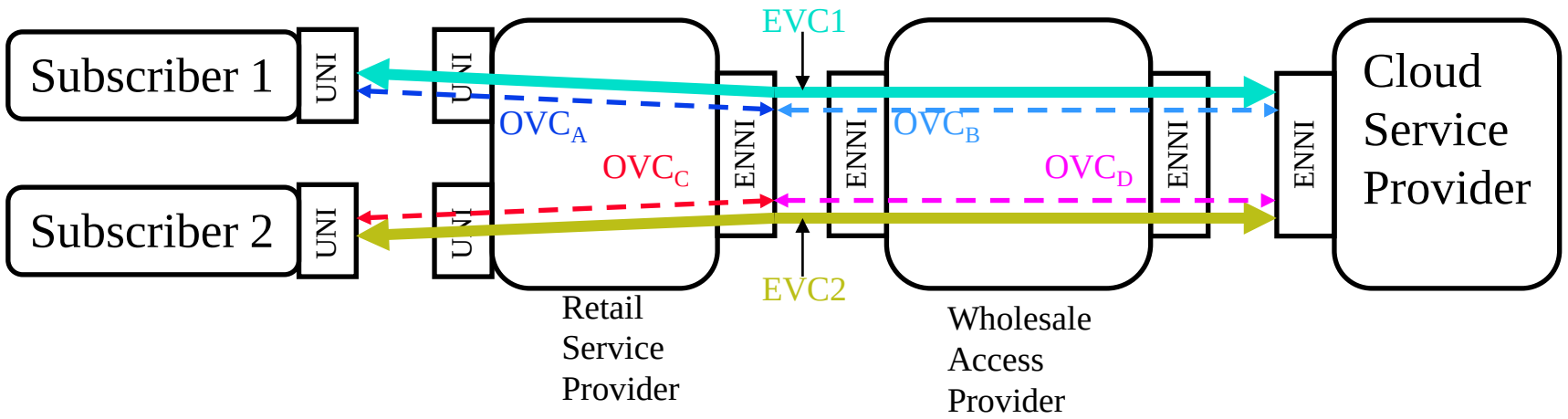
- Is C in FCAPS for configuration or capacity? *C=Configuration*

Metro Ethernet Use Cases

1. Head office to Satellite offices and/or Internet



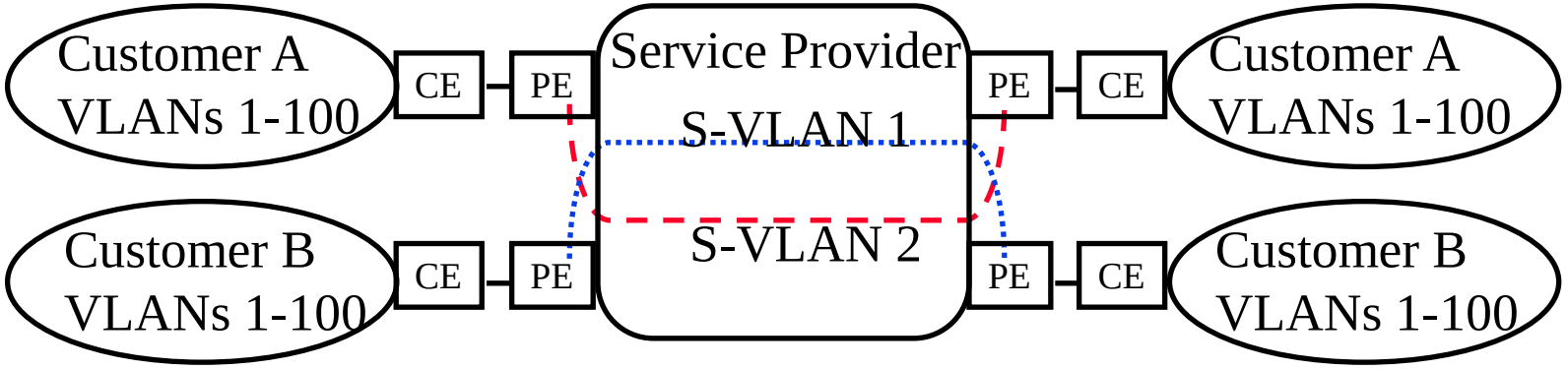
2. Customers to Cloud Service Provider



Student Questions

End of Part 1

Ethernet Provider Bridge (PB)

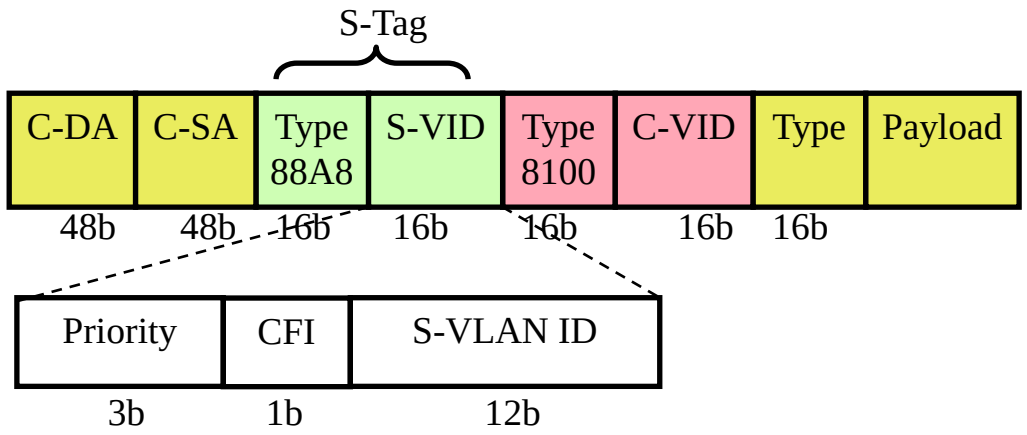


- IEEE 802.1ad-2005 incorporated in IEEE 802.1Q-2011
- Problem: Multiple customers may have the same VLAN ID. How do we keep them separate?
- Solutions:
  1. VLAN translation: Change customer VLANs to provider VLANs and back
  2. VLAN Encapsulation: Encapsulate customer frames

Student Questions

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 VLAN translation Changes VLANs using a table
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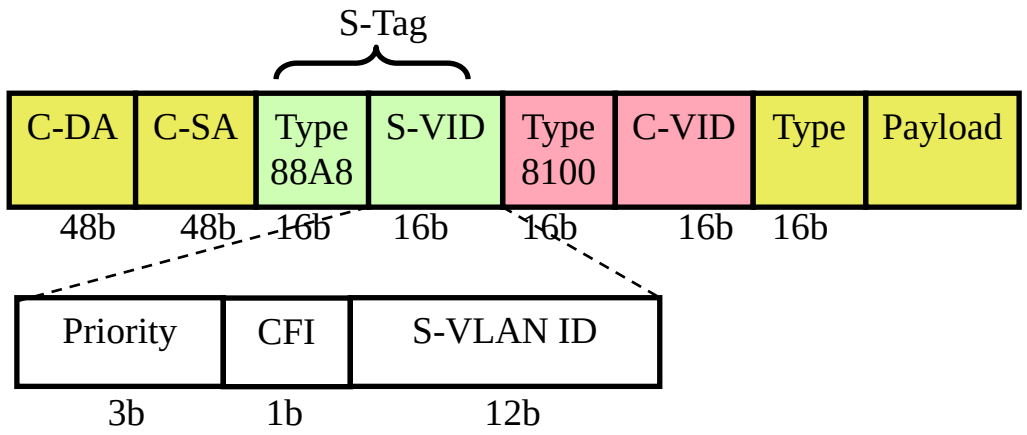


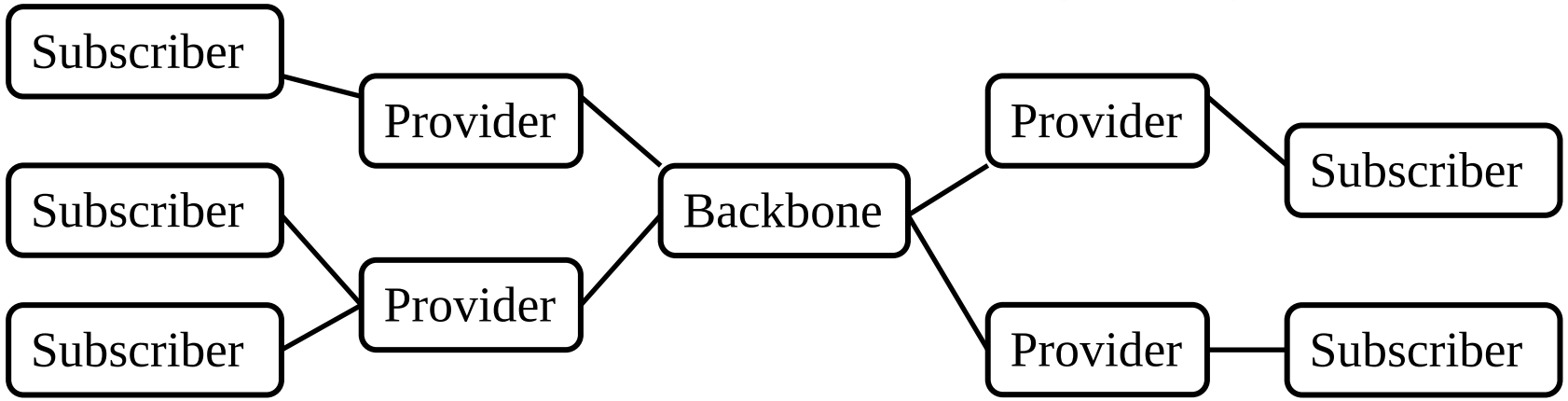
Student Questions

- 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)*

Provider Backbone Network (PBB)

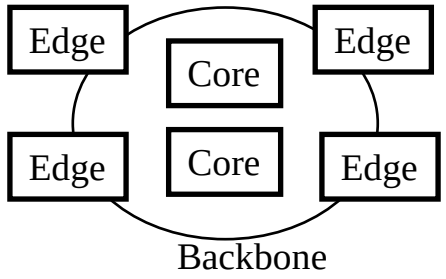


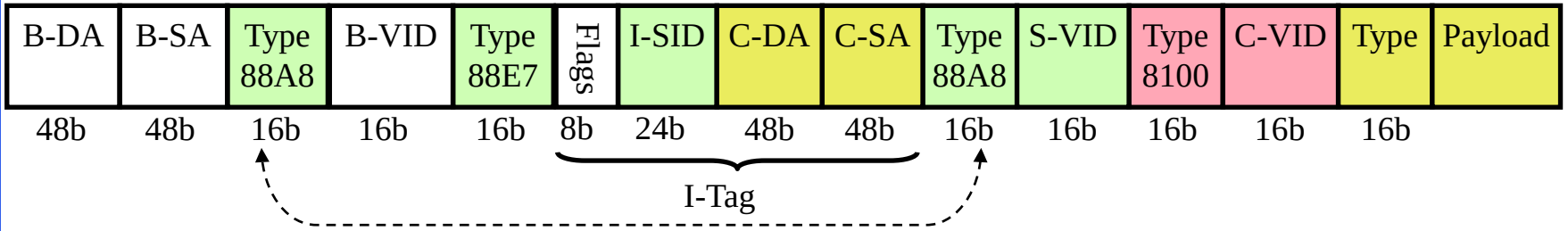
- Problem: The number of MAC addresses passing through backbone bridges is too large for all core bridges to remember Broadcast and flooded (unknown address) frames give unwanted traffic and security issues.
- Solution: IEEE 802.1ah-2008 incorporated in 802.1Q-2011
- Add new source/destination MAC addresses pointing to the ingress backbone bridge and egress backbone bridge
  ⇒Core bridges only know edge bridge addresses.

Student Questions

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 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 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-Tah 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
  ⇒ Backbone *core* bridges (BCB) do not learn customer MACs
- B-DA = Destination backbone bridge address Determined by Customer Destination Address
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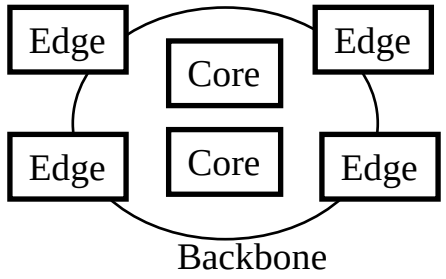

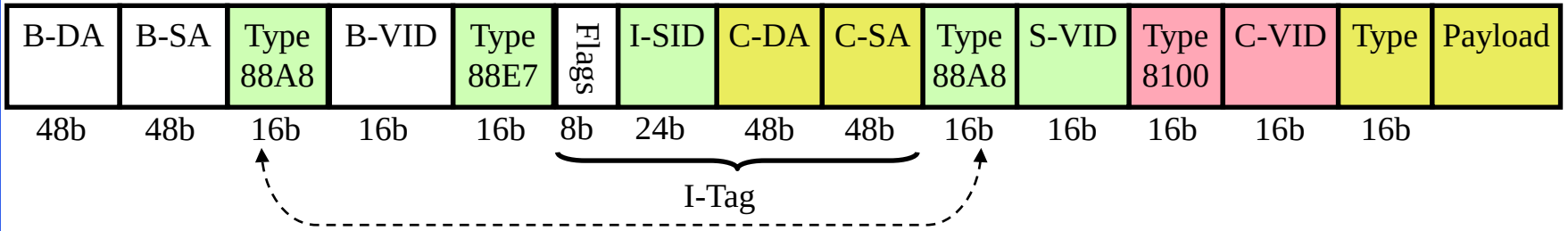

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  Similar to 802.1ad Q-in-Q. Therefore, the same EtherType.

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.

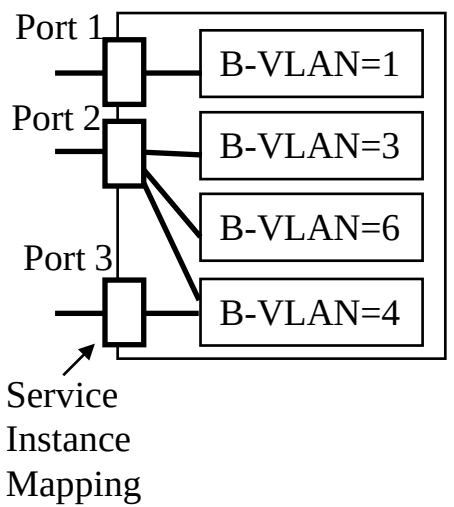
- Tags such as B-DA, I-SID, etc., are all added by the backbone edge bridges on the customer's packet (payload) that comes in.

Yes.

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

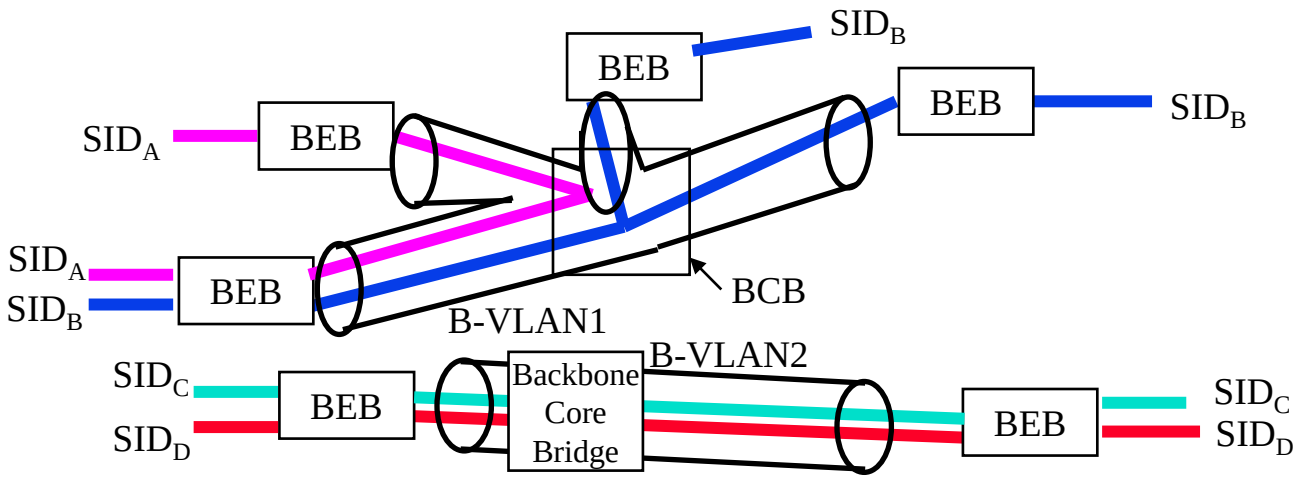
- What is B-VLAN? *Backbone VLAN*
- 88E7 indicates that I-tag is following, but what problem it solve? What is the point of using ports? Is it for multicast? Load balancing? Grouping? What is it for?

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.

MAC-in-MAC (Cont)



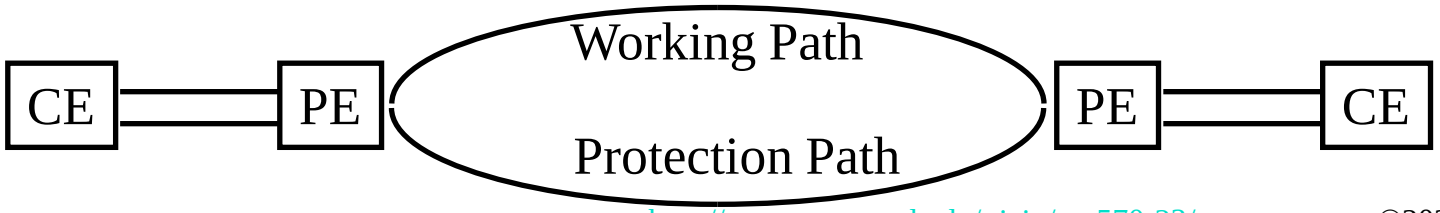
- Each Backbone VLANs (B-VLAN) can carry multiple services
- 24-bit SID $\Rightarrow 2^{24}$ Service Instances in the backbone
- I-Tag format: I-Tag is not looked at in the core.
  Includes C-DA+C-SA.
  UCA=1 $\Rightarrow$ Use customer addresses (used in CFM in the Edge)

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

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

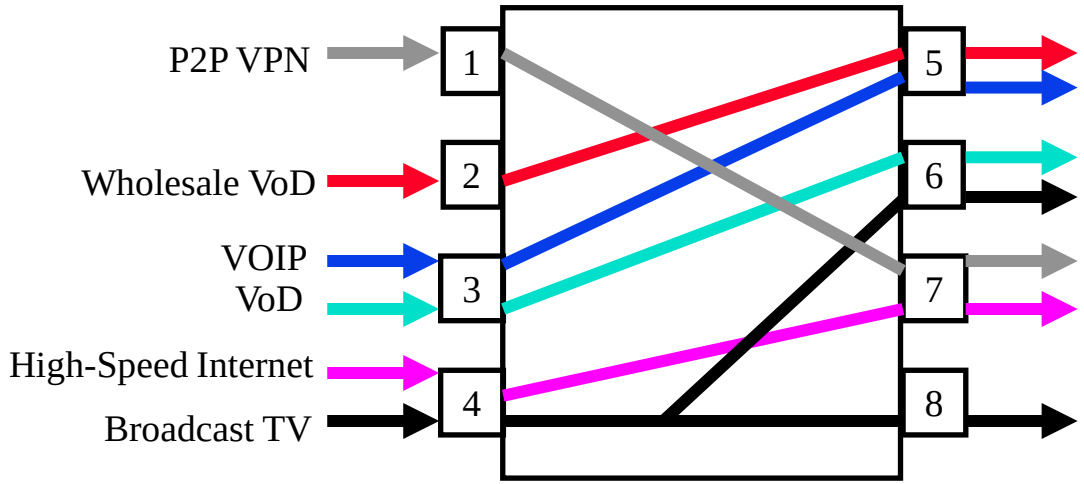


Student Questions

VLAN Cross-Connect

- Cross-connect ⇒ Circuit oriented
- Connection-oriented Ethernet with Q-in-Q
- Forward frames based on VLAN ID and Input port
  ⇒ 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

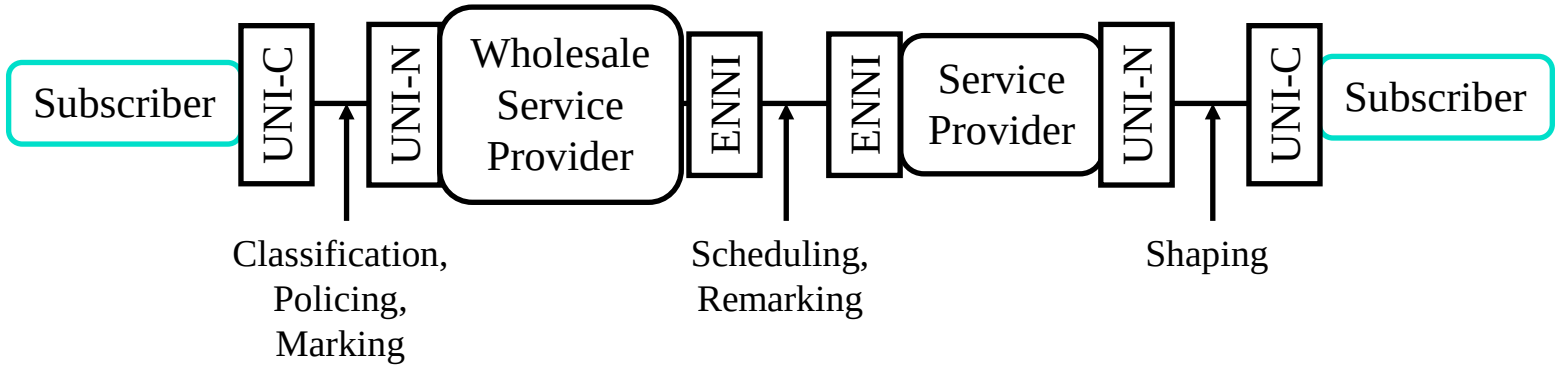
PBB-TE

- 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 ⇒ 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* ⇒ 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.

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?

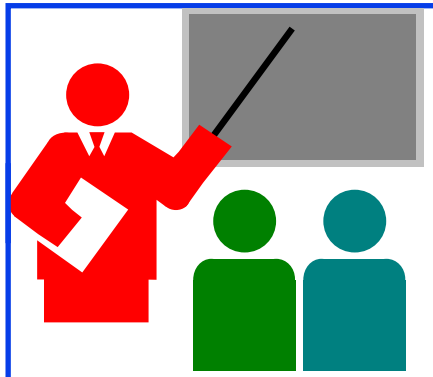
Service Tag

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.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/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

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http://rajjain.com

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

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