



> BUSINESS MADE **SIMPLE**

Provider Ethernet Standards

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MEF VP, Board Member and Technical Committee Co-chair

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IEEE, 802.1ah Chief Editor
MEF, Board Member, VP and Technical Committee Co-chair

For the last 25 years Paul has been a technologist and visionary of the communication industry. Starting in the early 1980s with the development of the first Ethernet products at Bridge Communications, Inc, Paul went on to advance the state of the art by working on the development and standardization of FDDI, ATM, 10 GE WAN, and Metro Ethernet. For the past 10 years Paul has lead the development of Metro and Wide area Ethernet through both innovation and standards development. Paul is currently the chief editor of the IEEE 802.1ah Provider Backbone Bridge standard and has serviced in the past as editor for the IEEE development of 10GE Ethernet. Paul was a founder of the Metro Ethernet Forum and has served on the board since the forum began in 2001. Paul co-chaired the MEF Technical Committee for the first 4 years of the Forum's development.

Paul is an inventor of a number of new Ethernet transport technologies including Provider Backbone Bridging, Provider Backbone Transport, Provider Link State Bridging and 10 GE WAN. Paul has led the standardization of these technologies in the IEEE 802.1 and 802.3 committees and at the Metro Ethernet Forum. Paul is a principle contributor to the Provider Backbone Bridge (IEEE 802.1ah) and Provider Backbone Bridge Traffic Engineering (IEEE 802.1Qay) and lead the formation and development of these standards projects.

Paul is an Architect at Nortel's new Metro Ethernet Network Division. He received his BS from University of Wisconsin Madison. He is the holder of six patents in the area of metro and wide area Ethernet. Paul serves as VP, Secretary of the MEF Board



Agenda

- > Introduction to Provider Ethernet
- > Provider Ethernet Standards Developments
- > PBB and PBB-TE Overview
- > Summary

IP and Provider Ethernet are different things?

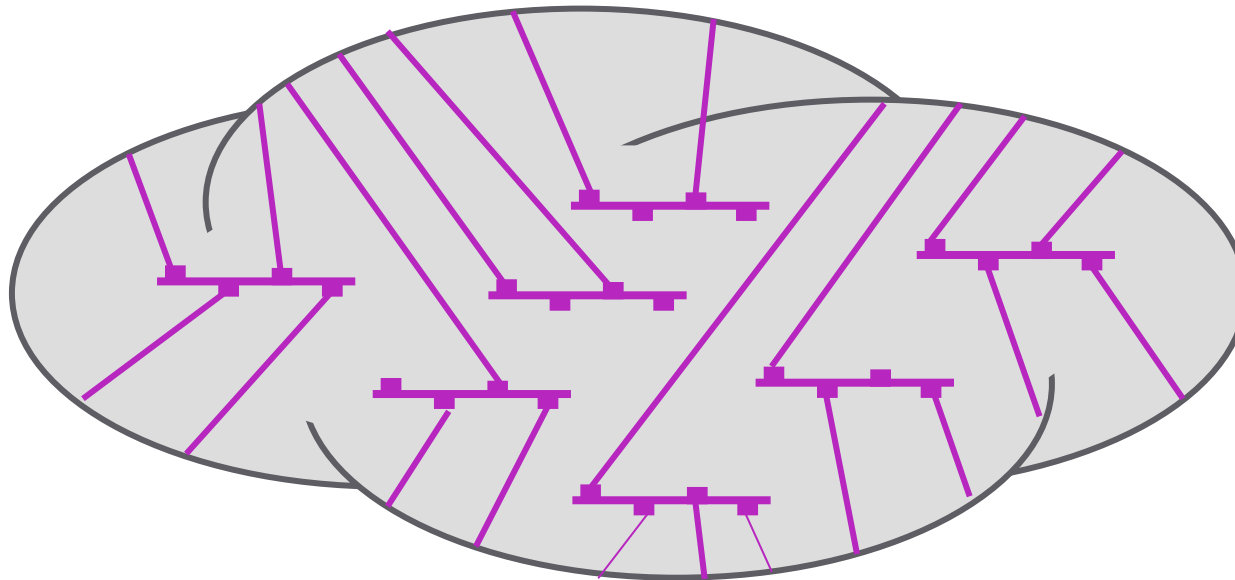


- > Ethernet is L2 and IP is L3, but:
 - Both do packet switching
 - Both can scale globally
 - Both use dynamic topology protocols
 - Both can provide protection, QoS, and traffic engineering
- > The fundamental difference is connectivity
 - IP can provide global any-to-any connectivity
 - Provider Ethernet can provide global connectivity between provisioned sets of network interfaces
- > Provider Ethernet is a global Virtual Private Ethernet multiplexing technology
- > IP is a global network technology
- > In the Enterprise and home IP runs over Ethernet networks
- > In the Metro and WAN IP will run over Provider Ethernet Virtual Private Networks

Provider Ethernet Is a Network Providing Many Virtual Private Ethernets



- > Each Virtual Private Ethernet is provisioned by the carrier
- > Traffic does not mix from one Virtual Private Ethernet to another
- > Each Virtual Private Ethernet is a carrier service instance
- > Metro Ethernet Forum is modeling Ethernet service instances also called Ethernet Virtual Circuits (EVCs)



Metro Ethernet Network (or MEF MEN)

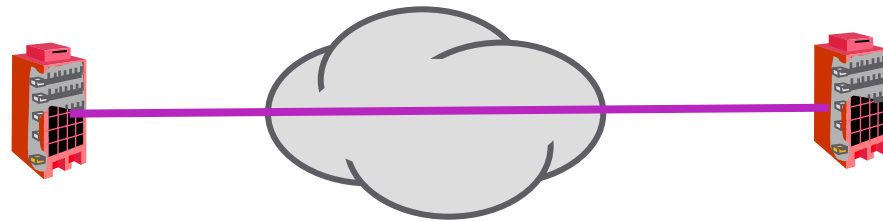
Basic Ethernet Service Types

MEF Ethernet Virtual Connections (EVCs)



E-LINE

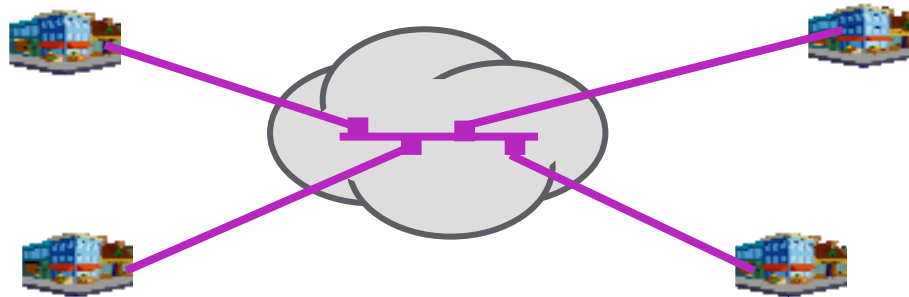
Router Mesh
MEF 10, 5



Pt-Pt, Like
Duplex Ethernet
Any-to-any

E-LAN

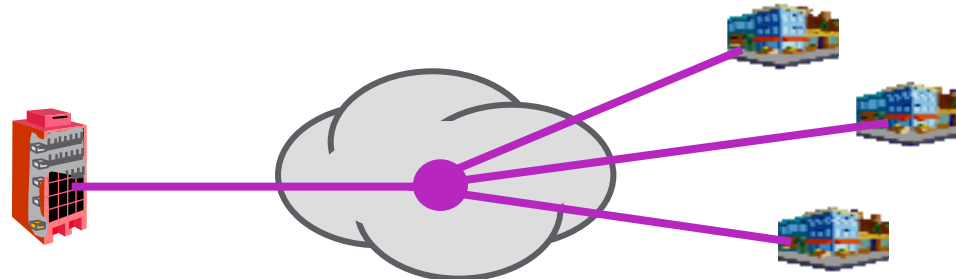
Multi-Site
MEF 10, 5



MPt, Like VLAN,
Any-to-any

E-TREE

Hub & Spoke
MEF 10.1
Rooted Multipoint



Pt-MPt, Like
EPON Ethernet,
Root-to-Leaf and
Leaf-to-Root



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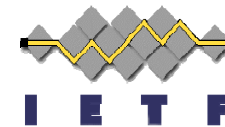


Each Standard Body Has an Angle

Working inward
from the edge



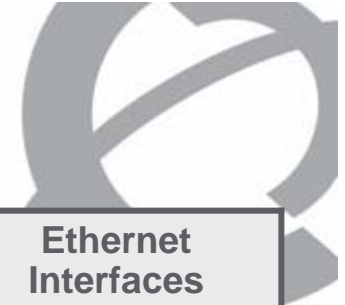
Working outward
from the core







Making it work
together



- > The biggest standards challenge is getting standards for the various pieces of a Provider Ethernet which allow interoperation between the various technologies which are being deployed.





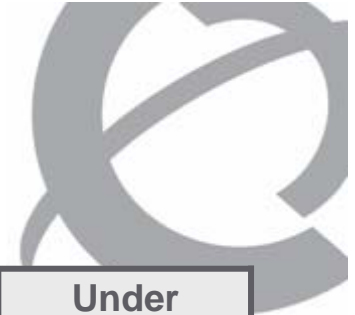
Ethernet Standards Summary

Standard Body	Ethernet Services	Architecture/Control	Ethernet OAM	Ethernet Interfaces
	-	<ul style="list-style-type: none"> > 802.3 – MAC > 802.3ar – Congestion Management > 802.1D/Q – Bridges/VLAN > 802.17 - RPR > 802.1ad – Provider Bridges > .1ah – Provider Backbone Bridges > .1ak – Multiple Registration Protocol > .1aj – Two Port MAC Relay > .1AE/af – MAC / Key Security > .1aq – Shortest Path Bridging 	<ul style="list-style-type: none"> > 802.3ah – EFM OAM > 802.1ag – CFM > 802.1AB - Discovery > 802.1ap – VLAN MIB 	<ul style="list-style-type: none"> > 802.3 – PHYs > 802.3as - Frame Expan.
	<ul style="list-style-type: none"> > MEF10.1–Service Attributes > MEF3 – Circuit Emulation > MEF6 – Service Definition > MEF8 – PDH Emulation IA > MEF9 – Test Suites > Service Definitions Phase 2 >Wireless Backhaul 	<ul style="list-style-type: none"> > MEF4 – Generic Architecture > MEF2 – Protection Req & Framework > MEF11 – UNI Req & Framework > MEF12 - ETH Layer Architecture >CoS Implementation Agreement >Ethernet Service Constructs 	<ul style="list-style-type: none"> > MEF7– EMS-NMS Info Model >Service OAM 	<ul style="list-style-type: none"> > MEF13 UNI Type 1 IA > MEF16 ELMI > UNI Type 2 > E-NNI
	<ul style="list-style-type: none"> >G.8011 – Services Framewrk >G.8011.1 – EPL Service >G.8011.2 – EVPL Service 	<ul style="list-style-type: none"> >G.8010 – Layer Architecture >G.8021 – Equipment model >G.8010v2 – Layer Architecture >G.8021v2 – Equipment model >Y.17ethmpls - ETH-MPLS Interwork 	<ul style="list-style-type: none"> > Y.1730 – Ethernet OAM Req > Y.1731 – OAM Mechanisms > G.8031 – Protection > Y.17ethqos – QoS > Y.ethperf - Performance 	<ul style="list-style-type: none"> >G.8012 – UNI/NNI >G.8012v2 – UNI/NNI
	-	-	>TMF814 – EMS to NMS Model	-



Ethernet Standards Status



Standards Body	Standards Project	Approved	Draft	Under Discussion	
	802.1Q VLAN Bridges 2005	✓			
	802.1AB Discovery 2006	✓			
	802.1ad Provider Bridges (aka QiQ) 2005	✓			
	802.1ag Connectivity Fault Management (CFM) 2007	✓			
	802.1ak Multiple Registration Protocol (MRP) 2007	✓			
	802.1ah Provider Backbone Bridges (aka MiM)		✓		
	802.1Qay Provider Backbone Bridge Traffic Engineering		✓		
	802.1aq Shortest Path Bridging			✓	
	802.1aj Two Port MAC Relay (aka Media Converter)			✓	
	802.1ap VLAN MIB			✓	
	MEF 10.1 Ethernet Service Attributes Phase II	✓			
	MEF 6 Ethernet Service Definitions Phase 1	✓			
	MEF 8 Emulation of PDH Circuits over Metro Ethernet	✓			
	MEF 4 Architecture/Framework	✓			
	MEF 7 EMS-NMS Information Model	✓			
	MEF 11 UNI Requirements and Implementation	✓			
	MEF 9 Abstract Test Suite for Ethernet Services at the UNI	✓			
	MEF 3 Circuit Emulation	✓			
	MEF 2 Protection Req & Framework	✓			
	MEF 13 UNI Type 1	✓			
	MEF 14 Abstract Test Suite for Traffic Management Phase I	✓			
	MEF 15 Requirements for Management of Metro Ethernet	✓			
	MEF 16 Ethernet Local Management Interface	✓			
	MEF 17 Service OAM Requirement and Framework	✓			
	MEF 18 Abstract Test Suite for CES Over Ethernet	✓			
	MEF 19 Abstract Test Suite for UNI Type 1	✓			
	Ethernet Service Definitions Phase 2			✓	
	E-NNI			✓	
	UNI Type 2			✓	



Ethernet Standards Status (cont'd)

Standards Body	Standards Project	Approved	Draft	Under Discussion
	G.8010 Ethernet layer architecture G.8011 Ethernet services framework G.8011.1 EPL services G.8011.2 EVPL services G.8021 Ethernet equipment model G.8012 Ethernet UNI/NNI Y.1730 Ethernet OAM Requirements Y.1731 Ethernet OAM Mechanisms Y.ethperf Ethernet Performance Monitoring G.8031 Ethernet Protection Y.17ethmpls Ethernet-MPLS Interworking G.pbt Provider Backbone Transport Architecture Y.17ethqos Ethernet QoS	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓	✓ ✓ ✓ ✓	
	TMF814 – EMS to NMS Model	✓		



IEEE Standards Process

1. Call For Interest
2. Study Group
3. Project Authorization Request (PAR)
4. Task Force
5. Balloting Cycles
 - a) Task Force
 - b) Work Group
 - c) Sponsor
6. Standards Board Approval
7. Publication

Key IEEE Provider Ethernet Standards, Status



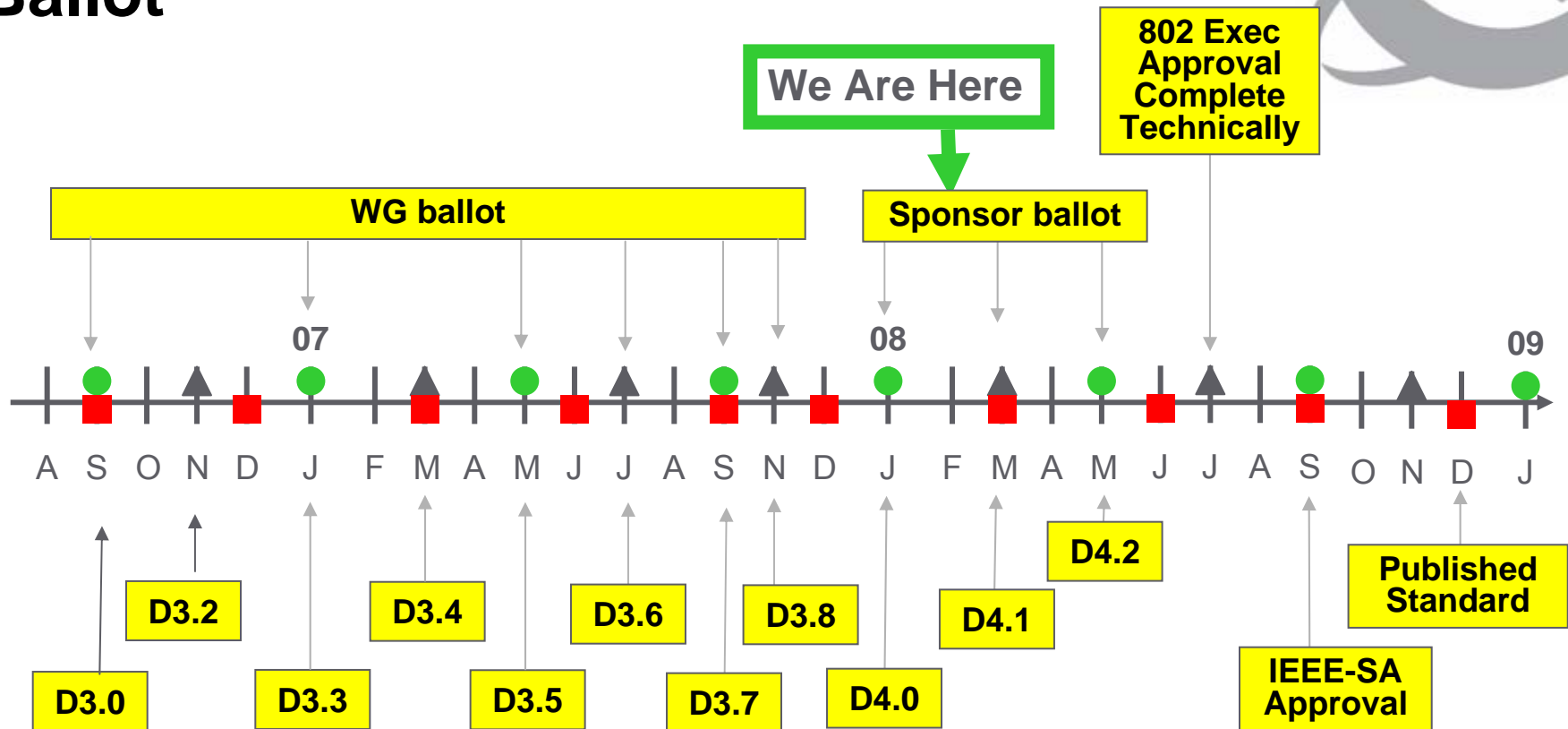
PBT Standard	Title	Status
802.1Q	VLAN Bridges	Approved 2005
802.1ad	Provider Bridges	Approved 2005
802.1ag	Connectivity Fault Management (CFM)	Approved July 2007
802.1ah	Provider Backbone Bridges	Sponsor Ballot November 2007
802.1ap	VLAN Bridge MIBs	Working Group Ballot September 2007
802.1Qay	Provider Backbone Bridge Traffic Engineering	Task Force Ballot November 2007
802.1aq	Shortest Path Bridging (PLSB)	Task Force Ballot November 2007



IEEE 802.1 January 2008 Interim

- > Los Gatos, January 27-30, 2008
- > 802.1ah – PBB first sponsor ballot complete and passed
 - 88 Voters - 59 Yes, 7 No, 22 Abstain
 - 78 Comments – 28 TR, 8 T, 1 GR, 1 G, 5 ER, 35 E
 - 91% Yes, 9% No, 75% responding
 - Next ballots are re-circulation ballots
 - All open issues resolved at the Los Gatos meeting
 - Reversible multicast address translation algorithm
 - Added Class III access protection when BPDUs are tunneled
 - Added management for dynamic component and port creation
- > 802.1Qay – PBB-TE first task force ballot complete
- > 802.1ap – MIBs moving toward sponsor ballot ballot

PBB (P802.1ah) –Finished first Sponsor Ballot



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Legend	
▲	802 Plenary
●	802.1 Interim
■	IEEE-SA Board



PBB-TE (P802.1Qay) –Progress

- > First presentations to IEEE in 2005
- > PAR approved by IEEE in March 2007
- > Editor Panagiotis Saltsidis from Ericson in March 2007
- > Draft D0.1 presented to IEEE in May 2007 meeting
- > Presentations in July, September and November 2007 meetings on protection and CFM.
- > Draft D1.1 sent to Task Force ballot start November 2007
- > First Task Force ballot completed in January 2008



Agenda

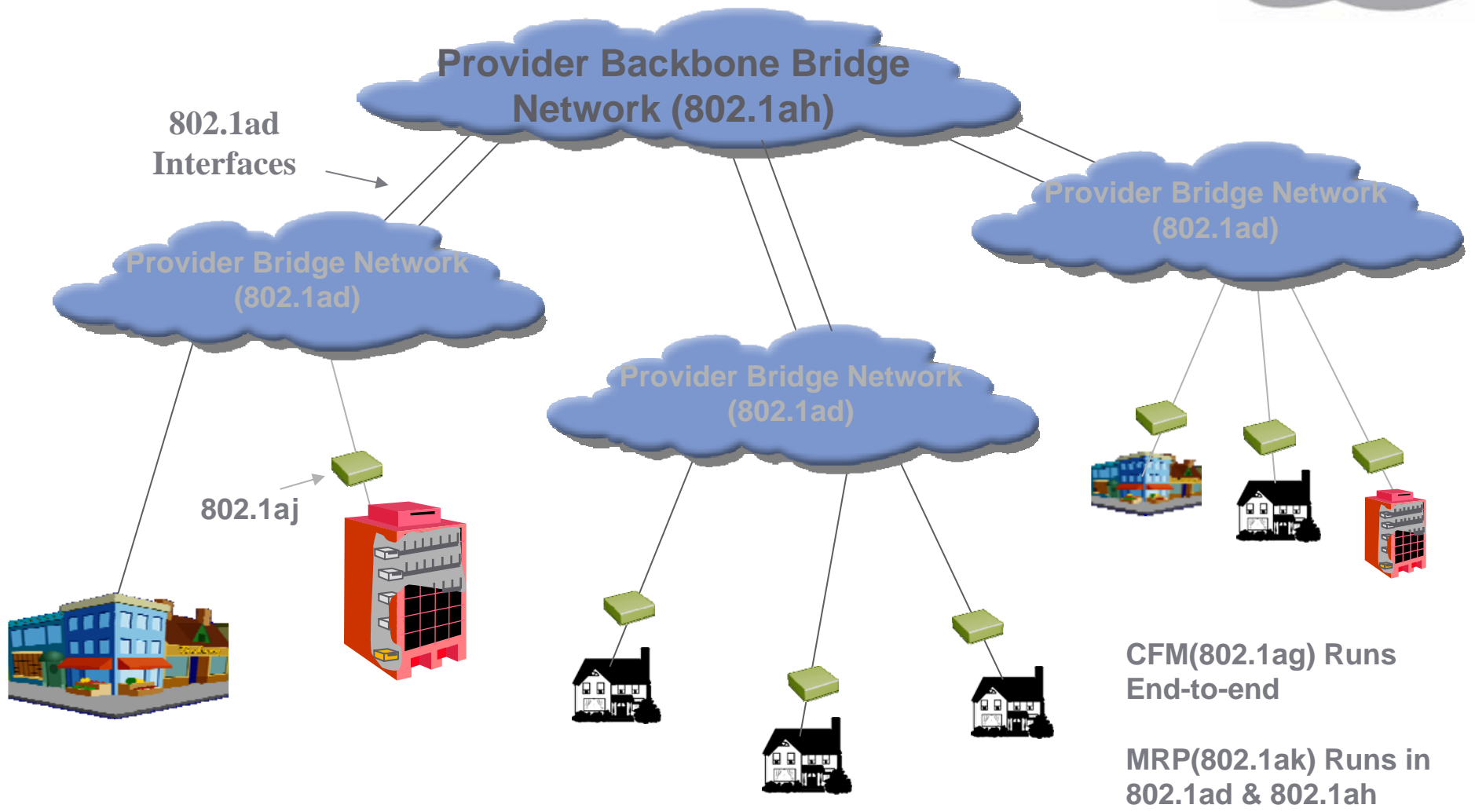
- > Introduction to Provider Ethernet
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- > PBB and PBB-TE Overview & Value Proposition
- > Summary



Motivations For PBB, PBB-TE, PLSB

- > Build packet based infrastructure allowing efficient support for packet data, voice, and video applications
- > Minimize capital costs to allow major build outs
- > Maximize facility utilization while providing high quality service
- > Minimize operational costs
- > Verify service level agreements
- > Minimize backward compatibility issues

IEEE 802.1 Provider Bridge Standards





Provider Backbone Bridge (802.1ah) Values

➤ Backbone separation

- Address space – isolates interior provider network from customer network changes
- Control plane – allows same protocols, but different instances, running in customer and provider network

➤ OAM

- Can test carrier facilities independent from services
- Supports Service-to-Performance Correlation (SPC) and Service-to-Fault Correlation (SFC) via Service ID (I-SID)

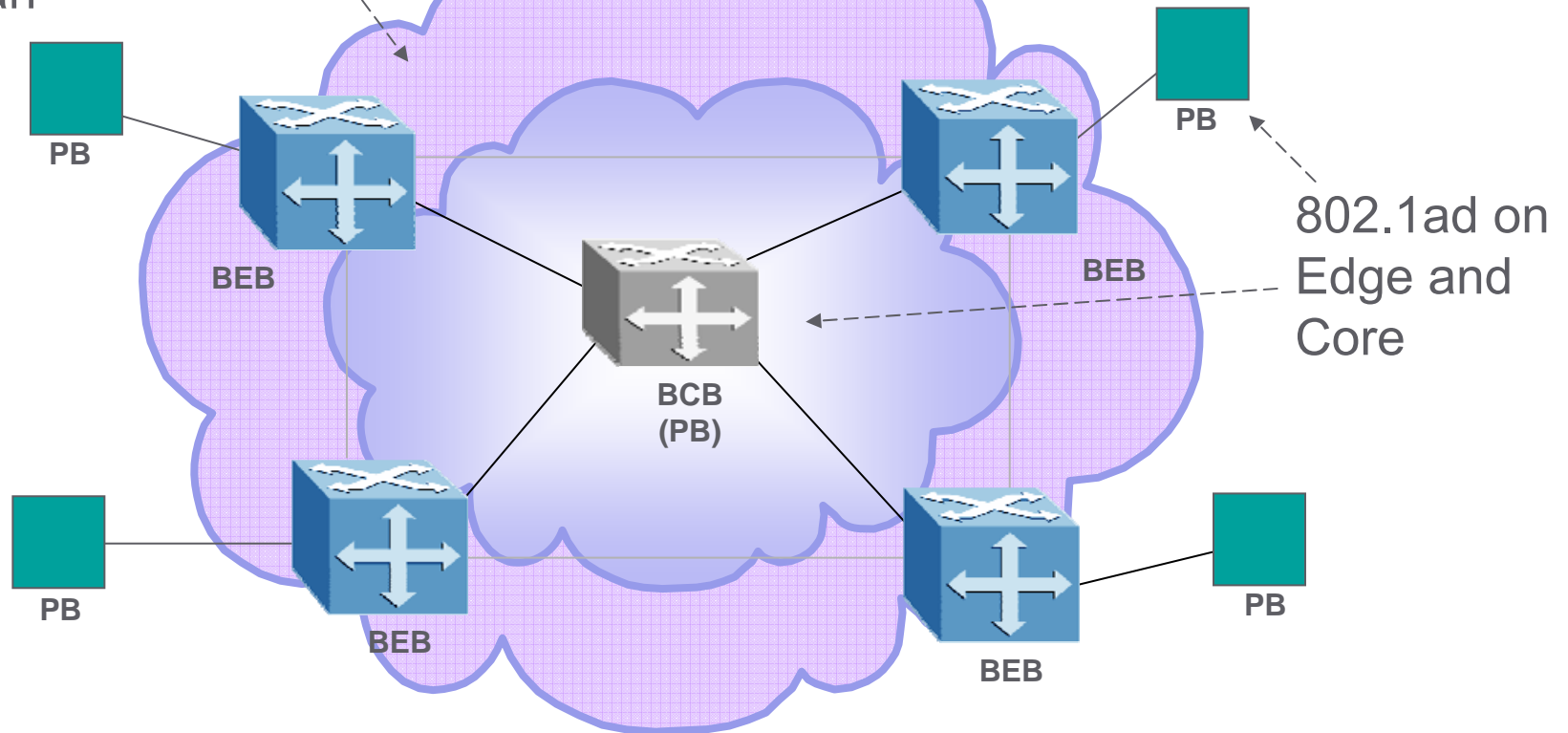
➤ Scalability

- Introduces hierarchy to Ethernet networks



Provider Backbone Bridge Network (PBBN)

Encapsulation Layer
802.1ah



- **PB**: Provider Bridge (as defined by 802.1ad)
- **BEB**: Provider Backbone Edge Bridge
- **BCB**: Provider Backbone Core Bridge



Terminology

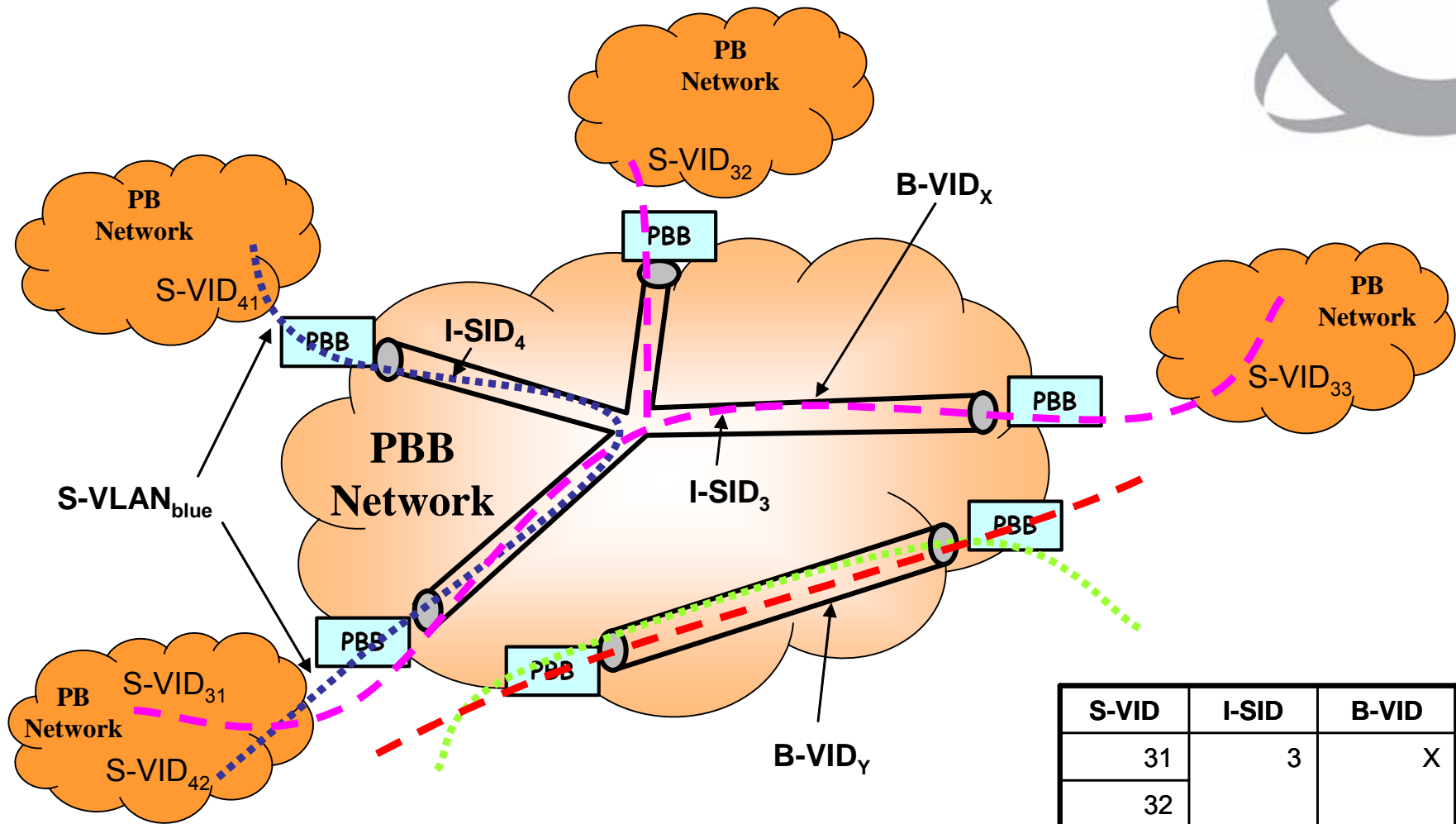
> IEEE 802.1ad Terminology

- C-TAG Customer VLAN TAG
- C-VLAN Customer VLAN
- C-VID Customer VLAN ID
- S-TAG Service VLAN TAG
- S-VLAN Service VLAN
- S-VID Service VLAN ID

> Additional Provider Backbone Bridge Terminology

- I-TAG Service Identifier tag
- I-SID Service Identifier
- BSI Backbone Service Instance
- C-MAC Customer MAC Address
- B-MAC Backbone MAC Address
- B-VLAN Backbone VLAN (tunnel)
- B-TAG Backbone TAG Field
- B-VID Backbone VLAN ID (tunnel)

PB S-VID, PBB I-SID and B-VID Relationship



S-VID	I-SID	B-VID
31	3	X
32		
33		
41	4	
42		

- An S-VID (S-VID₄₁) has local significance within a PB Network
- An S-VLAN (S-VLAN_{blue}) corresponds 1:1 with an I-SID (I-SID₄)
- Many S-VLANs (I-SIDs) can be carried via one B-VLAN



Important 802.1ah Features

- > Independent 8 levels of CFM from (Y.1731 also may be applied)
 - Customer CFM Flows which extend between interconnected PBN networks
 - Backbone Service Instance CFM Flows provide independent monitoring for the 802.1ah backbone service instance which may be extended over E-NNI
 - Backbone VLAN CFM Flows provide per PBBN B-VLAN monitoring
 - Physical level CFM for link monitoring
- > Support for both Link and Node-Link access protection
- > Two types of inter-provider E-NNI specified in 802.1ah
 - Hierarchal providing multiple encapsulation
 - Peer providing translation interface between PBBNs
- > MEF E-NNI also may be used with 802.1ah to provide a service level interface capable of connecting to any Ethernet service cloud.



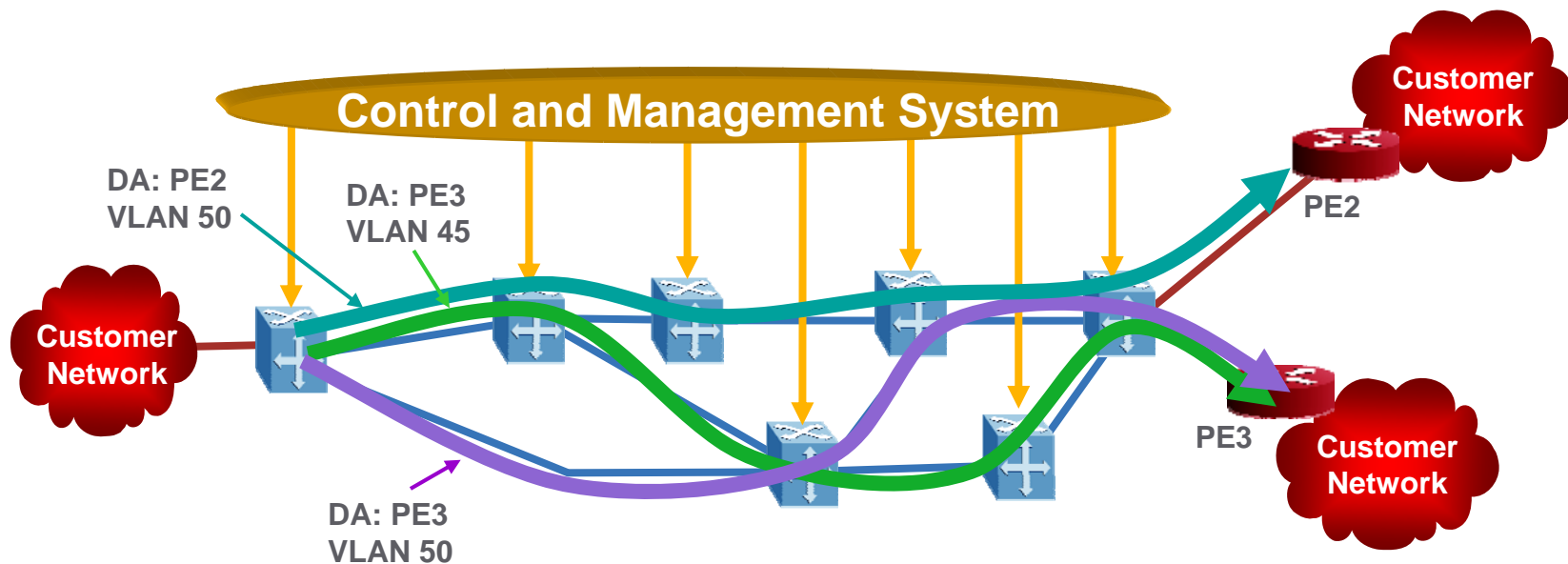
PBB-TE Filling Ethernet's Gaps

- > Traffic engineering requires the ability to route traffic in diverse ways to allow full utilization of carrier facilities
- > Traffic engineering requires the ability to perform constraint based route management and admission control for service guarantees
- > Protection requires the ability to recover some services very quickly. Many networks requirement less than 50 msec from the time of the failure to complete restoration.
- > Protection must support traffic engineering, must be able to protect the full QoS guarantees, must be constantly monitored.



PBB-TE Control and Management

- > So we split the B-VIDs, turn off MAC learning, Broadcast Unknown, and STP
 - Use PBB hierarchy to separate customers from the Provider network, and add hierarchical dataplane OAM for instrumentation and protection.
- > Place under a Comprehensive Management system
 - Use a base spanning tree to control switches using SNMP
 - Management build complete topology model using auto-discovery base on 802.1AB
- > Management sets up connections, populating switch bridging tables:
 - The VLAN tag is no longer a network global : scaling issues are removed;
 - VLAN tags now used to set up per destination alternate paths
 - A range of VLANs can be used for bridging and another range for PBB-TE



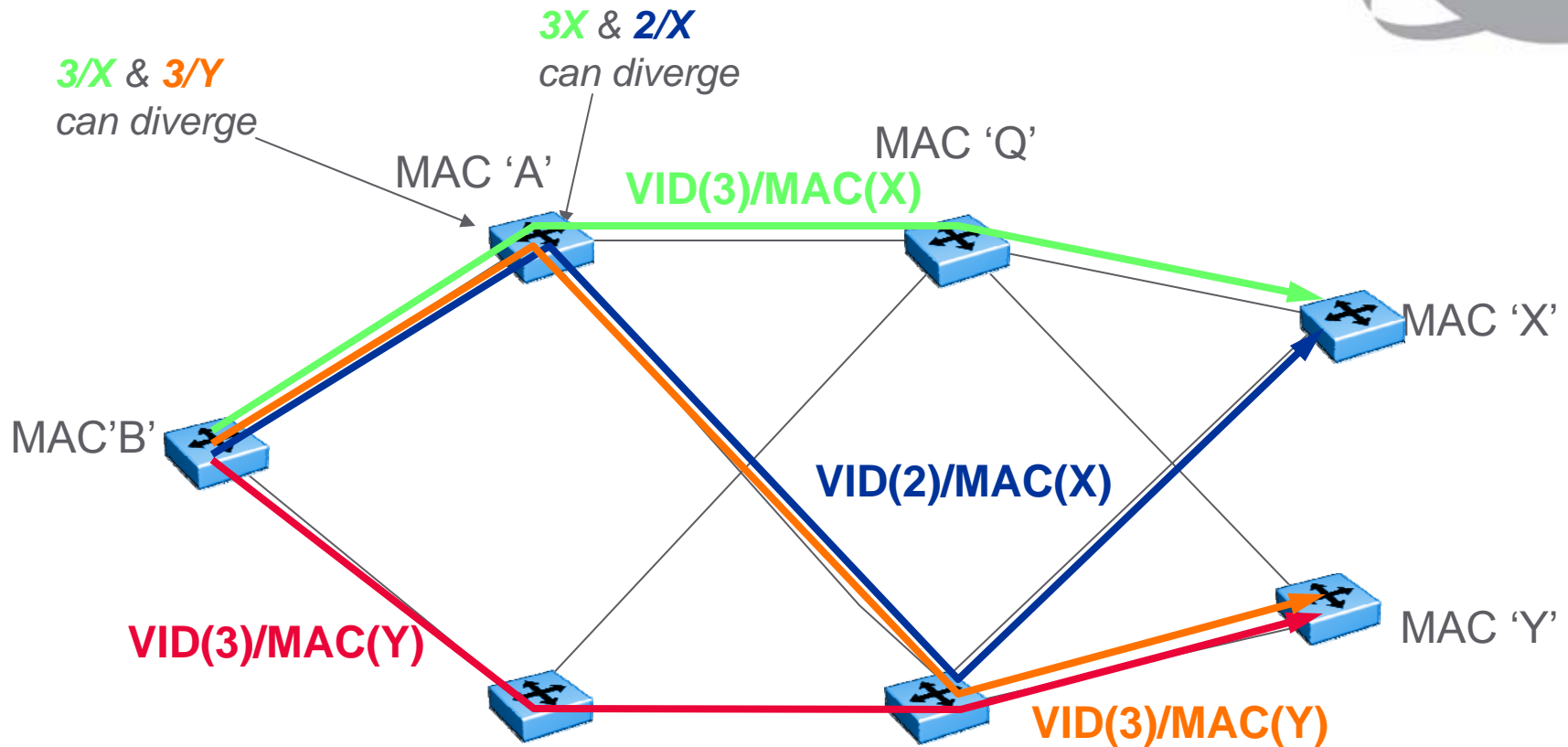
What do you get?



- > Complete route selection freedom for PBB-TE trunks
 - Each trunk may be along a different spanning tree
 - Provisioning systems may use shortest path, constraint based, manual placement, or any other route algorithm which assures loop free paths.
 - Each trunk may use a different routing strategy.
- > Load may be calculated for each trunk and allocated to each physical link, port, and switch.
- > Protection paths are pre-determined to allow rapid failover.
- > Both working and protection trunks are constantly monitored.

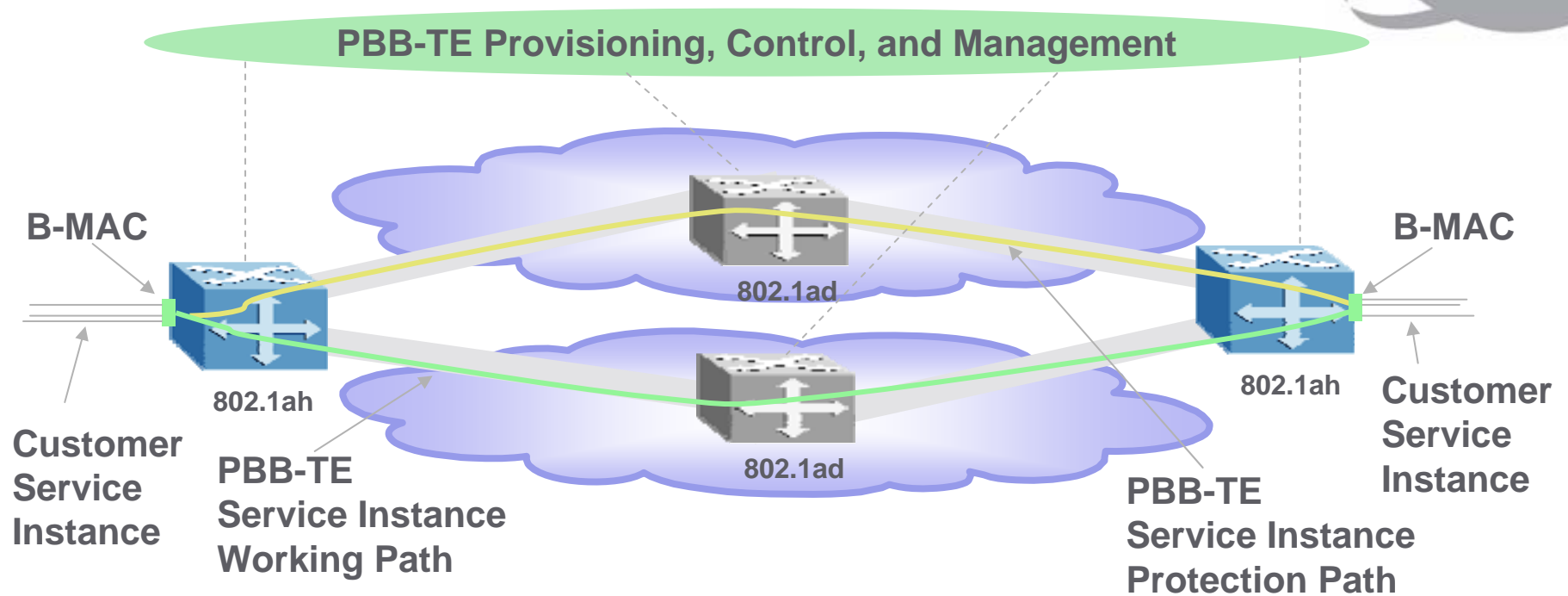


Dataplane Example



Note that MACs and VLANs can overlap, it is the combination of both that is unique and allows diverse routing

Protection Switching for PBB-TE



- > Working and protected path use different B-VIDs
- > Directed IEEE 802.1ag CC messages are sent over both the Working and Protection paths.
- > CC messages are used to determine failure events and cause protection switching.



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IEEE Provider Ethernet Summary

- > Major components are already complete
 - 802.1ad, 802.1ag, 802.1ak
- > The PBB standard is nearly complete
 - 802.1ah
 - Provides the scaling to practically unlimited network size
- > The PBB-TE work is under way and rapidly advancing
 - 802.1Qay
 - Providing traffic engineered service instances within PBBNs
- > Provider Link State Bridging (PLSB) is under 802.1aq project
 - Developing an advanced control plane for PBB
 - IS-IS used to build PBBN topology
 - May run as ships in the night with MSPT by splitting the VID space
 - Distributes all MAC addresses within the PBBN

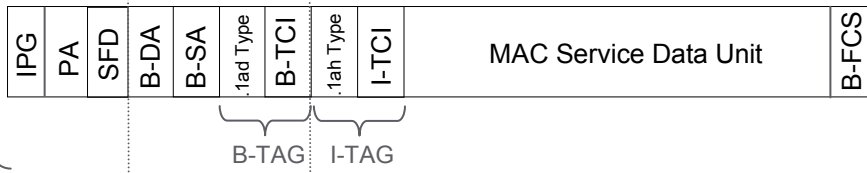


Backup Slides

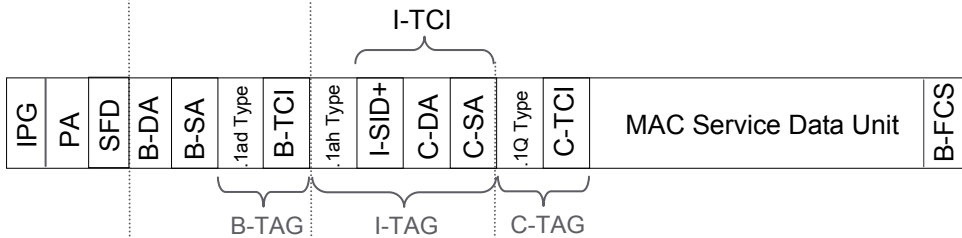


P802.1ah/D4.0 Data Frame Formats*

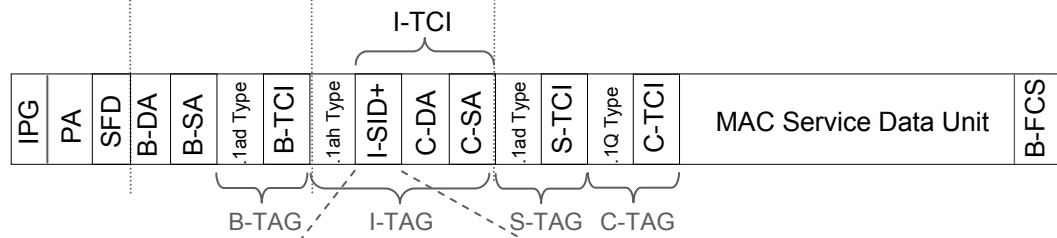
Voted out July 2006



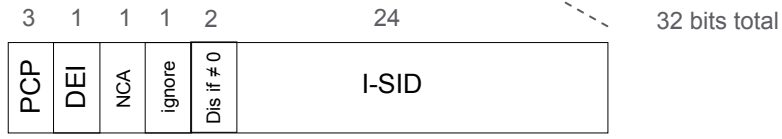
Multi-protocol encapsulated format for an I-Tagged interface (where a different TBD 802.1ah Ethertype is used to indicate a non-Ethernet client)



Ethernet encapsulated format for a 1:1 S-Tagged interface



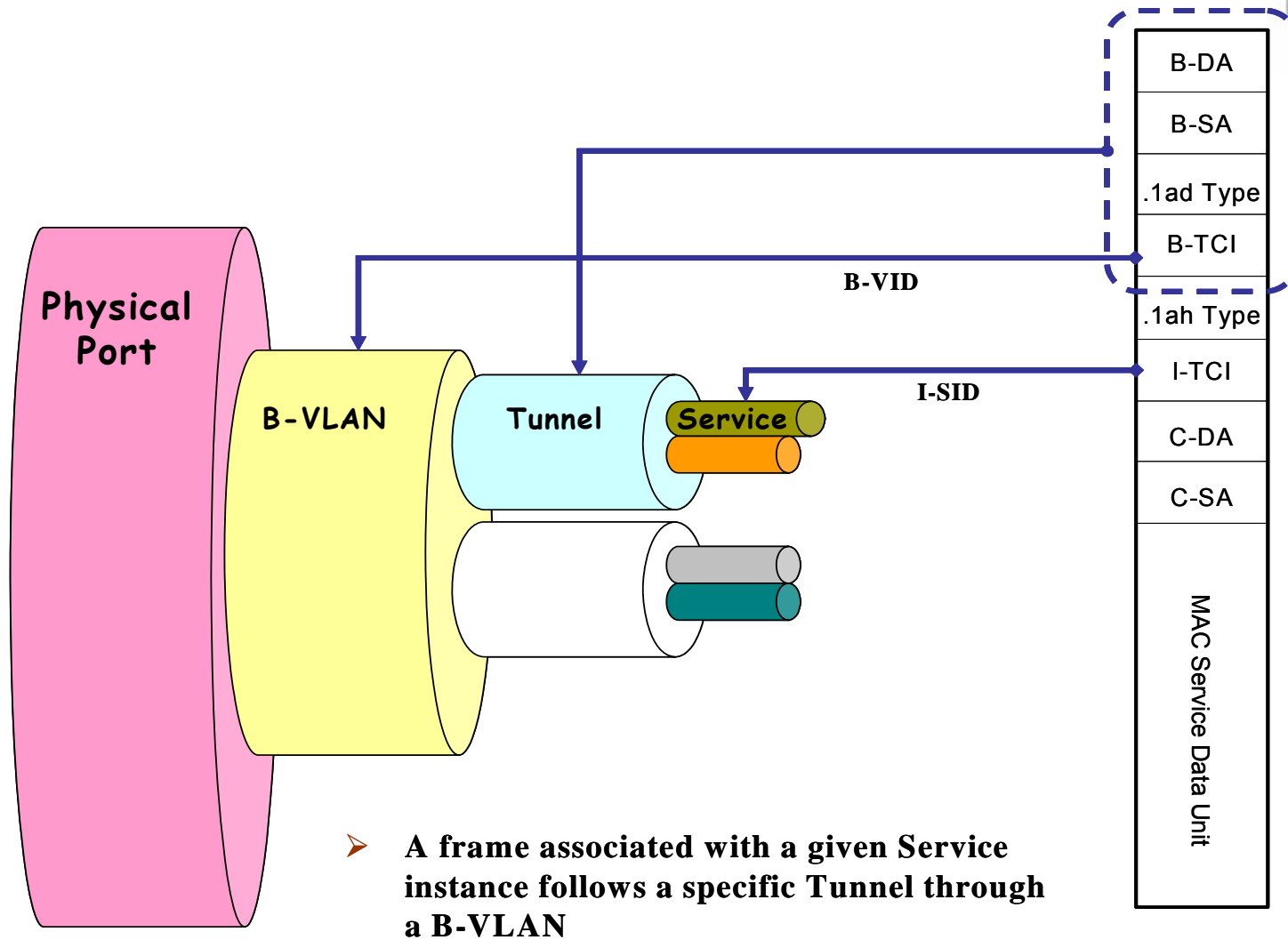
Ethernet encapsulated format for a Transparent interface or a many:1 bundled S-Tagged interface



Note: M_SDU = Length/Type + MAC Client Data

* Depicted at the 802.3 MAC server layer interface (i.e. the RS sublayer)

Provider Backbone Bridge Frames



Scaling Properties



- > The theoretical limit to the number of PBB-TE trunks is 2^{58}
 - A PBB-TE trunk is addressed by the combination of the B-MAC and B-VID
 - B-MAC provides 2^{46} addresses and the B-VID provides 2^{12} totaling 2^{58}
 - For large networks the B-VID address space will be removed over peer E-NNIs reducing the total available address space to the B-MAC address space of 2^{46} PBB-TE trunks (~70 trillion)
- > Since PBB-TE can distribute the PBB-TE trunks over the network it is possible to scale well beyond the forwarding database limit by selecting routes through parallel switches.
 - Each switch must have a filtering database entry for each PBB-TE trunk supported, therefore the number trunks on any individual switch is limited to the capacity of the filtering database
- > Practically the number of PBB-TE trunks is limited by the size of the database which the provisioning system can support and manage.
 - Today's SONET networks have provisioning systems which can support all the trunks currently used in the world, therefore this limitation must not be a barrier to building a world wide PBB-TE network on the same scale as today's SONET network
- > Another scaling consideration for PBB-TE is the load generated by CCM messages used to manage PBB-TE trunks
 - CFM at 10 msec. interval is ~ 6.4 Kbytes/sec (100 x 64 byte packets = 6.4 Kbytes/sec)
 - 3.3% of a T1
 - 0.5% of a 10BaseT
 - PBB-TE is a P2P ***trunking*** technology
 - Each trunk would normally have assigned bandwidth greater than 10 Mbits and would carry many services
- > The number of PBB-TE trunks supported by a BEB will be limited by the CCM packet processing capability of the BEB.
 - For 1000 trunks with 50 msec protection the total load is about 200,000 f/s.
- > The I-SID address space limits any PBBN to handling 2^{24} service instances.
 - This can be extended by dividing the network into separate PBBNs connected by E-NNIs as specified in 802.1ah
 - For peer E-NNI the I-SID is translated over the E-NNI allowing the service address space to indefinitely extended.

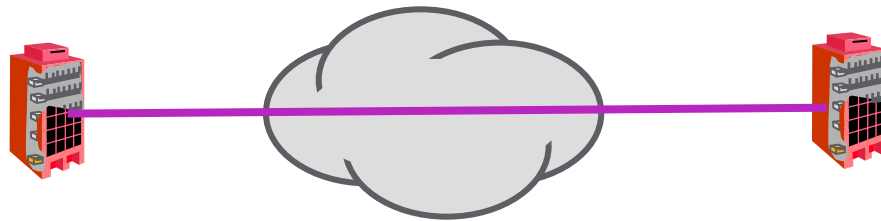


Engineered Circuit Types

MEF Ethernet Virtual Connections (EVCs)

E-LINE

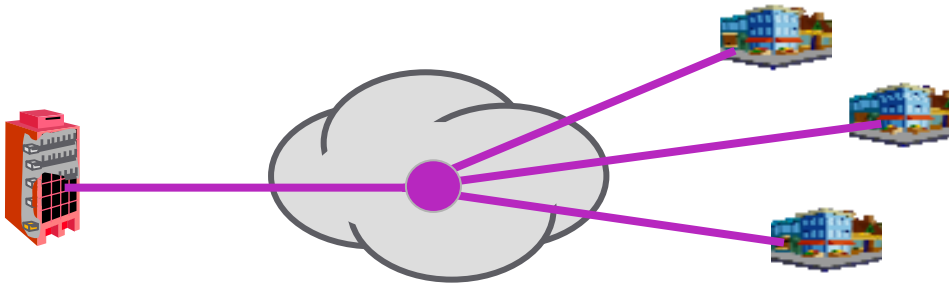
Router Mesh



Pt-Pt, Like
Duplex Ethernet
Any-to-any

E-TREE

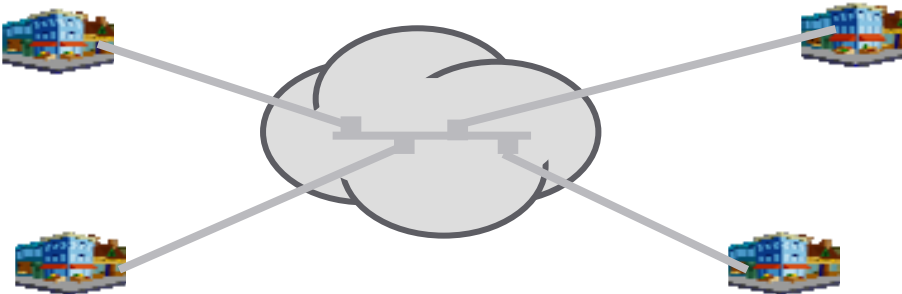
MEF Rooted
Multipoint



Pt-MPt, Like
EPON Ethernet,
Root-to-Leaf and
Leaf-to-Root

E-LAN

Multi-Site



MPt, Like VLAN,
Any-to-any