# MPLS + 802.1ah

Luyuan Fang, Cisco Systems

Nabil Bitar, Verizon

Raymond Zhang, BT

Future-Net
April 15, 2008
Boston

Outlines

- Data service market trends

- Carrier Ethernet Service Requirements

- MPLS and 802.1ah (PBB) interworking

  - H-VPLS with 802.1ah extension

  - 802.1ah aggregation over MPLS core

- Design/Deployment Scenarios

- Design Considerations

- Conclusions

Enterprise Data Connectivity Service Spending Trends
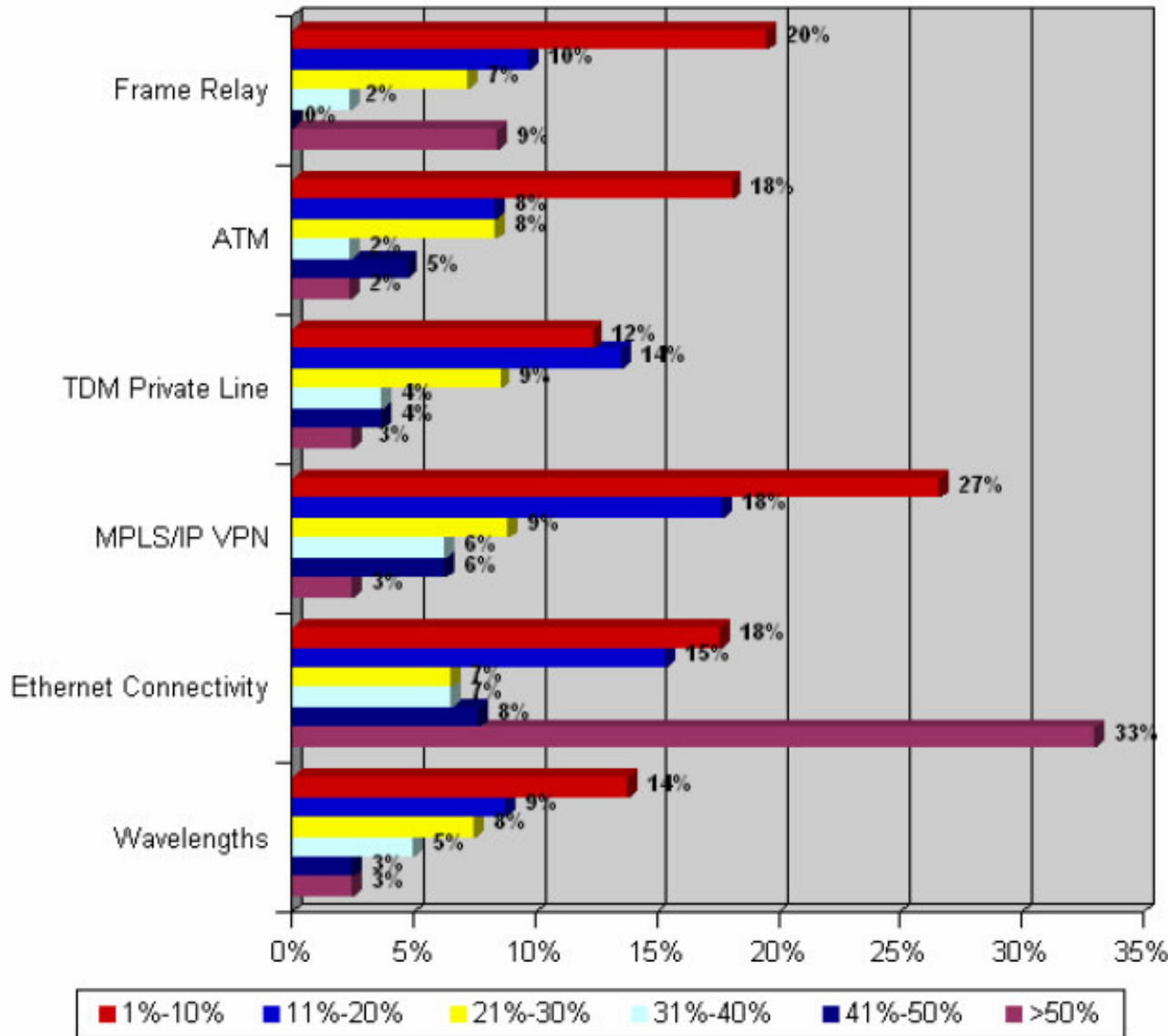
What accounts for 50% of their spending?

33% said: Ethernet
3% said: MPLS/IP VPN

Responses : 91

Source: Heavy Reading, February 2008

Carrier Ethernet Service Requirements (1)

- **Services:**
  - Support E-Line, E-LAN, and E-Tree services defined by MEF

- **Security:**
  - IP/MPLS protocol authentication
  - Provider and Customer L2 control plane separation
  - Access control and resource usage control

- **Scalability:**
  - EVCs:
    - Enterprise services: 100's of thousands EVCs across a WAN.
    - Residential service transport: 100's of thousands to millions for large metro
  - MAC addresses:
    - Large Metro: 10s to 100's of thousands for E-LAN services
    - Global services: 100s of thousands or millions across a WAN.

Carrier Ethernet Service Requirements (2)

- **Reliability:**
  - NSR, NSF, ISU.
  - FRR, BFD, and fast network convergence

- **QoS**
  - Hierarchical Queuing
  - Traffic profile enforcement on an UNI or an E-NNI per EVC
  - Preserve customer markings

- **Manageability**
  - Minimize network touch points in provisioning:
    - MRP, E-LMI for Ethernet, BGP auto-discovery for VPLS
  - Standards-based OAM to support SLA:
    - IEEE 802.1ag (802.1ag), 802.3ah, ITU Y1731
    - IETF VCCV, MPLS LSP Ping/BFD, and IP BFD
  - Native Ethernet and MPLS OAM interworking

MPLS + 802.1ah Technologies Overview

1. Ethernet Building Blocks

2. MPLS and 802.1ah (PBB) interworking

   - H-VPLS extension with 802.1ah
   - 802.1ah aggregation over MPLS core

Ethernet Basic Building Blocks

- **IEEE 802.1Q - Virtual LANs (VLANs)**:
    - Tagging Ethernet frames with VLAN ID's
    - Scale: 2^{12} ~ 4K VLANs

- **802.1Q-in-802.1Q   (Q-in-Q)**:
    - VLAN stacking on the same Ethernet frame to overcome the 4K VLAN limit in 802.1Q
    - Scale: 2^{12} service instances

- **IEEE 802.1ad - Provider Bridges (PB)**:
    - Standardized VLAN stacking. Defines C-VLAN and S-VLAN, and separate customer and provider L2CP
    - Scale: 2^{12} service instances

- **IEEE 802.1ah – Provider Backbone Bridges (PBB)**
    - For the interconnection of Provider Bridged Networks (PBNs).
    - Scale: 2^{24} service instances

- **Virtual Private Wire Services (VPWS)** and **Virtual Private Line Services (VPLS)**
    - P2P and Multipoint L2 MPLS VPN technologies
    - Scale: 2^{12} service instances with 802.1ad, and 2^{24} with 802.1ah extension

- **Hierarchical VPLS (H-VPLS)**:
    - Partitions the network into several edge domains that are interconnected using an MPLS core to enhance VPLS scalability
    - Scale: service instances: same as VPLS; hierarchy for scaling

802.1ah Terminologies

- **BEB**: Backbone Edge Bridge – encapsulates customer frames for transmission across backbone.

- **B-BEB**: B type BEB – contains a B-component, supports bridging in the provider backbone based on B-MAC and B-TAG info.

- **I-BEB**: I type BEB – contains an I-component for bridging in the customer space, including attached customer MAC, service VLAN IDs.

- **B-TAG**: Backbone VLAN Tag – an S-TAG used in conjunction with backbone MAC addresses for switching in the B component.

- **I-TAG**: Service Instance Tag - encapsulates customer addresses and contains the Service Instance identifier (I-SID).

- **I-SID**: Service Instance identifier - A field of the Service Instance tag which identifies the service instance of the frame.

- **S-TAG**: Service VLAN (S-VLAN) Tag - A field which is defined in the 802.1ad Q-in-Q encapsulation for provider Service VLAN.
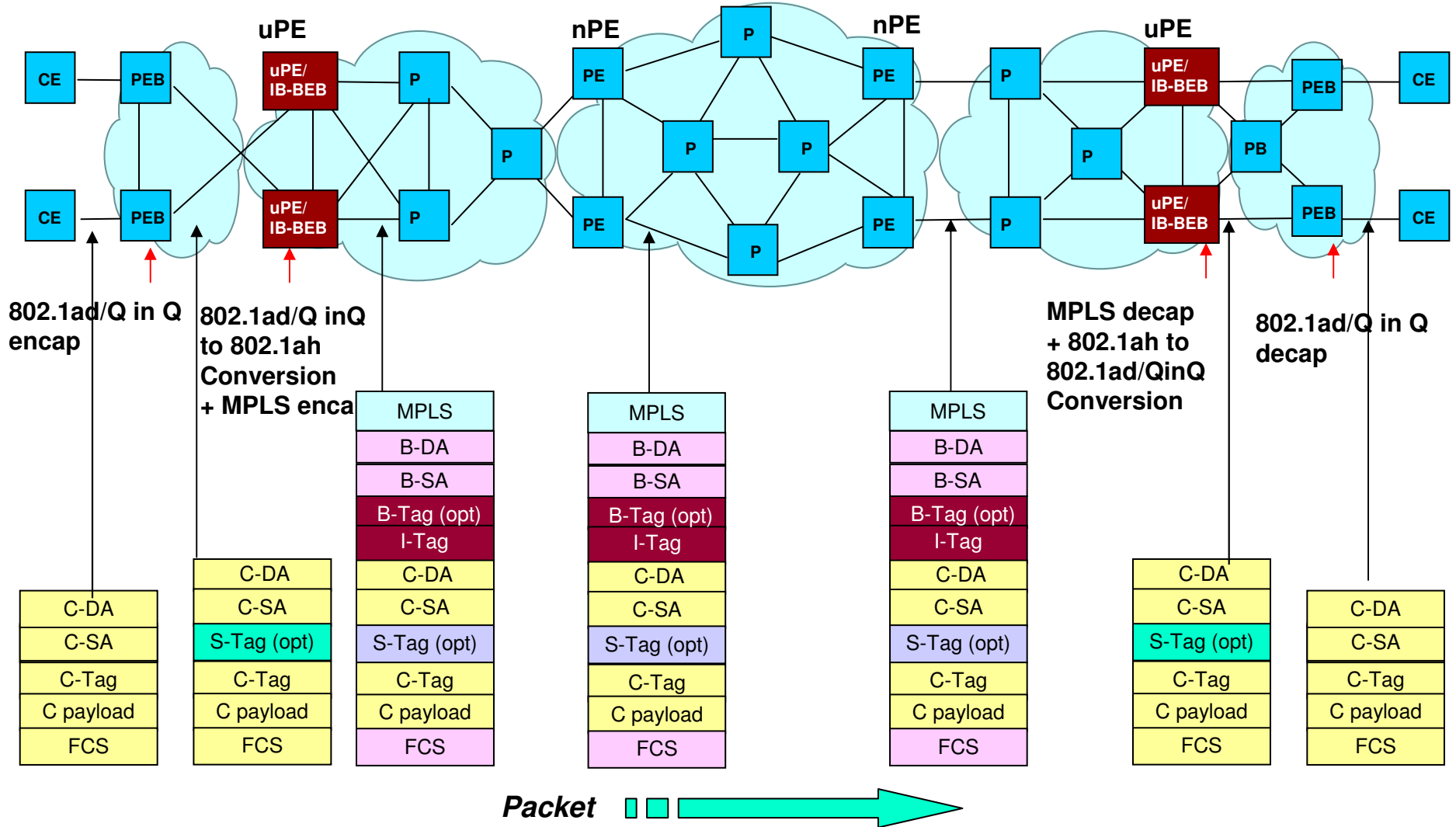
Why MPLS + 802.1ah?

- MPLS is the core technology today deployed in most of the service provider networks, it offers:
  - Maturity
  - Multi-service support: internal, L2/L3 VPNs, VoIP, IPTV, etc.;
  - Feature rich: p2p, p2mp, mp2mp connectivity; QoS, TE, FRR, OAM

- Combining with 802.1ah for enhanced scalability
  - MAC-address Scaling
    - 802.1Q or 802.1ad /Q-in-Q: PE needs to learn all customer MAC addresses (C-MACs)
    - 802.1ah: C-MACs are hidden under B-MAC (MAC-in-MAC). PE only need to learn B-MAC for PE reachability.
  - Service Instance Scaling
    - 802.1Q or 802.1ad/Q-in-Q: VLAN identifier is 12-bits, 4094 service instances per network
    - 802.1ah: Provider service instance (I-SID) scales to 2^{24} (~16 M)
  - Separation of Backbone VLAN (B-VID) and provider service instance (I-SID)
    - Further multiplexing is possible, e.g. mapping group of I-SID into a B-VID
    - Provider VLANs (B-VID) segregates backbone into broadcast domains.

H-VPLS Scale Enhancement with 802.1ah
- draft-sajassi-l2vpn-vpls-pbb-interop-02.txt

Access Network (802.1ad)   **Aggregation Network (H-VPLS + 802.1ah)**   **Core Network (H-VPLS)**   **Aggregation Network (H-VPLS+ 802.1ah)**   **Access Network (802.1ad)**

802.1ad/Q in Q encap

802.1ad/Q inQ to 802.1ah Conversion + MPLS enca

MPLS decap + 802.1ah to 802.1ad/QinQ Conversion

802.1ad/Q in Q decap

	C-DA
	C-SA
	S-Tag (opt)
	C-Tag
	C payload
	FCS

C-DA
C-SA
C-Tag
C payload
FCS

MPLS
B-DA
B-SA
B-Tag (opt)
I-Tag
C-DA
C-SA
S-Tag (opt)
C-Tag
C payload
FCS

MPLS
B-DA
B-SA
B-Tag (opt)
I-Tag
C-DA
C-SA
S-Tag (opt)
C-Tag
C payload
FCS

MPLS
B-DA
B-SA
B-Tag (opt)
I-Tag
C-DA
C-SA
S-Tag (opt)
C-Tag
C payload
FCS

C-DA
C-SA
S-Tag (opt)
C-Tag
C payload
FCS

C-DA
C-SA
C-Tag
C payload
FCS

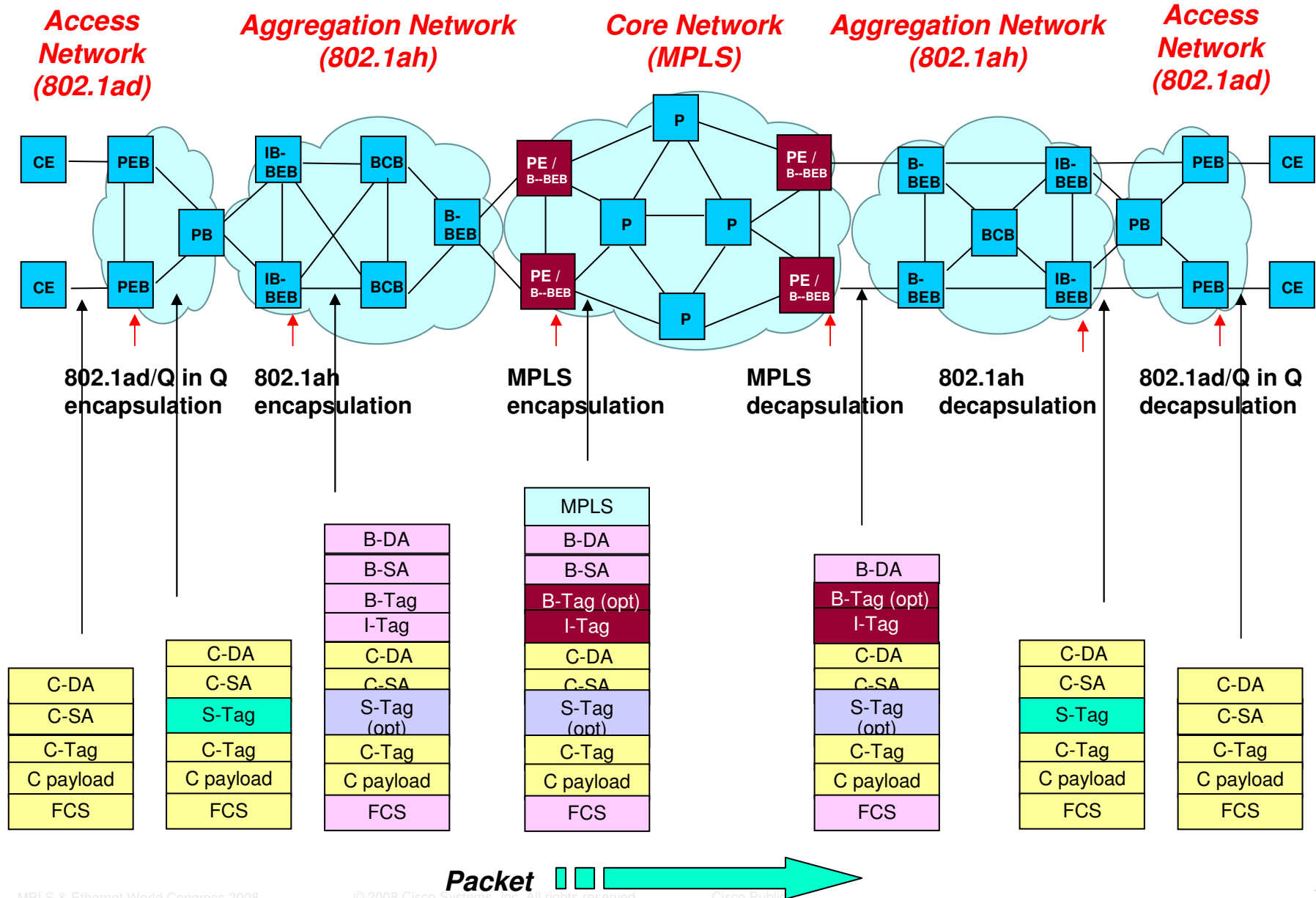***Packet*** ➡

VPLS + 802.1ah – How does it work?

- Integrate IB-BEB function into the H-VPLS PE

- IB-BEB function can be placed at n-PE or u-PE depending on the SPs' design.

- Interface of uPE/IB-BEB to attached PB:

  Port mode

  VLAN mode

  VLAN-bundle mode

- Mapping the above service interfaces to I-SID

- Multiplex I-SIDs within a single B-VLAN (N:1 or 1:1).

- 802.1ah to VPLS VSI mapping

  Per B-TAG to VSI mapping

  Per I-SID to VSI mapping

  - new PW type required - *draft-martini-pwe3-802.1ah-pw-01.txt*

  Per group of I-SID to VSI mapping

Interface Type Summary -
VPLS w/ MPLS Aggregation and 802.1ah on uPE

Interface	Service Delimit.	I-SID domain	Mode	VPLS instance per	PW Requirements:
S-Tagged	S-Tag	Same Domain	Port	I-SID bundle	Type 5 as default (may use type 4)
				I-SID	New type to carry I-Tagged Frames. No I-SID Translation is needed.
			VLAN	I-SID bundle	Type 5 as default (may use type 4)
				I-SID	New type to carry I-Tagged Frames. No I-SID Translation is needed.
			VLAN Bundle	I-SID bundle	Type 5 as default (may use type 4)
				I-SID	New type to carry I-Tagged Frames. No I-SID Translation is needed.
		Different Domains	Port	I-SID	New type to carry I-Tagged Frames. I-SID Translation on egress uPE.
			VLAN	I-SID	New type to carry I-Tagged Frames. I-SID Translation on egress uPE.
			VLAN Bundle	I-SID	New type to carry I-Tagged Frames.I-SID Translation on egress uPE.

MPLS Core and 802.1ah Aggregation
- draft-sajassi-l2vpn-vpls-pbb-interop-02.txt

Access Network (802.1ad) | **Aggregation Network (802.1ah)** | **Core Network (MPLS)** | **Aggregation Network (802.1ah)** | **Access Network (802.1ad)**

802.1ad/Q in Q encapsulation

802.1ah encapsulation

MPLS encapsulation

MPLS decapsulation

802.1ah decapsulation

802.1ad/Q in Q decapsulation

C-DA	
C-SA	
C-Tag	
C payload	
FCS	

C-DA
C-SA
S-Tag
C-Tag
C payload
FCS

B-DA
B-SA
B-Tag
I-Tag
C-DA
C-SA
S-Tag (opt)
C-Tag
C payload
FCS

MPLS
B-DA
B-SA
B-Tag (opt)
I-Tag
C-DA
C-SA
S-Tag (opt)
C-Tag
C payload
FCS

B-DA
B-Tag (opt)
I-Tag
C-DA
C-SA
S-Tag (opt)
C-Tag
C payload
FCS

C-DA
C-SA
S-Tag
C-Tag
C payload
FCS

C-DA
C-SA
C-Tag
C payload
FCS

Packet

802.1ah Aggregation over MPLS Core – How does it work?
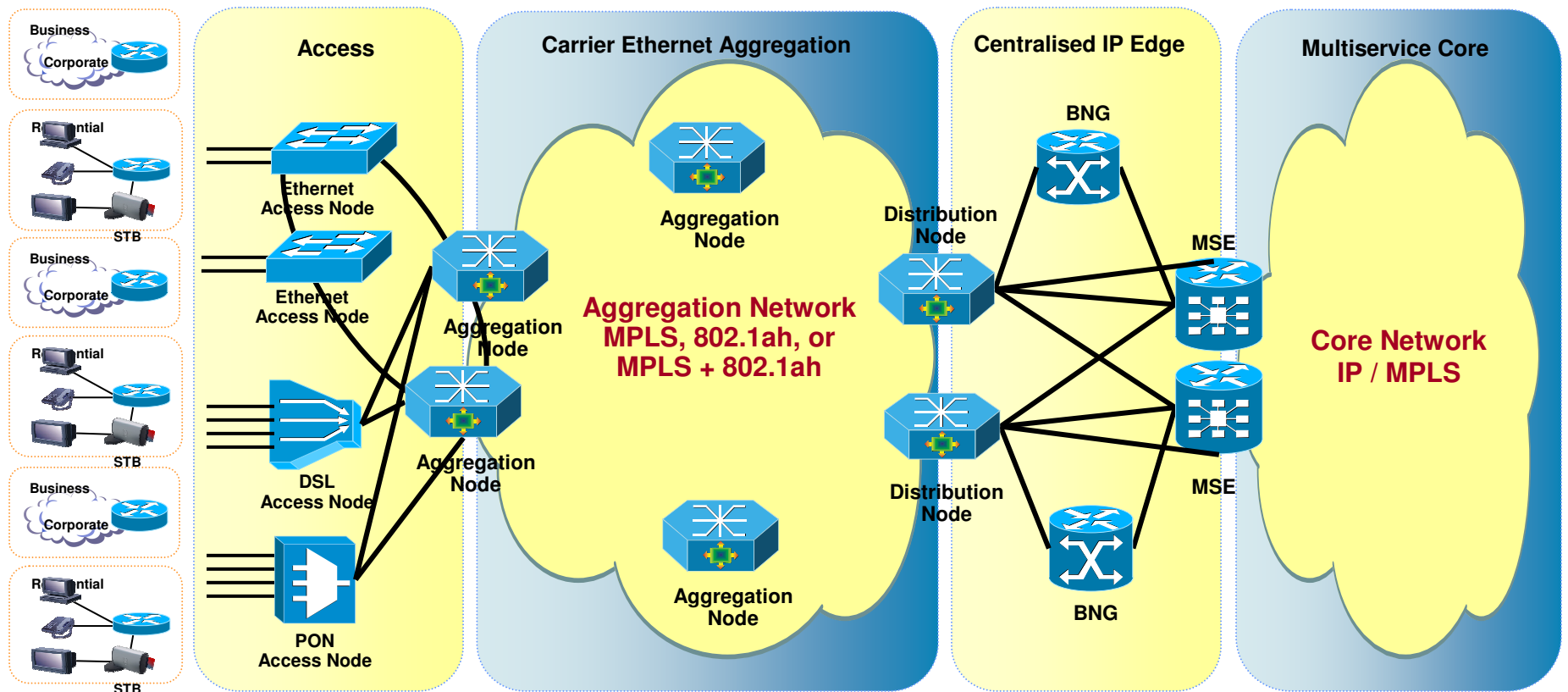
- Integrate IB-BEB function in the MPLS/VPLS PE in the MPLS core

- Interface of PE/B-BEB to aggregation network may

  - Connect to 802.1ah aggregation

    BCB or

    B-BEB (new PW required)

  - Interface to MPLS core

    Using B-tagged interface or

    I-tagged interface (new PW required, with Port-mode, I-SID mode, and I-SID bundling mode) - *draft-martini-pwe3-802.1ah-pw-01.txt.*

  - May use one of the following as service delimiter

    B-VID or

    I-SID (new PW is required)

  - B-VID, I-SID assignment

    Globally unique or only locally unique

Interface Type Summary
- VPLS with 802.1ah Access

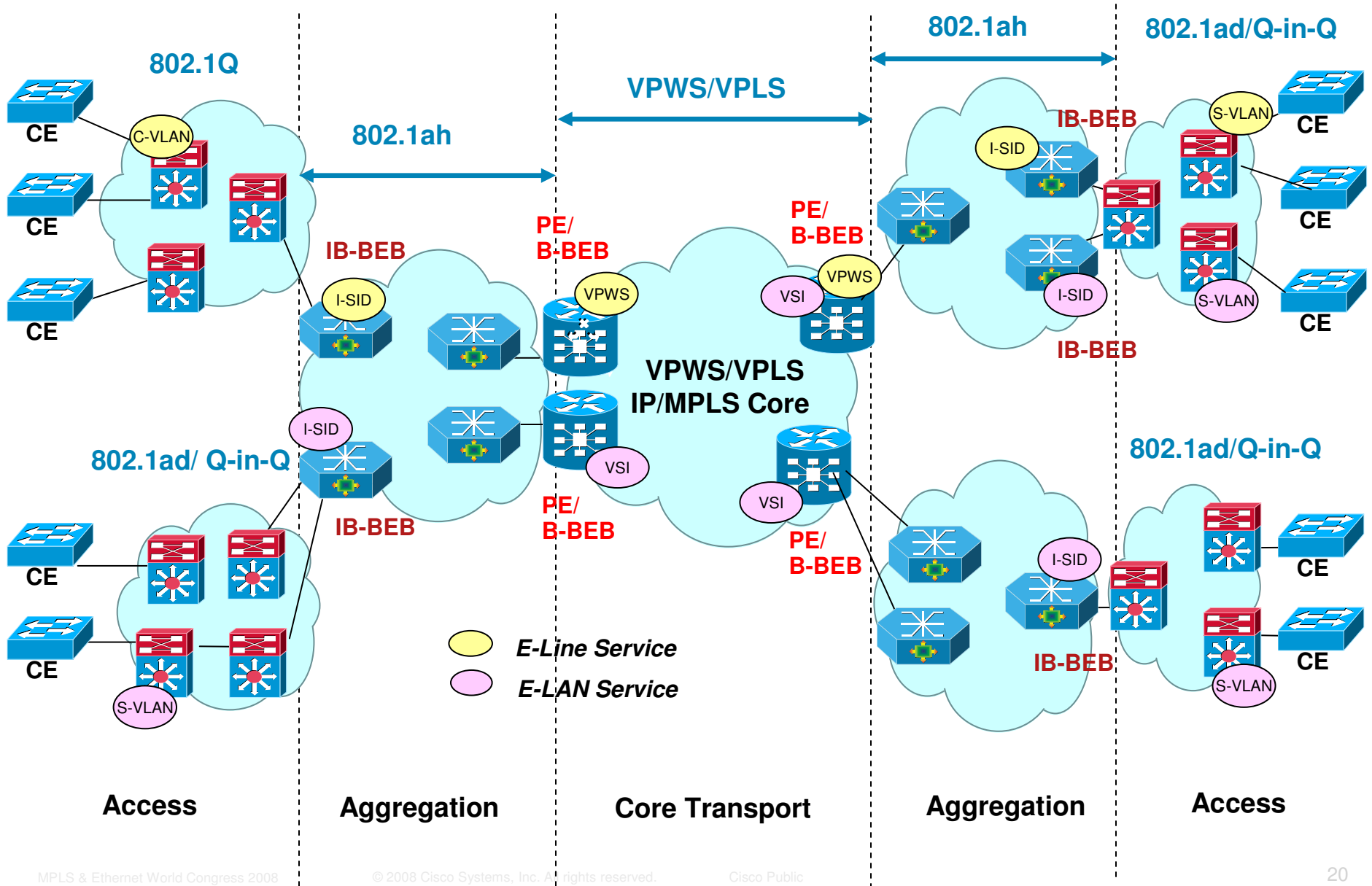| Interface	Service Delimit.	I-SID domain	Mode	VPLS instance per	PW Requirements
Type I B-Tagged	B-Tag	Tightly Coupled	Port	Port	Type 5 as default (may use type 4)
			VLAN	B-Tag	Type 5 as default (may use type 4)
			VLAN Bundle	Group of B-Tags	Type 5 as default (may use type 4)
Type II B-Tagged	I-SID	Loosely Coupled	I-SID	I-SID	New type to carry I-Tagged Frames. No I-SID Translation is needed.
			I-SID Bundle	Group of I-SIDs	Type 5 as default (may use type 4)
	I-SID	Different domains	I-SID	I-SID	New type to carry I-Tagged Frames. I-SID translation at the egress PE
Type III I-Tagged	I-SID	Loosely Coupled	I-SID	I-SID	New type to carry I-Tagged Frames. No I-SID translation is needed
			I-SID Bundle	Group of I-SIDs	Type 5 as default (may use type 4)
	I-SID	Different domains	I-SID	I-SID	New type to carry I-Tagged Frames. I-SID Translation at the egress PE or on CBP of B-BEB (symmetric)
			I-SID Bundle	Group of I-SIDs	Type 5 as default. I-SID Translation on AC (symmetric) or on CBP of B-BEB (symmetric)

Carrier Ethernet End-to-End Solutions

Portal

Registration

Monitoring

Billing

Subscriber Database

Identity

Address Mgmt

Policy Definition

Service Exchange System

Business Corporate

Residential

STB

Business Corporate

Residential

STB

Business Corporate

Residential

STB

Access

Ethernet Access Node

Ethernet Access Node

DSL Access Node

PON Access Node

Carrier Ethernet Aggregation

Aggregation Node

Aggregation Node

Aggregation Node

Aggregation Node

Aggregation Node

Aggregation Network MPLS, 802.1ah, or MPLS + 802.1ah

Centralised IP Edge

BNG

Distribution Node

Distribution Node

BNG

Multiservice Core

MSE

MSE

Core Network IP / MPLS

Design and Deployment Scenarios

1. H-VPLS with 802.1ah extension
2. MPLS core with 802.1ah aggregation

1. MPLS Core & Aggregation: H-VPLS extension with 802.1ah

VPLS w/ 802.1ah extension

- Improved scalability for native Ethernet aggregation

    Service Instances scaling: from 4K of 802.1ad to 16M of 802.1ah

    MAC scaling: MAC-in-MAC: customer MAC address hiding.

- Use cases:

    SP has converged MPLS core and MPLS in the Aggregation/Access.

- Operations:

    – The ingress IB-BEB maps a 12-bit VLAN ID from the PBN to a 24-bit I-SID in the I-Tag of PBBN (802.1ah)

    – A Backbone VLAN ID (B-VID) is used to build point-to-point or multipoint tunnels between BEB's.

    – MPLS control plane for core and aggregation provides simplified operation

      • Single VSI for an customer E-LAN connections
      • Auto-discovery aids provisioning
      • No STP
      • Using MPLS diff-serve, HA, p2mp, TE, and OAM

2. MPLS Core, 802.1ah Aggregation

802.1ah

802.1ad/Q-in-Q

802.1Q

VPWS/VPLS

802.1ah

C-VLAN

CE

CE

CE

IB-BEB

I-SID

PE/
B-BEB

VPWS

PE/
B-BEB

VSI

VPWS

IB-BEB

I-SID

S-VLAN

CE

CE

CE

I-SID

S-VLAN

I-SID

802.1ad/ Q-in-Q

IB-BEB

VPWS/VPLS
IP/MPLS Core

VSI

IB-BEB

PE/
B-BEB

VSI

PE/
B-BEB

802.1ad/Q-in-Q

I-SID

CE

CE

CE

CE

S-VLAN

IB-BEB

S-VLAN

E-Line Service

E-LAN Service

Access   **Aggregation**   **Core Transport**   **Aggregation**   **Access**

802.1ah over MPLS core

- Improved scalability for native Ethernet aggregation

    Service Instances scaling: from 4K of 802.1ad to 16M of 802.1ah

    MAC scaling: MAC-in-MAC: customer MAC address hiding.

- Use cases:

    SP has converged MPLS core and prefer to use native Ethernet aggregation to interconnect the 802.1ad (PBN)/Q-in-Q/802.1Q islands.

- Operation:

    – The ingress IB-BEB maps a 12-bit S-VLAN ID from the PBN to a 24-bit I-SID in the I-Tag of 802.1ah PBBN.

    – B-VID is used to build point-to-point or multipoint tunnels between BEB's.

    – Path selection in PBBN is based on STP (alternative is turning off STP and use NMS). STP in PBN are confined in its own island, not in PBBN.

    – Signaling for B-VID registration is based on GVRP, MVRP. Otherwise, B-VID can be provisioned

    – A PBBN assigns a multicast MAC address per I-SID for flood/broadcast containment

    – At the PE/B-BEB, B-VID or I-SID, or group of I-SID is mapped to the VSI depending on the topologies and interface type used.

E-Line / E-LAN Transport Design Option Comparison

	Maturity	New dev.	Scale limit	Optimal Mcast	HA	CoS	OAM	TE	Where it Fits?
VPWS	High	None	No std limit. System resource	N/A	MPLS HA	MPLS Diffserv	MPLS OAM	MPLS TE	MPLS base, E-Line
VPLS/H-VPLS	High	None (exc. Mcast)	H-VPLS scale better than VPLS. SI:4K plus	mLDP	MPLS HA	MPLS Diffserv	MPLS OAM	MPLS TE	MPLS base, E-LAN
VPLS w/802.1ah	Evolving	Low impact	C-MAC hiding SI:16M	mLDP	MPLS HA	MPLS Diffserv	MPLS OAM	MPLS TE	MPLS base, E-LAN scale
802.1ah agg. over MPLS core	Evolving	Low impact	C-MAC hiding SI:16M	mLDP for core, need E-p2mp dev	MPLS HA for core, STP for agg.	MPLS CoS for core; PCP+DEI for Ethernet	MPLS OAM for core, E-OAM for agg	MPLS TE for core, need PBB-TE agg	MPLS core; Ops prefer native Ethernet agg

Design considerations and future work

- Support 802.1ah interconnect to 802.1ad/Q-in-Q, as well as 802.1Q islands (extension to 802.1ah spec).

- Support new PW type (needed in I-SID mode) in MPLS

- Support L3 and MPLS L3 VPN termination.

- Ethernet Control plane for native 802.1ah aggregation/access instead of using STP

- B-MAC distribution with dynamic control plane protocol

- Scalable mp2mp for multicast

- C-MAC flushing mechanism

- Multicast pruning mechanism

- Migration considerations

  – MPLS core connects to 802.1ah in some locations, and connects to 802.1ad/Q-in-Q or 802.1Q in others

  – Not all n-PE / u-PE are 802.1ah capable during the interim period.

  – The solution must support partial 802.1ah capable network for proper handing of 802.1ah frames

Summary

- Carrier Ethernet Service requirements:
  - Focus on improving Scalability, HA, QoS, Security, and OAM.

- Why MPLS + 802.1ah?
  - MPLS is the choice of the core technology
    - Maturity, Multi-service support, p2p, p2mp, mp2mp connectivity; QoS, TE, FRR, OAM
  - 802.1ah add scaling advantages
    - MAC-address Scaling: C-MIC hiding
    - Service Instance Scaling: from ~4K to ~16M

- MPLS + 802.1ah scenarios
  - H-VPLS with 802.1ah extension
  - 802.1ah aggregation over MPLS core

References

- *"VPLS Interoperability with Provider Backbone Bridges*," draft-sajassi-l2vpn-vpls-pbb-interop-02.txt, A. Sajassi et.al. Nov. 2007.

- "*802.1ah Ethernet Pseudowire,*" draft-martini-pwe3-802.1ah-pw-02.txt, Martini, L. and A. Sajassi, Feb. 2008.

- *"Provider Backbone Bridging and MPLS: Complimentary* technologies for Next-Generation Carrier Ethernet Transport," by S. Salam and A. Sajassi, IEEE Communications Magazine, Vol. 46, No. 3, March 2008.

- *"The Evolution of Carrier Ethernet Services – Requirements and Deployment case Studies,"* by L. Fang, N. Bitar, R. Zhang, and M. Taylor, IEEE Communications Magazine, Vol. 46, No. 3, March 2008.

Thank You!

 Cisco Public