The NGN Carrier Ethernet System: Technologies, Architectures and Deployment Models

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Technical Leader
Agenda

• Next Generation Carrier Ethernet (NGN CE) System: Overview
• The context of Broadband Forum’s TR-101
• NGN CE Design:
  - Architecture Description
  - Service Delivery Models
  - High Availability
  - Quality of Service
  - Security Considerations
• Summary
• Questions and Answers
NGN Carrier Ethernet System:
Overview
Dominance of Video, Mobile, and Cloud
Fundamentally Different Traffic Mix

Exponential Growth + Evolving Traffic Mix = Complexity

IP traffic will increase 4X (767 exabytes by 2014)

Source: Cisco Visual Networking Index—Forecast, 2009-2014
How will NGN CE enable the transition

Transport Centric Model
Packet Optical Transport Network

Service Centric Model + Flexible Service Edge
### NGN Carrier Ethernet System

- **IP/MPLS-Based Transport/Per Service**
- **Flexible Service Mapping**
- **Subscriber Awareness Where Needed**
- **Video Optimisations**

![Network Layer Diagram](image)

**Application Layer**
- Video and Gaming
- Data Center
- Presence-Based Telephony
- Web Services
- Mobile Apps
- IP Contact Center

**Service Layer**
- Service Exchange

**Network Layer**
- Customer Element
- Access/Aggregation
- Intelligent Edge
- Multiservice Core

**Carrier Ethernet**

**Architectural Framework and Functionality**

**Physical Instantiation**
- Network Layer
- Operational Layer

**Application**
- VoD
- BNG
- DPI
- AGG
- DIST

**Access**
- MSE

**Aggregation**
- Core

**Edge**
- OSS/BSS

**Location Server**
- Billing
- NMS
NGN System
Technology Overview

- TR-101 Functions
- MSTP/REP/G.8032
- L2 Access Network
- 802.1Q NNI
- Local VLAN Significance
- Flexible service mapping
- Ethernet virtual connection infrastructure
- Security features
- ATM/TDM backhaul over MPLS
- EoMPLS/VPLS/L3VPN
- IP Unicast/Multicast Forwarding
- Ethernet/MPLS OAM
- Pseudowire Redundancy
- MPLS-TP
- Unified MPLS
- Fast Convergence
- IPTV Edge
- Backhaul HSI to BNG
- Distributed Triple Play Edge
- Interworking MPLS with MST/REP/G.8032
- Multi-Chassis Link Aggregation
- IPoDWDM integration
IP NGN Carrier Ethernet Design

- IP/MPLS-Based Transport/Per Service
- Flexible Service Mapping
- Subscriber Awareness Where Needed
- Video Optimisations

Architectural Framework and Functionality
How to Build the Ethernet Multipoint/ Multi-Edge Architecture? VPLS or…

- VPLS = LAN emulation
- Smells like a LAN, but is not a LAN
- H-VPLS is just a scaling option, retains full mesh notion

- EoMPLS Pseudowire (PW) serving as ‘virtual’ bridge trunk into a 802.1ad Bridge Domain (BD)
- Idea ‘divorces’ Transport Protocols from Service Instance Identifier (although only 4k service instances can be multiplexed across a single PW)
- Scaling can be improved with 802.1ah, Unified MPLS, MS-PW, etc
Converged SP Network Architecture

- **Services**
  - Residential: BTV/VoD, VoIP, HSI
  - Ethernet VPN: E-Line
  - Ethernet VPN: E-LAN/-Tree
  - IP and IP-VPN

- **Aggregation Service Models**
  - 802.1ad (Q-in-Q) Ethernet
  - MST/LAG/REP

- **Service Models**
  - L2 MPLS
  - L2+L3 MPLS

- **Network Components**
  - Access
  - Aggregation
  - Distribution
  - Edge
  - Core

- **Protocols**
  - EoMPLS
  - 802.1ad
  - IP or IP-VPN
  - Ethernet VPN: E-Line
  - Ethernet VPN: E-LAN/-Tree
  - IP and IP-VPN
Some Words about MPLS-TP

Connection Oriented, pre-determined working path and protect path
Transport Tunnel 1:1 protection, switching triggered by in-band OAM,
Options with NMS for static provisioning, or dynamic control plane for routing and signaling

Note: The cloud represents one MPLS-TP network, e.g., it may be in aggregation or access
Some words about Unified MPLS

IP Fast Convergence
RFC3107
MPLS OAM

LDP Downstream Ondemand
Static Routing

MPLS-TP (Optional)

1.000 Nodes / Core
10.000 Nodes / Aggregation
100.000 Nodes / Access
Cisco’s NGN CE Transport Direction

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SONET/SDH</th>
<th>Optical OTN (ROADMs)</th>
<th>Electrical OTN</th>
<th>PBB-TE</th>
<th>MPLS-TP</th>
<th>IP/MPLS</th>
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<tr>
<td>Ethernet</td>
<td>E-line (10GE)</td>
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<td>Time Division</td>
<td>Wave Division</td>
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<td>Multiplexing Technology</td>
<td>Time Division</td>
<td>Wave Division</td>
<td>Time Division</td>
<td>Statistical</td>
<td>Statistical</td>
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<td>UNI processing</td>
<td>Limited</td>
<td>None</td>
<td>None</td>
<td>Typically rich</td>
<td>Typically rich</td>
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<td>Granularity</td>
<td>VC-4</td>
<td>Lambda</td>
<td>ODU</td>
<td>Variable</td>
<td>Variable</td>
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<td>Technology Maturity</td>
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</table>

- Cisco focuses on IP/MPLS for the Carrier Ethernet Transport architecture.
- Cisco targets MPLS-TP for the POTS and Access Networks while supporting already Ethernet Bridged Access.
- Cisco also addresses MPLS to the access with Unified MPLS.
NGN Carrier Ethernet System

- IP/MPLS-Based Transport/Per Service
- Flexible Service Mapping
- Subscriber Awareness Where Needed
- Video Optimisations

Architectural Framework and Functionality

Framework for User and Application-Based Control

Carrier Ethernet

Physical Instantiation

Network Layer

Application Layer

Service Layer

Network Layer

Operational Layer

Access

Aggregation

Edge

Core

OSS/BSS

Billing

Location Server

NMS
Ethernet Virtual Connection (EVC) Framework

Policy Control Plane (per Subscriber)

- Portal
- Monitoring
- Billing
- Subscriber Database
- Identity
- Address Mgmt
- Policy Definition

Access
- Residential
  - MSPP
  - Cable
  - Untagged
  - Single Tagged
  - Double Tagged
  - 802.1q
  - 802.1ad
  - etc.

- Business
  - Corporate

- Residential

Aggregation
- L2 P-to-P
- L2 MP local bridging
- L2 Multipoint
- L3 routed
- Transport/tunnel protocol independent
- Provider Bridging over MPLS
- Provider Backbone Bridging over MPLS

Edge
- BRAS
- DPI
- SR/PE

Core Network
- MPLS/IP

Content Farm
- VoD
- TV
- SIP
NGN Carrier Ethernet System

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Architectural Framework and Functionality

Framework for User and Application-Based Control

Application Layer
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Carrier Ethernet

Access
- VoD
- BNG
- DPI
- AGG
- DIST

Aggregation
- MSE

Edge

Core

OSS/BSS
- Billing
- Location Server
- NMS
From Design Principles to Implementation

Centralized Edge

RAN Backhaul
- L1 CES over Packet
- Per Service QoS
- Distribution of Clock

High Speed Internet (HSI)
- L2 EoMPLS Backhaul
- Per sub QoS
- Central L3 and services
- PPPoE and DHCP

Video and Voice
- L3/MPLS edge distributed for efficient multicast and resiliency
- Per service QoS

Business VPN
- L2 EoMPLS backhaul
- Per sub QoS
- Central or distributed services (L3 VPN, L2 VPN, VPLS, FW)
Intelligent Services Gateway
Subscriber Session Handling

- Identifies sessions and service flows
  Traffic classification for all access architectures
  Session and flow provides per user granularity
- Dynamically assigns the session to a configured QoS policy (MQC) via Radius
- Establishes Virtual Route per Session
- Provides Policing, Access Control, Accounting, via Radius Push/Pull
  Authentication
  Logon
  Change of Authorization (Policy Push)
  L4 re-direction
  Accounting details
- Fully integrated with Routing Infrastructure
  e.g. mapping traffic to VRF, various routing tables

RADIUS
DHCP
Portal

RADIUS/AAA Push/Pull per Sub/Service Accounting

PPPoeoX
IPoE
ISG Sessions
L4R
Internet
Self-Provisioning/ Self-Care
Increased Scalability / Resiliency via Distributed Services

Drivers for More Clouds and Less Circuits

- **Reduction of CAPEX and OPEX**
  - Single provisioning point for all services (L2/L3)
  - Common converged infrastructure
  - Bandwidth Efficiency

- **Scale**
  - Integration and Distribution = Scale

- **Enhanced resiliency**
  - Automated rerouting, no need for interbox redundancy (VRRP)
  - Evolution to zero-loss video failover (0 ms)

- **Monitoring, control, billing of future services**
  - Video 2.0: P2P legal distribution model
  - Local content injection (VOD/I-frame caches)
  - Cloud Computing

- **However, SP Org. structures will be diverse**
  - Cisco supports circuit and cloud models
  - Organizational consolidation may lead to acceptance for cloud network configuration

![Diagram of Centralized BRAS/PE with 100–200K Subs and Distributed Residential 3Play with 8–24K Subs]
Dynamic Ethernet Service Activation (DESA)

- Ethernet infrastructure with programmatic interface
- Intelligent Service Management engine
- Power of dynamic subscriber management from ISG to automate provisioning of Ethernet Services
- Automated, customized Ethernet service provisioning infrastructure that saves OPEX

```
|  Ethernet Virtual Circuit (EVC) Framework   |  Intelligent Services Gateway (ISG) |
```
Dynamic Ethernet Service Activation: A Use Case

1. Customer orders L2 service at portal
   - Box is shipped to customer with minimal configuration (MAC, VLAN ID)
   - Customer plugs in CPE

2. First L2-traffic triggers Radius request to activate services

3. L2 Service profile applied (ACLs, QoS, Psuedowire...)

4. Activates billing and inventory functions.

5. Customer can change profile dynamically at any time
NGN Carrier Ethernet System

- IP/MPLS-Based Transport/Per Service
- Flexible Service Mapping
- Subscriber Awareness Where Needed
- Video Optimisations

Framework for User and Application-Based Control
Architectural Framework and Functionality

Application Layer
- Video and Gaming
- Data Center
- Presence-Based Telephony
- Web Services
- Mobile Apps
- IP Contact Center

Service Layer
- Service Exchange

Network Layer
- Customer Element
- Access/Aggregation
- Intelligent Edge
- Multiservice Core
- Carrier Ethernet

Physical Instantiation
Network Layer
Access
Aggregation
Edge
Core
OSS/BSS
Billing
Location Server
NMS

VoD
BNG
DPI
AGG
DIST
MSE
IP for Video and IP/TV Service Delivery

Key Characteristics and Benefits

• **Simplified Operations**
  IGMP/PIM only required, no snooping necessary in Aggregation network; snooping contained in DSLAM
  Single point of L3 termination for IP/TV (no VRRP required)
  No overlay topology

• **Optimal and Scalable Forwarding**
  SSM multicast distribution model for optimal tree creation under all conditions
  Dynamic load balancing on equal cost paths (!!)
  Optimized ARP and IGMP tables through distribution
  Flexible content injection, including localized content
  Same topology for unicast and multicast (!!)
  Scales in terms of network nodes and subscribers in any topology due to distributed L3
  Allows for on-path CAC

• **Resiliency**
  Consistent convergence in all failure cases: Source-, Node-, Link-Failure.
  Anycast-Source model for enhanced redundancy
  SSM security and address-space efficiency proven architecture in many 3Play production networks today

• **Future Ready**
  Possibility to add/distribute video monitoring and error concealment techniques easily
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Native IP Multicast</th>
<th>VPLS</th>
<th>p2multipoint MPLS Traffic Engineering</th>
<th>Multicast LDP (mLDP)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Convergence</strong></td>
<td>&lt; ~1s (link and node failures)</td>
<td>~50 ms (link failures)</td>
<td>~50ms (link failures only)</td>
<td>&lt; ~1s (~50ms with p2p MPLS TE FRR LP)</td>
</tr>
<tr>
<td><strong>Offload routing</strong></td>
<td>✓ (IGP metric based traffic engineering)</td>
<td>✓</td>
<td>✓</td>
<td>✓ (IGP metric based traffic engineering)</td>
</tr>
<tr>
<td><strong>Path separation</strong></td>
<td>✓ (MoFRR or MTR)</td>
<td>✓</td>
<td>✓</td>
<td>✓ (MoFRR or MTR)</td>
</tr>
<tr>
<td><strong>Admission control and bw reservation</strong></td>
<td>✓ (RSVP)</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>Scalable mp2mp MulticastVPN</strong></td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Typical Application</strong></td>
<td>Secondary Distribution (TV)</td>
<td>(Wholesale) Secondary Distribution (TV)</td>
<td>Contribution (TV)</td>
<td>Enterprise VPN</td>
</tr>
</tbody>
</table>

- MoFRR = Multicast Only Fast ReRoute, MTR = Multi Topology Routing
- Note: VPLS-LSM and E-VPN are not currently part of the system
Broadband Forum’s TR-101: An application of the NGN CE System
TR-101 Scope and Content

Technical Considerations

- VLAN architecture
- Multicast considerations
- Use of a **video-optimised Service Router** (next to ‘traditional’ TR-59 type BRAS)
- Resilience in the Ethernet Aggregation Network
- QoS in the Ethernet Aggregation Network
- Ethernet OAM
- Support for PPPoA and IPoA (aka interworking between XoA and XoE)

Note: TR-101 introduces the term Broadband Network Gateway (BNG) to differentiate from the legacy ‘BRAS’ term
VLAN Architecture: VLAN per User (1:1)

- VLAN use similar to ATM, i.e. connection-oriented, i.e. **configuration intensive**
- IEEE802.1ad—Inner Tag = Port Identifier, Outer Tag = DSLAM Identifier
- Multicast replication inside **Single** BNG, **not** inside Ethernet Aggregation Network
- Multi-homing to two BNGs is complex
- Good for p2p business services; less ideal for Triple-Play Services
VLAN Architecture:
VLAN Per Service/SP (N:1)

- Single tagged (802.1Q or 802.1ad) VLANs—double tagging not needed

- **Connectionless provisioning** benefit; Access Node inserts **Line ID** (DHCP Opt 82, PPPoE Intermediate Agent)

- Network Elements take care of subscriber MAC isolation through ‘**split horizon forwarding**’

- Multiple injection points per VLAN (BRAS and Video Service Router) possible

- Multicast **replication** within access/aggregation
The models considered are part of DSL Forum TR-101 section 2.5.1:

- Multiple VC DSL UNI
- Trunk UNI—Single VC DSL or Ethernet
- Non-Trunk UNI—Single VC DSL or Ethernet

In the Multiple VC DSL UNI model, the VC is used for both service prioritization and service connectivity.

In the Single VC DSL and Ethernet UNI models, these functions are distributed in 802.1p COS and 802.1Q VLANs.

Choice of model will be dependent on Access Node and RG capability, number and type of services offered and available bandwidth on local loop.
Ethernet Aggregate QoS Within the Access/Aggregation Network

- Per Class scheduling within Access/Aggregation Network
- Per Class scheduling is essential for Video as the Access Node is effectively a multicast insertion/replication point (replicating per subscriber line)
- Per Class scheduling essential when separate Video BNG is deployed
Cisco’s TR-101 Architecture
From Discrete Elements

Aggregation Node: Carrier Ethernet Switch/Service Router with Aggregation Function

Aggregation Node: Carrier Ethernet Switch/Service Router with Aggregation Function

BNG/BRAS Extremely Important for PPP Services/Migration/Legacy ATM Support

L2 Aggregation with IGMP Snooping

Video BNG

IP/MPLS Core

Business

Residential
Cisco’s TR-101 Architecture
To Integrated Network Elements

Carrier Ethernet Service Router (L1, L2, L3)
Video BNG (L3 IP/PIM-SSM) + L2 Aggregation
Option to Virtualize L2 Aggregation (IP Control Layer, MPLS Techniques)

BNG/BRAS Extremely Important for PPP Services/Migration/Legacy ATM Support

BNG BRAS
IP/MPLS Core

L2 Aggregation + L3 IP/PIM-SSM

Business
Residential
NGN Carrier Ethernet System:
Architecture Options
NGN Carrier Ethernet System
Ethernet Virtual Connection (EVC) Overview

- One EFP Can Match One or Multiple or Range of VLANs at a Time
- Flexible VLAN Tag Matching
- Flexible VLAN Tag Rewrite
- H-QoS Per EFP
- Security
- Flexible VLAN Tag Manipulation, Pop/Push/Translate
- VLAN Local Port Significance
- Two VLAN Tag Aware
- Flexible VLAN Tag Matching (Combination of Up to Two Tags)

- Service Instance (Ethernet Flow Point)
  - L3
  - VPLS
  - EoMPLS
- Local Connect (P2P)
- Local Bridging (MP)
- 802.1ah Bridging

- Flexible L2/L3 Service Mapping, One or Groups of EFPs Can Map to Same EVC
Cisco EVC Infrastructure

EVC infrastructure
- Provides flexible classification of L2 flows on Ethernet interfaces
- Supports dot1q and Q-in-Q, 802.1ad with local VLAN significance
- Supports VLAN list, ranges & combinations
- Coexists with routed subinterfaces
- Flexible VLAN acrobatics (translate, pop, push)
- Full H-QOS support
Cisco EVC UNI
Flexible Frame Matching with Ethernet Flow Points

**EFPs ...**

- Provide classification of L2 flows on Ethernet interfaces
- Are also referred to as EVC service-instances
- Support dot1q and Q-in-Q
- Support VLAN lists
- Support VLAN ranges
- Support VLAN Lists and Ranges combined
- Coexist with routed subinterfaces
- Both EFPs and routed Subinterfaces support H-QOS

**EFPs on Interface**

- Match VLAN: 14
- Match VLAN range: 100-102
- Match VLAN list: 200, 203, 210
- Match VLAN: 300,100
- Match outer VLAN 400, inner VLAN range: 1-3
- Match outer 400, inner VLAN list: 11,17,34

**Physical Ethernet interface (GE/10GE)**
Flexible Service Mapping/Forwarding

interface GigabitEthernet3/0/0
  description Sample Configs

  service instance 1 ethernet
    encapsulation untagged
    rewrite ingress tag push dot1q 3 symmetric
    xconnect 10.30.30.173 2 encapsulation mpls

  service instance 10 ethernet
    encapsulation dot1q 10
    rewrite ingress tag pop 1 symmetric
    bridge-domain 500 split-horizon

  service instance 20 ethernet
    encapsulation dot1q 20 second-dot1q 200
    rewrite ingress tag pop 1 symmetric
    bridge-domain 500 split-horizon

  service instance 30 ethernet
    encapsulation dot1q 20 second-dot1q any
    rewrite ingress tag pop 1 symmetric
    bridge-domain 500 split-horizon

interface GigabitEthernet3/0/1
  description Sample Configs

  service instance 1 ethernet
    encapsulation default
    xconnect 10.30.30.173 2 encapsulation mpls

* Not All Configuration Combinations Shown Here
NGN Carrier Ethernet System: Service Delivery Models
IP NGN Carrier Ethernet Design—VLAN Models

- VLAN Models in accordance with TR-101 (residential) and MEF (business services)
- Business Services make use of 1:1 VLANs
- Video (unicast and multicast) always delivered across an N:1 VLAN from Aggregation node to Access Node
  - Allows efficient replication
  - Allows RSVP based CAC
  - Allows multicast CAC
- Other Services can either:
  - Share that N:1 VLAN (non trunk UNI model at Access Node)
  - Use a different N:1 VLAN (trunk UNI/Multi-VC model at Access Node)
    - Per Service N:1 VLANs
  - Use a different 1:1 VLAN (trunk UNI/Multi-VC model at Access Node)
    - 1:1 VLAN for Internet Access (and Voice), N:1 VLAN Video
- Wholesale Models make use of 1:1 and N:1 VLAN models
Residential Services Architecture (Centralized BNG)

Retail 3Play Services

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>HSI, VoIP VLAN(s)</td>
<td>Non/Trunk UNI, N:1 or 1:1 VLAN</td>
</tr>
<tr>
<td>VoD+IPTV, VoIP VLAN</td>
<td>N:1 VLAN</td>
</tr>
</tbody>
</table>

Transport Deployment

- EoMPLS PW
- 802.1Q, QinQ
- MPLS/IP, IP Multicast, MoFRR

Wholesale 3Play Services

<table>
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<tr>
<th>Service</th>
<th>Description</th>
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<tbody>
<tr>
<td>HSI, VoIP VLAN(s)</td>
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</tr>
</tbody>
</table>

Transport Deployment

- EoMPLS PW
- 802.1Q, QinQ
- MPLS/IP, IP Multicast, MoFRR

Efficient Access Network

- DSL, PON, Ethernet
- Aggregation Node ASR9k, ME3800X, 7600

Large Scale Aggregation Network

- Service Aware or Transport VPWS, VPLS, MPLS/IP
- Distribution Node ASR9k, 7600

Intelligent Services Edge

- HSI SEN, ASR1k
- Ethernet UNI
- Ethernet/MPLS NNI
- Video SEN, 7600

Multiservice Core Network

- Ethernet UNI
- Core Node
- PPP, IP, MPLS
- MPLS

Enables PPPoE to IPoE migration, usage based services with service and session control, DPI and SBC

May include in future service supporting functions; Content Cache, FCC, RET, VoD CAC
Non-Trunk UNI, N:1 VLAN
Residential Services Aggregation Model

- Port-significant VLAN ids removed on ingress
- Routing AND bridging in a common N:1 VLAN
- VLAN id added on egress towards BNG
Residential Services Architecture (Distributed BNG)

Retail 3Play Services

Enables PPPoE and IPoE coexistence, support for video and voice services over FTTX and future PON access

MPLS/IP, PIM
MPLS VPNs, Multicast VPNs

MPLS VPN based managed wholesale services,

May include service supporting functions: Content Cache, FCC, RET, Vod CAC, DPI, SBC,

Wholesale 3 Play Services

Enables PPPoE and IPoE coexistence, support for video and voice services over FTTX and future PON access

MPLS/IP, PIM
MPLS VPNs, Multicast VPNs

MPLS VPN based managed wholesale services,

May include service supporting functions: Content Cache, FCC, RET, Vod CAC, DPI, SBC,
Non Trunk UNI, 1:1 VLAN Model
Residential Services Aggregation Model, Distributed Edge
Business Services Architecture

- **Business L3 VPN**: Port, 1Q, QinQ
- **Business E-LAN**: Port, 1Q, QinQ
- **Business E-LINE**: Port, 1Q, QinQ

**Transport Deployment**
- Ethernet
- MPLS VPN

**Service Aware Deployment**
- QinQ
- H-VPLS or VPLS and VPLS+1ah

**MPLS VPN/Multicast VPN (GRE)**
- MPLS VPN
- EoMPLS

**Large Scale Aggregation Network**
- Ethernet UNI
- Ethernet/MPLS NNI
- Business SEN, ASR9k

**Efficient Access Network**
- Access Node
- Aggregation Node ASR9k, ME3800X, 7600
- Distribution Node ASR9k, 7600
- DSL, PON, Ethernet
- 802.1ad NNI, MPLS / IP Transport

**Intelligent Services Edge**
- Business SEN, ASR9k

**Multiservice Core Network**
- MPLS
Wholesale Transport Services Architecture

- HSI, VoIP, VoD, TV
- N:1 or 1:1 VLAN
- TV
- N:1 VLAN w/ Access Node MVR

- HSI, VoIP, VoD
- N:1 or 1:1 VLAN
- TV
- N:1 VLAN w/ Access Node MVR

- VPLS+IGMP Snooping over Physical Topology
- VPLS+802.1ah (ISID per Retailer/Access Node)
- VPLS+IGMP Snooping over Physical Topology

- 802.1ad
- SP NNI
- PIM SSM

- 802.1ah
- SP NNI
- PIM SSM

Efficient Access Network
Large Scale Aggregation Network
Intelligent Services Edge
Multiservice Core Network

- DSL, PON, Ethernet
- 802.1ad NNI, MPLS / IP Transport
- PPP, IP, MPLS
- MPLS

Access Node
Aggregation Node
Distribution Node
Core Node

Service Aware or Transport
VPWS, VPLS, MPLS/IP

Ethernet UNI
Ethernet/MPLS NNI
Ethernet UNI
IEEE 802.1ah Service Aggregation Model

- EPLAN: Port
  Classify default
- EPLAN: QinQ Access
  Classify S-VLAN
  Ingress Pop S-VLAN
  symmetric
- EVPLAN: 802.1q Access
  Classify C-VLAN
  Ingress Pop C-VLAN
  symmetric

802.1q or QinQ

- C-MAC BD2
- ISID-1

802.1q or QinQ

- C-MAC BD2
- ISID-2

20xGE

Access

2x10GE

Aggregation

2x10GE

Distribution

20xGE

Core

VFI

H-VPLS Transport

VPLS PW
Residential Services Architecture with MPLS-TP Aggregation

Retail or Wholesale 3Play Services

HSI, VoIP VLAN(s)

Trunk UNI, N:1 or 1:1 VLAN

EoMPLS PW (static or LDP)

802.1Q QinQ

802.1Q

VPLS LDP, IGMP snooping per VFI

IPTV Transport

VoD, IPTV VLAN

Trunk UNI, N:1 VLAN

N:1 VLAN

Video Unicast Transport

EoMPLS PW (static or LDP)

802.1Q QinQ

802.1Q

ISG Sessions

HSI SEN

MPLS/IP MPLS VPN

MPLS/IP MPLS/Multicast VPN

EoMPLS PW (static or LDP)

802.1Q QinQ

802.1Q

VPWS, VPLS over MPLS TP

Large Scale Aggregation Network

Transport Focused Deployment

Intelligent Services Edge

HSI SEN, 7600

Ethernet UNI

Core CRS-3

Multiservice Core Network

Efficient Access Network

Access Node

Aggregation Node NGXP, CPT

Distribution Node NGXP, CPT

DSL, PON, Ethernet

802.1adNNI, DWDM+MPLS TP

PPP, IP, MPLS

MPLS
Business Services Architecture with MPLS-TP Aggregation

**Efficient Access Network**
- DSL, PON, Ethernet
- 802.1adNNI, DWDM+MPLS TP

**Large Scale Aggregation Network**
- Aggregation Node
- NGXP, CPT
- VPWS, VPLS over MPLS TP

**Intelligent Services Edge**
- Business SEN, ASR9k
- Ethernet UNI
- MPLSNNI

**Multiservice Core Network**
- CRS-3
- Ethernet UNI
- Business SEN, ASR9k

**Transport Focused Deployment**
- VPWS, VPLS over MPLS TP
NGN Carrier Ethernet System: High Availability
Baseline Network Availability Mechanism

- **Access Mechanisms**
  - Multiple Spanning Tree (MST) or MST Access Gateway
  - Resilient Ethernet Protocol (REP)
  - LACP, Multi-Chassis LACP
  - Inter Chassis Control Protocol (ICCP)

- **IP Services and MPLS IGP:**
  - IP Fast Convergence
  - BFD
  - Multicast Fast Convergence, MoFRR

- **MPLS Services:**
  - VPLS mac-address withdrawal; MST/REP and VPLS interworking
  - Pseudowire redundancy including pseudowire status bit support
  - MPLS TE-FRR Link and Node protection with IP services, PW/VPLS PW tunnel selection
Tight SLAs for CE/MPLS Infrastructure
Technology Options Overview

• **Simplicity** should be the guiding rule of all Tight SLA designs

• Service Recovery = Protection (super-fast) and Restoration (fast)

• **IP/MPLS fast convergence baseline has improved dramatically**
  - IGP Fast Convergence (FC) broke the barrier of <200msec restoration time
  - Powerful and simple baseline tool for all L2 and L3 services, covering multiple failures
  - Combined with BGP PIC* ensures fast convergence for IP/IPVPN service edge
  - **It is simple – a built-in property of the IP/MPLS network**

• **Protection with IP Fast ReRoute (FRR)**
  - Tool to improve on IGP FC for some topologies (e.g. Two-plane designs)
  - Provides local protection with <50msec recovery

• **Protection with MPLS TE FRR**
  - Local Link and Node Protection for deterministic <50msec recovery
  - Seamless service restoration (make-before-break)
  - Applies to all transit MPLS link and node failures

---

* BGP PIC – BGP Prefix Independent Convergence
IGP Fast Convergence (IPFC)

Properties and Benefits

• Enabled by IGP fast topology updates and distributed computation
  - Optimized SPF calculation
  - Optimized RIB and FIB calculation
  - Optimized FIB distribution to the forwarding plane (e.g. linecards)

• IGP FC always matters
  - BGP next-hop, IPTV PIM-SSM source availability, VOD services
  - MPLS pseudowires leverage IP FC
  - MPLS TE topology and resource information
  - Catastrophic events

• No impact on the network stability
• Works out of the box on Cisco devices
  - 200-500 ms convergence

• Years of experience with large SP networks deployments
• Operational simplicity is achieved!
Tight SLAs for L3 Services

• Leverage IP/MPLS infrastructure tight-SLA technologies
  - IGP Fast Convergence
  - MPLS TE FRR
  - IP FRR Loop Free Alternative (LFA)

• Optimize L3 PE forwarding plane for fast convergence
  - BGP Prefix Independent Convergence
  - IP Multicast PIM Fast Convergence
  - Multicast only Fast ReRoute (MoFRR)
IP/MPLS optical integration - IPoDWDM

IP / optical integration enables the capability:

- To identify degraded link using optical data (per-FEC BER)
- Start protection (i.e. by signaling to the IGP) before traffic starts failing, achieving hitless protection in many cases

<table>
<thead>
<tr>
<th>IP / optical integration enables the capability:</th>
<th>Packet Loss (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest</td>
</tr>
<tr>
<td>Yes, pre-FEC BER</td>
<td>Optical-switch</td>
</tr>
<tr>
<td>Yes, Optical-switch</td>
<td>Fibre-pull</td>
</tr>
<tr>
<td>Yes, PMD-Injection</td>
<td>Noise-injection</td>
</tr>
<tr>
<td>No, Noise-injection</td>
<td>PMD-Injection</td>
</tr>
</tbody>
</table>

MPLS FRR, IP FRR, IS-IS fast convergence : all achieve near zero outage for slow failures
MST Access Gateway

Operation and Benefits

• Operation
  Top PE sends “pre-canned” BPDUs (best root) into L2 access network
  Access network runs normal MSTP, MSTP is terminated locally on the PE access ports
  MSTP TCNs trigger VPLS MAC Flush + Withdraw
  MST instances have per port local significance – greatly improves scalability
  Only subset of functionality needed for REP Access Gateway (future)

• Benefits
  Seamless integration with any L2 access network or node running MSTP, full standard compliance
  Inherent scalability and faster L2 convergence due to local Rapid STP behaviour
Ring protection protocols: another push beyond spanning tree

- A ring topology is a cheap method of achieving redundancy, suitable for access networks.

- Spanning tree is geared toward loop avoidance in a general topology and does not require configuration, but this comes at the cost of convergence time.

- If a topology is known to be a ring at the outset, a loop avoidance protocol can be designed and optimized to achieve rapid 50ms convergence (but does require configuration and some hardware support).

- G.8032 and Cisco’s REP are such examples.
What Is Resilient Ethernet Protocol (REP) ?

• A new protocol designed to provide a solution for fast and predictable Layer 2 convergence for Carrier Ethernet networks

• Fast and predictable convergence
  Convergence time: 50 to 250ms
  Fast failure notification even in large rings

• Limit the scope of Spanning Tree
  STP is deactivated on REP interfaces
  STP TCN sent away from the segment if segment fails

• Allows VLAN load balancing for optimal bandwidth utilization

• Cisco proprietary (future alignment and interworking with ITU-T G.8032)
REP
A Segment Protocol

• REP guarantees there is **no connectivity between two edge ports** on a segment

• A **REP segment** is a chain of ports connected to each other and configured with a **segment ID**

• When all interfaces in the segment are UP, the **alternate port** is blocking

• When a link or switch failure occurs on the segment, then blocked port goes forwarding
REP Edge No Neighbour

- Enhancement to REP introduced in latest Ethernet Access Node releases
- Allows interconnection of REP segments with STP/VPLS domains
G.8032 Ethernet Ring Protection (ERP)  
Objectives and Principles  

• Protection switching on Ethernet layer  
• Utilizes conventional Ethernet bridge domains as forwarding plane  
• Preventing any loops by blocking mechanism  
• Can protect against any single failure on the ring  
• Fast convergence (50 ms)  
• Support of administrative commands (e.g. to force a failure etc)  
• Relies on Ethernet OAM for fault detection and as its control channel, and Y.1731 Ring-Automatic Protection Switching (R-APS) to signal a failure upstream  
• Supports Closed and Open (like a REP Segment) Rings  
• Functionally Equivalent to REP
Pseudowire-Redundancy

Signalling the Status of A PW

Use Case:

- T-LDP PW Status TLV:
  - 0x00000000 - Pseudowire forwarding (clear all failures)
  - 0x00000001 - Pseudowire Not Forwarding
  - 0x00000002 - Local Attachment Circuit (ingress)
    Receive Fault
  - 0x00000004 - Local Attachment Circuit (egress)
    Transmit Fault
  - 0x00000008 - Local PSN-facing PW (ingress)
    Receive Fault
  - 0x00000010 - Local PSN-facing PW (egress)
    Transmit Fault
  - 0x00000020 - PW Forwarding Standby
    (NEW Status Bit)
  - 0x00000040 – Request switchover to this PW
    (New Status Bit)*

- Two modes of operation
  - Independent Mode: Each side signals its separate state (forwarding/standby)
  - Master/Slave Mode: One Master imposes the PW state onto slaves

- Works across single segment and multisegment PWs

See draft-ietf-pwe3-redundancy
draft-ietf-pwe3-redundancy-bit
Pseudowire Redundancy (Two-way)
Leveraging ICCP and Multi-Chassis LACP

- Failures within MPLS network are protected by IP FC, IP FRR, MPLS FRR
- Failures of Ethernet Attachment Circuits or PE handled by two-way PW redundancy (Note: both sides of the PW are protected)
- Inter-Chassis Communication Protocol (ICCP) for synchronization of redundancy state control for LACP and PW redundancy
Aggregation Redundancy
Active/Active Aggregation Node Redundancy

- Natural” load balancing between BRASs
- Behavior can be influenced with PADI-delay
- Terminating two pseudowires into VFI/Bridge
- Learning can be disabled + Static mac-address entries + IGMP Snooping
Aggregation Redundancy

Active/Backup Access Node Redundancy (FlexLink)
Aggregation Redundancy
Interworking MPLS and MST for Active/Active

- Aggregation node participates with MST, PW dedicated to BPDU handling
- MST Access Gateway allows better scaling and MST separation between access rings/links
“REP or G.8032 is running on Aggregation / Integrated Edge Nodes

- REP Segment or G.8032 ERP Open Ring unblocks in any failure case
- TCN sent on segment failure → Triggers VPLS MAC-Withdrawal
Aggregation Redundancy
Interworking REP and MPLS

- "REP Edge No Neighbor" on access nodes
- REP Segment unblocks in any failure case
- TCN sent on segment failure → Triggers VPLS MAC-Withdrawal
NGN Carrier Ethernet System: Quality of Service
Ensuring QoS SLAs

**UNI**
- Ingress and Egress maximum/minimum bandwidth
- Ingress hierarchical shaping/scheduling
  - (e.g. Port, S-VLAN, C-VLAN, Class)
  - ingress hierarchical policing
- Ingress and Egress DiffServ queuing per shaped max Bw
  - 4 scheduling levels
- 2 strict priorities
- 3 parameter scheduler (max, min, remaining)
- Service grouping for shared policies
- Classification on customer or provider marking
- Traffic stats per VLAN interface and per QoS class

**MPLS Transport**
- DiffServ queuing
- Aggregate queuing and scheduling
- 2 strict priorities
- 8 classes

**NNI/Metro-Core**
- EVC - An association of two or more UNIs
  - Connection between two or more devices

**CE-A**
- Ethernet Virtual Circuit (EVC) – Point-to-Point

**CE-B**
- Ethernet Virtual Circuit (EVC) – Multipoint

**UNI**
### Linecards with Scalable H-QoS

#### 4-Level Hierarchy Example

<table>
<thead>
<tr>
<th>Port Level</th>
<th>Subscriber group Level</th>
<th>Subscriber Level</th>
<th>Class Level</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PQ1</td>
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<td>BW</td>
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<td></td>
<td></td>
<td></td>
<td>BW</td>
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<td></td>
<td></td>
<td>VolP – Bearer + Control</td>
<td>Business Critical</td>
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<tr>
<td></td>
<td></td>
<td>VolP – Bearer + Control</td>
<td>Internet – Best Effort</td>
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<td></td>
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<td></td>
<td></td>
<td>VolP – Bearer + Control</td>
<td>Telepresence</td>
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</tbody>
</table>

- **4 layers H-QoS** for MEF and TR-101 compliant SLA applications
- **Ingress and egress H-QoS** with hierarchical shaping
- **Shared H-QoS policy** applied across multiple EVCs – allows for bundled SLAs
- **Dual Priority** scheduling with priority propagation for minimum latency and jitter (Voice+Video)
- **Flexible & granular** classification: Full Layer 2, Full Layer 3/4 IPv4, IPv6 (even for L2 services)
## Multicast CAC Models

<table>
<thead>
<tr>
<th>Single Mroute state limits</th>
<th>Multiple Mroute state limits</th>
<th>Cost factor Mroute state limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Limits the number of multicast streams sent towards the DSL Access Node&lt;br&gt;• Applies to deployment models that have the same stream encoding and assumes the maximum bandwidth per stream is known and used to calculate the number of possible streams&lt;br&gt;• The streams encoding is the same and known</td>
<td>• Limits the number of multicast streams sent towards DSLAM, per TV programs bundles&lt;br&gt;• Enables TV programs to be bundled and delivered to the DSLAM based on different CAC rules</td>
<td>• Enables bandwidth CAC control per TV bundles or content providers&lt;br&gt;• Enables global bandwidth CAC control per stream types</td>
</tr>
</tbody>
</table>

### Single Mroute state limits

- Limits the number of multicast streams sent towards the DSL Access Node
- Applies to deployment models that have the same stream encoding and assumes the maximum bandwidth per stream is known and used to calculate the number of possible streams

### Multiple Mroute state limits

- Enables bandwidth CAC control per TV bundles or content providers
- Enables global bandwidth CAC control per stream types

### Cost factor Mroute state limits

- Enables bandwidth CAC control per TV bundles or content providers
- Enables global bandwidth CAC control per stream types

---

**Multicast CAC**

- IP Multicast or VPLS IGMP snooping CAC options on the Access Node:
  - Single Mroute state limits
  - Multiple Mroute state limits
  - Cost factor Mroute state limits

---

**Access UNI**

- Multicast VPN/PIM
- VPLS IGMP snooping

---

**Efficient Access Network**

- DSL, PON, Ethernet, 2G/3G
- 802.1ad NNI, MPLS / IP Transport

---

**Large Scale Aggregation Network**

- Service or Transport VPWS, VPLS, MPLS/IP

---

**Intelligent Services Edge**

- HSI SEN
- Video SEN
- Business SEN

---

**Multiservice Core Network**

- Core Node
- MPLS
NGN Carrier Ethernet System: Security
Carrier Ethernet—New EVC Model

Centralized Model
- Subscriber session awareness for PPPoE, IP Session
- Authentication: PPPoE or Web-Based
- Authorization: Radius based on Username, DHCP Option 82
- IP Address Management: RADIUS, DHCP

Distributed Model
- Subscriber session awareness for PPPoE, IP Session
- Authentication: PPPoE or Web-Based
- Authorization: RADIUS based on Username, DHCP Option 82
- IP Address Management: RADIUS, DHCP

Distributed Model
- IP Unicast/Multicast/VRF routing
- No Network awareness for subscriber sessions
- Per VLAN MAC Limiting
- VLAN-based Access Lists
- DHCP Snooping/DAI/Mac Security
- Storm Control
- L3/L4 ACLs
- Split Horizon
NGN Carrier Ethernet System: Summary
Summary: NGN CE System

- IP/MPLS-Based Transport/Per Service
- Flexible Service Mapping
- Subscriber Awareness Where Needed
- Video Optimisations
NGN System
Technology Overview

- TR-101 Functions
- MSTP/REP/G.8032
- L2 Access Network
- 802.1Q NNI
- Local VLAN Significance
- Flexible service mapping
- Ethernet virtual connection infrastructure
- Security features
- ATM/TDM backhaul over MPLS
- EoMPLS/VPLS/L3VPN
- IP Unicast/Multicast Forwarding
- Ethernet/MPLS OAM
- Pseudowire Redundancy
- MPLS-TP
- Unified MPLS
- Fast Convergence

- IPTV Edge
- Backhaul HSI to BNG
- Distributed Triple Play Edge
- Interworking MPLS with MST/REP/G.8032
- Multi-Chassis Link Aggregation
- IPoDWDM integration

- IPampoWDM Integration
- Optical Network Aggregation Node
- MPLS/IP
- Carrier Ethernet Aggregation
- Edge Aggregation Node
- Ethernet Node
- Internal VLAN Significance
- Flexible service mapping
- Ethernet virtual connection infrastructure
- Security features

- ATM/TDM backhaul over MPLS
- EoMPLS/VPLS/L3VPN
- IP Unicast/Multicast Forwarding
- Ethernet/MPLS OAM
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- MPLS-TP
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