Carrier Ethernet and Mobile Backhaul

Hernán Contreras G.
Consulting Systems Engineer
Cisco Systems Chile
hcontrer@cisco.com
CCIE #5288
Agenda

1. What is Carrier Ethernet
2. Scaling Carrier Ethernet with IP/MPLS
3. Scaling Carrier Ethernet with 802.1ah+VPLS/H-VPLS
4. Aggregation at Mobile Networks (RAN)
5. Clock Distribution at Ethernet Mobile Backhaul
6. Summary
What is Carrier Ethernet

**Carrier Ethernet**: the extensions to Ethernet necessary to enable telecommunications network providers to provide Ethernet services to customers and to utilize Ethernet technology in their networks.

- Media and Access Technology Agnostic
- Ethernet over Anything
- Consistent Service Level Agreements
- Rapid Deployment Velocity

**Convergence**:
- Business & Consumer
- Wireline & Mobile
- Personalized Service Distribution
- Policy Enforcement

**Centralized Services**
- Business VPNs
- Policy Management
- Flexible Business Models

**Consistent Management and Provisioning**
Carrier Ethernet System - Objectives

- **Offer optimal Access to Aggregation inter-connect:**
  - Flexibility
  - Scalability
  - Service level identity
- **Reduce complexity:**
  - Operations
  - Network planning

- **Support residential, business and wholesale services, with:**
  - Service level identity
  - Transparency
  - Scalability
  - Carrier-class redundancy
  - Transport efficiency

- **Offer optimal Aggregation / Core inter-connect:**
  - Scale
  - Redundancy
  - Service level identity
- **Reduce complexity:**
  - Operations
  - Network planning

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**Efficient Access**

- **Access Node**

**Large Scale Access Aggregation**

- **Aggregation**

**Retail Intelligent Edge**

- **BNG**
  - **PE**

**Multiservice Core**

- **Core**

**Content Services**

**L3 Services**

**L2 Services**

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DSL, PON, Ethernet, WiMAX
Using IEEE MAC Bridging with extensions for 802.1Q VLANs and 802.1ad (QinQ) Control Plane based on MST/RSPT (802.1w/s) Typically using a GE Ring Topology
Ethernet Aggregation Domain
Scalability and Reliability Issues

In the Core network, Ethernet and its associated control protocol (SPT, MAC Forwarding) have not considered as a suitable transport technology

- Relies on MAC Address learning for forwarding and the address space of original Ethernet (802.1ad) poses significant scalability challenges due to inability to summarize or aggregate MAC addresses
- Limitation on the number of services instance (not enough for scalable end-to-end L2 Ethernet services)
- Spanning Tree Protocol calculates only one path and lacks sophisticated Traffic Engineering and Resilience capabilities
Layer 2 virtualized transport mechanisms provide service isolation
Support for point to point and multipoint services with centralised or distributed service edge
IP/MPLS based Aggregation Network permits to scale L2 services instance through point to point Pseudowires (EoMPLS) and multipoint services (VPLS/H-VPLS) with support for centralised or distributed Intelligent L3 service edges (VPN/Multicast)
1. Transport Functions between Access and Edge
2. Intelligent Access Multiplexing
3. MPLS/IP Layer 2 and Layer 3 transport services
   - Transparent Ethernet transport (P2P and MP)
   - Service aware IP transport for 3play (IPTV, VoD, Voice) services.
4. Provides the option for implementing L2/L3 Business VPN Services
## Carrier Ethernet Services

<table>
<thead>
<tr>
<th>Market</th>
<th>Services</th>
<th>Access</th>
<th>SLA Type</th>
<th>SLA Example</th>
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</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Internet Access</td>
<td>Ethernet, DSL, PON</td>
<td>Transport</td>
<td>Dynamic access bandwidth, session/idle timeout, advertisements, post paid/prepaid (time and volume)</td>
</tr>
<tr>
<td></td>
<td>VoIP Telephony</td>
<td>Ethernet, DSL, PON</td>
<td>Application</td>
<td>The number of VoIP appliances, SIP URLs/PST Phone numbers, active calls, VoIP call quality</td>
</tr>
<tr>
<td></td>
<td>VoD</td>
<td>Ethernet, DSL, PON</td>
<td>Application</td>
<td>The number of STBs, stream quality, content flavours, charging models</td>
</tr>
<tr>
<td></td>
<td>TV</td>
<td>Ethernet, DSL, PON</td>
<td>Application</td>
<td>The number of STBs, type of TV packages, SD vs HD content and delivery quality</td>
</tr>
<tr>
<td>Business</td>
<td>L3 VPN</td>
<td>Ethernet, DSL, PON</td>
<td>Transport</td>
<td>Access bandwidth, differentiated services support, L3 VPN topology, managed services (Unicast/Multicast VPN)</td>
</tr>
<tr>
<td></td>
<td>E-Line</td>
<td>Ethernet, DSL, PON*</td>
<td>Transport</td>
<td>Access bandwidth, differentiated services support, transparency</td>
</tr>
<tr>
<td></td>
<td>E-LAN</td>
<td>Ethernet, DSL, PON*</td>
<td>Transport</td>
<td>Access bandwidth, differentiated services support, multipoint transport, transparency</td>
</tr>
</tbody>
</table>
Residential Services Architecture

- **Non Trunk UNI, N:1 VLAN**
- **Trunk (Multi VC) UNI, N:1 Service VLAN**
- **Trunk (Multi VC) UNI, 1:1 Internet Access VLAN**

These models are the baseline in TR-101 and present in existing Access Nodes implementations.

**Efficient Access**

- HSI, VoIP
- N:1, 1:1 VLAN models

**Large Scale Aggregation**

- IP Model
  - VoD, IPTV, VoIP
  - N:1 VLAN model

**Intelligent Edge**

- MPLS/IP Model
  - VoD, IPTV, VoIP
  - N:1 VLAN model

**Multiservice Core**

- EoMPLS PW
- PIM and IGP control plane
  - IP unicast/multicast data plane

- MPLS/IP data plane
  - VoD control plane: LDP, RSVP-TE
  - TV control plane: PIM, 2nd IGP

- Access Node UNI and connectivity models:
  - Non Trunk UNI, N:1 VLAN
  - Trunk (Multi VC) UNI, N:1 Service VLAN
  - Trunk (Multi VC) UNI, 1:1 Internet Access VLAN

- EoMPLS Pseudowire
- HSI, VoIP
- N:1 VLAN model

- MPLS/IP Model
  - VoD, IPTV, VoIP
  - N:1 VLAN model

- 3Play IP service subnet

- IP Model
  - VoD, IPTV, VoIP
  - N:1 VLAN model

- 3Play IP service subnet

- Access Node UNI and connectivity models:
  - Non Trunk UNI, N:1 VLAN
  - Trunk (Multi VC) UNI, N:1 Service VLAN
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EoMPLS Operation in MPLS Networks

Packets are transported over IP/MPLS networks using:

1. **Tunnel Label or outer label**, used to forward the packet across the network (LSP tunnel)
   
   LSP, a uni-directional path to the destination PE setup between PEs thru LDP link establishment or RSVP-TE signalling.

2. **VC Label or Inner Label (4 Byte MPLS Label)** used uniquely to identify the VC and bind it to the L2 interface where packets must be forwarded
   
   Signalled thru Directed LDP session established between PEs
EoMPLS Operation

Packet Flow
Business Services Architecture

- **Efficient Access**
  - Access Node: DSL, WiMAX, Ethernet
  - Aggregation Node
  - Distribution Node

- **Large Scale Aggregation**
  - EoMPLS PW
  - Ethernet
  - QinQ

- **Intelligent Edge**
  - L3 VPN PE
  - Ethernet UNI

- **Multiservice Core**
  - MPLS NNI
  - MPLS
  - IP, MPLS

- **Business L3 VPN**
  - Port, 1Q, QinQ
  - MPLS-VPN

- **Business E-LINE**
  - Port, 1Q, QinQ
  - EoMPLS
  - MPLS NNI

- **Business E-LAN**
  - Port, 1Q, QinQ
  - H-VPLS or VPLS
  - VPLS/H+802.1ah

- **MPLS/ IP**
  - MPLS
Virtual Private LAN Service (VPLS) Using Label Distribution Protocol (LDP) Signaling (RFC 4762)

- VLAN tag
- Tunnel label
- VC label

Customer Equipment

Ethernet UNI

VFI Instance doing MAC-Based Learning-Forwarding among Pws and ACs

FULL mesh of Pseudo-Wires Running Split-Horizon (NO STP)
Hierarchical VPLS (H-VPLS)

- Core interconnects edge domains (MPLS or Ethernet)
- Hub-and-spoke topology in IP/MPLS edge
  - Smaller full mesh in core
  - Mesh per VPLS customer

H-VPLS with PBB

- U-PE adds/removes PBB encapsulation
- U-PE can group multiple I-SIDs in a B-VID
- Multiple customers per mesh possible if using VPLS instance per B-VID

VPLS

1. Full mesh of PWs between virtual switching instances (VSI)
2. Mesh per VPLS customer
3. PW scale challenges

Pseudowire Scalability in VPLS
Ethernet Encapsulation Evolution
802.1Q --> 802.1ad --> 802.1ah

- 802.3
- 802.1Q
- 802.1ad
- 802.1ah PBB

Service Instances (VID) $2^{12} = 4,096$
Service Instances (I-SID) $2^{24} = 16,777,216$

- C-DA: Customer dest addr
- C-SA: Customer src addr
- C-TAG: Customer tag
- S-TAG: Service tag
- B-DA: Backbone dest addr
- S-SA: Backbone src addr
- I-TAG: Service instance tag
- VID: VLAN identifier (part of C-/S-/B-TAG)
- I-SID: Backbone service instance identifier (part of I-TAG)
- PB: Provider Bridges
- PBB: Provider backbone bridges

802.1Q/ad service instances ($2^{12}$)
802.1ah service instances ($2^{24}$)
802.1ah + VPLS/H-VPLS

Access  Aggregation  Core Transport  Aggregation  Access

E-Line Service  E-LAN Service

802.1Q

VPWS/VPLS  VPWS/VPLS  VPWS/VPLS  VPWS/VPLS

VPWS/ H- VPLS w/ 802.1ah  VPWS/ H- VPLS w/ 802.1ah

802.1ad/Q-in-Q  802.1ad/Q-in-Q

uPE/ IB-BEB  uPE/ IB-BEB  uPE/ IB-BEB  uPE/ IB-BEB

nPE  nPE  nPE  nPE

CE  CE  CE  CE

VPWS  VPWS  VPWS  VPWS

802.1Q

S-VLAN  S-VLAN  S-VLAN  S-VLAN

C-VLAN  C-VLAN  C-VLAN  C-VLAN

802.1ad/ Q-in-Q  802.1ad/ Q-in-Q
IEEE 802.1ah Service Aggregation Model

1. E-LAN service instance:
   EVPLAN: local, access network C-VLAN
   EPLAN: local port, access network S-VLAN

2. Integrated edge node provides:
   H-VPLS with 802.1ah IB-BEB MAC tunneling with each ELAN mapped in a different ISID, all ELAN access EFIs in the same C-MAC bridge
   VPLS auto-discovery

1. The distribution node provides
   H-VPLS, connecting the integrated edge node access pseudowires
   VPLS auto-discovery
MAC Address Scalability in H-VPLS

H-VPLS

- No customer MAC addresses on N-PE nodes
- N-PEs only learn backbone MAC addresses imposed by U-PEs

H-VPLS with PBB
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6. Summary
Fixed/Mobile Networks Today

Mobile Subscriber

TDM/ATM Access

Wireless 2G/3G, LTE, WiMAX

Access

Wireline

ETT x

DSLAM

xDSL

OLT

xPON

Cable DOCSIS

M-CMTS

Residence

Corporate

Mobile Subscriber

TDM/ATM Access

Wireless 2G/3G, LTE, WiMAX

Access

Wireline

ETT x

DSLAM

xDSL

OLT

xPON

Cable DOCSIS

M-CMTS

Residence

Corporate

TDM Legacy

Carrier Ethernet - IP/MPLS Service Richness & Scale

Presented by

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• Mobile Networks follows a structure very similar to data networks: Access, Aggregation and Core

• However have been dominated by non-IP transport mechanism, such as TDM (PDH, SDH) and ATM

• At physical level, they typically use wireless media (μW and RF Radio at access) and low bandwidth wireline facilities like E1 circuits
RAN via Traditional Transport

- RAN traffic via TDM/SDH Network
- All bandwidth is “nailed-up”
- All scaling must be planned for provisioning
- Separate networks for RAN and Core
2.5G adds GPRS low speed data
3G R99 adds ATM RAN and higher speed data
Next Generation Mobile Backhaul

- Single IP/MPLS backhaul network serves 2G/3G/4G
- Common and cheap transport
- Access agnostic, allow for transition to broadband backhaul
- Generation and service independent (support voice, data, video)
- No change to RAN backhaul design
Cisco's Mobile Transport over Packet (MToP)

Evolution of Future-Flexible RAN for 2G/3G/4G Services

- Reduce OPEX – Bandwidth Flexibility
- MToP in the RAN shortens TDM/SDH distance
  - PWE3 Standards Pseudowire
  - Industry Standard Clock over Packet
- Pre-Provisioning for Intuitive Scaling
- IP-MPLS Core is extended into the RAN
MPLS Pseudowires: The Building block for MToP

- Pseudowire (PW): A mechanism that carries the essential elements of an emulated service from one Device to one or more other Devices over a Packet Switched Network (PSN).

- Within the context of PWE3, this is a network using IP or MPLS as the mechanism for packet forwarding

- Having a common PW layer provides the simplification of deployment, management and provisioning

- Industry has GOOD experience deploying some of these PW types already, and the concept now can be extended to TDM & ATM for RAN purpose

TDMoMPLS – either SAToP or CESoPSN
SAToP: Structured Agnostic TDM over Packet: draft-ietf-pwe3-satop-05.txt, RFC-4553
CESoPSN: Circuit Emulation Services over Packet Switched Network: draft-ietf-pwe3-cesopsn-07.txt
ATM Pseudowires: Types used for RAN

**ATM AAL5 Service**

- E1 ATM
- E1 IMA
- VC 1/32
- MWR
- AAL5 PW
- 7600
- VC 11/32
- E1 ATM / IMA (E1 SPA)
- E1 ATM / IMA (STM1 ATM)

**ATM AAL0 VC Mode**

- E1 ATM
- E1 IMA
- VC 0/32
- MWR
- AAL0 VC PW
- 7600
- VC 10/32
- E1 ATM / IMA (E1 SPA)
- E1 ATM / IMA (STM1 ATM)

**ATM AAL0 VP Mode**

- E1 ATM
- E1 IMA
- VP 0
- 7600
- AAL0 VP PW
- 7600
- VP 10
- E1 ATM / IMA (E1 SPA)
- E1 ATM / IMA (STM1 ATM)
CEoP: Circuit Emulation over Packet

CEoP emulates T1/E1, T3/E3 and OC3/STM-1, unstructured and structured, down to nxDS0 circuits.

**Unstructured E1 SATOP PW (RFC 4553)**

- Unframed E1
- MWR
- SATOP PW
- 7600
- Unframed E1 (E1 SPA)
- Unframed E1 (Ch.STM1 VC12)

**Structured Unchannelized E1 CESoPSN PW (RFC 5086)**

- Framed E1 (1984kbps)
- MWR
- CESoPSN PW
- 7600
- Framed E1 (E1 SPA 1984kbps)
- Framed E1 (Ch.STM1 1984kbps)

**Structured Channelized E1 CESoPSN PW (RFC 5086)**

- Framed E1 (Nx64kbps)
- MWR
- CESoPSN PW
- 7600
- Framed E1 (E1 SPA Nx64kbps)
- Framed E1 (Ch.STM1 Nx64kbps)
Legacy ATM and TDM Transport
Converged Packet Network with L2 in access/Pre-Agg.

TDM (CESoPTN, SAToP) & ATM (VC, VP) PWE3

L2 Rings pt-to-pt

L2 Rings/pt-to-pt

IP/MPLS

L2 with rings and pt-to-pt using REP/MSTP/dot1q

SDH, PDH, microwave transport
Legacy ATM and TDM Transport
Converged Packet Network with L3 in access/Pre-Agg.
Ethernet IP NodeB Transport
Converged Packet Network with L2/L2VPN

L2/L2VPN

L2VPN

L3/MPLS VPN

Cell Site

Access Layer

Pre-Aggregation Layer

Aggregation Layer

Distribution node

IP RNC

GE Ring

10 GE Ring

Aggregation node

Ethernet uW

Fibre

Rings

REP Ethernet Bridged FTTX Access

REP Ethernet Bridged

100, 1000 FX/TX

100, 1000 FX/TX

EoMPLS

Ethernet

100, 1000 FX/TX

REP Ethernet Bridged FTTX Access
Ethernet IP NodeB Transport
Converged Packet Network with Distributed L3 Edge

- Cell Site
- Access Layer
  - Ethernet uW
  - Fibre
  - Rings
- Pre-Aggregation Layer
- Aggregation Layer
  - Aggregation node
  - Distribution node
- GE Ring
- 10 GE Ring

L2/L2VPN
L3/MPLS VPN

- EoMPLS
  - Ethernet
  - 100, 1000 FX/TX
- REP Ethernet Bridged FTTX Access
  - Ethernet
  - 100, 1000 FX/TX
  - REP Ethernet Bridged

- REP Ethernet Bridged FTTX Access
- 4x10GE
- GE
- GE
- GE
- GE
Mobile RAN Services

UMTS ATM Node B, GSM BTS
AToM Pseudowire
AToM Pseudowire

ATM VC, TDM (SATOP, CESoPSN)
E1 (w/ IMA)
S-PE, MS-PW

ATM or TDM
BSC
ATM RNC

MPLS / IPoDWDM

Distribution Node
2G/3G Cell Site, SyncE, 1588
MPLS / IPoDWDM

ATM, TDM, Ethernet Cell Site
MPLS enabled Cell Site

MPLS/IP, MPLS VPN
for LTE IP RAN and UMTS IP RAN

VPLS/HVPLS for UMTS

REP
Ethernet RNC, SAE
Ethernet RNC
Greenfield
LTE S-GW, Ethernet RNC

SyncE
Aggregation Node

Efficient Access
Large Scale Aggregation
Mobile RAN Edge
Multiservice Core

VPWS, VPLS+1ah, MPLS/IP
ATM or TDM or Ethernet NNII
ATM, TDM, Ethernet Cell Site

2G/3G Cell Site, SyncE, 1588
MPLS / IPoDWDM

ATM, TDM, Ethernet Cell Site
ATM or TDM or Ethernet NNII

SyncE
Aggregation Node

MPLS
Core
RNC or BSC
Network Clock Synchronization Options

Synchronize the clock between the disjoint TDM Links

1. **Synchronous**: Cell site router receives the same TDM clock from an external source, like, BITS, SONET, GPS, etc.

2. **Adaptive**: Routers do NOT have common clock source. Instead, the clock is derived based on packet arrival rates.

3. **Differential**: Both Cell site and Aggregation routers have the same clock source. In addition, the TDM clocks are derived from differential information in RTP header of the packet with respect to the common clock.
Synchronization in Mobile Packet Networks

TDM or ATM PseudoWires

PHY-Layer Synchronous Ethernet

Non-capable PHY Layer Synchronization Network

CEnP w/packet-based method (adaptive): SAToP, PTP, ...

TDM or ATM PW with IEEE1588v2 PTP session

Synchronization Network

Level II Clock BITS/SSU

Gigabit Ethernet

Synchronization Network

IP RNC

OC3/STM1 TDM

BSC

PRC/PRS
How Could we Clock Using an Ethernet Network? SyncE

Pros:
- “Gauranteed” Clock (Frequency) = Independent to Traffic Model or Load
- Independent of Equipment Design (Compliant to ITU-T Specifications)
- Parallels Today’s Clock Distribution for SDH (Straightforward Adoption)

Cons:
- Requires a Certain Amount of Time to Deploy “End-to-End”
- Most Radio Vendors Currently Support 1588-2008 on End Platforms
How Could we Clock Using 1588-2008?

**Pros:**
- Could be Deployed “Today” over Current Packet Networks
- Provides a Means to Distribute Both Frequency and Phase (Time)

**Cons:**
- Requires a Close Understanding of Traffic Model and Load

Would We Want to Have SyncE and 1588?
SyncE and 1588-2008: Will Co-Exist to Provide the Best Means for Frequency and Eventually Phase Distribution

Recommendation:
- Use SyncE Where You Can and 1588-2008 Where You Have to for Frequency
- SyncE “Gaurantees” a Stable Means of Frequency Distribution (GSM/UMTS/LTE-FDD)
- Re-use 1588-2008 Deployments to Support Phase Requirements (LTE-TDD)
- SyncE and 1588 Together Can Distribute Frequency and Phase Respectfully

“Conclusion: Use SyncE Where You Can and 1588 Where You Have To.”
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Converged IP Fixed & Mobile NGN

Network Convergence
- Converged Wireless & Wireline offering with common Distributed L3 Edge

Services Offering
- L2 VPN & L3 VPN, Residential & Business including IP, Multicast & Wholesale services

Intelligent L3 Edge
- Distributed GW functions
- Bandwidth saving i.e. offload traffic
- Minimal Latency

Resiliency/Availability
- Common convergence & Resiliency technique with same Control plane to the Network edge

Flexible UNI Architecture
- Traffic Flows identification
- VLAN manipulation
- Services application i.e. QoS, security, E-OAM

Advanced Feature Set
- Security/IPSec
- IPv6 capability
- Synchronisation (SyncE, 1588v2, ACR)
Converged IP Fixed & Mobile NGN

Common Application Integration and service control for all technology types

Common Access presentation with converged Aggregation networks

Flexible Service Edge placement with in-built network simplicity & optimisation

Mob. GW: GGSN, Serving-GW, PDN-GW, PDG (3G, 4G, Femto) HA, ASN-GW (WiMAX), Security Gateway

L2/L3 BNG: ISG PPP/IP/L2 Sessions, DHCP, Carrier Ethernet, IPv4/IPv6, H-QoS
Carrier Ethernet Design
Beyond Transport ➔ Service Enabled Ethernet

Scalability
- Services and bandwidth
- From Mbps to x10Gbps
- VLAN, PW, MAC scale

Any-Play Service
- Business and residential services in the same aggregation network
- L2 and L3 Biz VPNs, BB/ISG, Mobility

Service Management
- Carrier-class OAM capabilities
- Customer network management (CNM), carrier Ethernet MIBs

Reliability
- Network outage protection
  > 5.9s service availability
- Resiliency features

Guaranteed QoS
- Guaranteed end-to-end SLA
- End-to-end CIR and EIR
- Voice, video, business VPNs, mobile, residential, wholesale