Designing Broadband Networks to Deliver Business and Triple Play Residential Services

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Cisco Networkers Solutions Forum 2007
Agenda

- Carrier-Class Ethernet Network Concepts
- Broadband Services Overview
- Broadband Transport Architecture
- Subsystems
  - Service Deployment Models
  - Quality of Service
  - Broadcast TV and IP Multicast
  - Network Availability
Carrier-Class Ethernet Network Concepts
Broadband Services Overview
Broadband Service Offering

- **Residential services**
  - Video—Broadcast TV
  - Video—Video on demand
  - Voice—Voice over IP
  - Data—High-Speed Internet

- **Business services**
  - E-LINE
  - E-LAN
  - IP VPN
Broadcast Television

- **Service considerations**
  - User selects a broadcast channel among multiple channels (<200)
  - Service controlled by video middleware

- **Application requirements**
  - Real-time traffic where majority of traffic is downstream
  - Efficient method of distributing high bandwidth traffic:
    - MPEG2: 3.75M to 14M
    - Channel change time < 1500 ms
    - End-to-end delay requirement: < 100–500 ms
  - Network loss < 1E-07
  - Network jitter < 100–200ms
  - 50ms recovery in failure scenario
  - Very low packet loss is key
Video on Demand (VoD)

- **Service considerations**
  - User selects on video on demand (non-scheduled videos)
  - Service controlled by video middleware

- **Application requirements**
  - Real-time traffic where majority of traffic is downstream
  - Method of call admission control for high bandwidth traffic (3.75M to 14M video streams)
  - End-to-end delay requirement: < 100–500 ms
  - Network loss < 1E-07
  - Network jitter < 100–200ms
  - 50ms recovery in failure scenario
  - Very low packet loss is key
Voice over IP (VoIP)

- **Service considerations**
  - User makes IP, non-circuit based voice calls as alternative to traditional PSTN
  - On-net VoIP calling
  - Off-net calling (hopoff to PSTN)

- **Application requirements**
  - Real-time bi-directional traffic
  - End-to-end delay requirements: 150ms
  - Network loss < 1E-02
  - Network jitter < 20–30ms
  - < 1s recovery in failure scenario
  - Low jitter is key
Internet Access Data

- Service considerations
  - Best effort data service (Internet, e-mail, chat rooms, gaming)
  - Bridged or PW (EoMPLS)
  - Provisioned via IP or PPPoE Internet access

- Application requirements
  - Non-real-time bi-directional traffic
  - Best effort
E-LINE

- **Service considerations**
  - Port/VLAN based point-to-point business service
  - Service multiplexing at UNI (VLAN)
  - High availability-protected
  - Fully transparent offering

- **Service requirements**
  - Scalability for large sites
  - Real-time traffic and stringent packet loss requirements
  - SLA—CIR/PIR/burst, loss
Distributed L3 Service Edge

L3 Edges Are Distributed at Different Points in the Network

- For example, VoIP, VOD IP/TV®, broadcast IP/TV insertion point: driven by the minimal network operational needs, the simplicity and efficiency of the IP multicast transport
E-LAN

- **Service considerations**
  - Port/VLAN-based multipoint business service
  - Service multiplexing at UNI (ERMS)
  - High availability-protected
  - Fully transparent offering (EMS)

- **Service requirements**
  - Small-to-mid size multipoint connectivity
  - Corporate/campus LAN extension
  - Disaster recovery
Broadband Transport Architecture
Broadband System Architecture

Service/Policy Management Plane

Business Services
- EPL
- EVPL
- E-LAN
- L3VPN
- VoIP
- Entertainment Video/Gaming

Residential Services
- Personal Computing
- Monitoring

Aggregation Node
- Distribution Node
- Internet Service Gateway
- Deep Packet Inspection
- MPLS Provider Edge

BB Transport Network
- Corporate
- Residential
- CPE
- Access Ethernet/DSL
- Aggregation Network MPLS, Ethernet, IP
- Core Network IP/MPLS
Aggregation Network Models

- Two aggregation network models
- Similar Layer 2 and Layer 3 BUS mechanisms
- Support point to point and multipoint Layer 2 and Layer 3 transport
- Support the same residential, business and wholesale broadband services
Aggregation Network Option #1 Ethernet/IP

- May use Spanning Tree Protocol (STP) domain for the Layer 2 BUS transport
- Supports virtualized Layer 2 services thru native 802.1q and 802.1ad bridges
- Provides optimal Layer 2 multipoint transport that is topology independent
- Can aggregate other access services as: Mobile RAN, Legacy ATM/FR/TDM with L2TPV3
Aggregation Network Option #2 MPLS/IP

- Allows different or common administrative domains
- Supports virtualized Layer 2 and 3 services thru MPLS-based VPNs (EoMPLS and H-VPLS)
- Supports traffic engineering thru MPLS TE mechanisms
- Can aggregate other access services as: Mobile RAN, Legacy ATM/FR/TDM with MPLS AToM
- Pseudo Wire (PW) used to transport Layer 2 domain across the MPLS/IP network
Subsystems - Service Deployment Models
Defining the L3 Service Edge

- L3 edge point—why is this significant?
  - Operational
  - Bandwidth efficiency
  - Scalability

- This influences possible architectures
  - Centralized vs. distributed L3 edge points
  - Centralized = service L3 edge at a single “point”
  - Distributed = service L3 edge at multiple “points”
Centralized L3 Service Edge

Layer 3 Edge Point Reside at Central Location in Network

- **Ethernet/IP**
  - L2 service VLANs used from subscriber to MCO-PE

- **MPLS/IP**
  - Pseudowire used from LCO-PE to MCO-PE for L2 tunneling
    - For example, Internet access insertion point: driven by the existing service model, operational structure, traffic patterns
L3 Service Edge—Residential Hybrid Approach

- **Distributed L3 edge for VoIP/IP/TV Broadcast/IP/TV VOD**
  
  Minimal network operational needs

  - Allows multicast channels to be distributed at closest edge to subscribers

- **Centralized L3 edge for data**

  Driven by the existing service model, operational structure, traffic patterns
Centralized L3 Edge for Data

**Ethernet/IP Aggregation**
- PPPoE or IP subscriber sessions carried over a VLAN (802.1q) in the Ethernet/IP aggregation network
- Subscriber line identity provided by the DSL Forum PPPoE line-id VSA or DHCP Op82

**MPLS/IP Aggregation**
- PPPoE or IP subscriber sessions carried over a EoMPLS PW in the MPLS/IP aggregation network
- Subscriber line identity provided by the DSL Forum PPPoE line-id VSA or DHCP Op82
Distributed L3 Edge—VoIP, VoD and B-TV IP Aggregation

This Service Model Is Same for Both Ethernet/IP and MPLS/IP Aggregation
L3—VPN Service

- DSL UNI (PVC or 802.1q) 1:1 VLAN mapping in DLAM
- L3-VPN provided by a dedicated L3 VPN PE or by N-PE

- DSL UNI (PVC or 802.1q) 1:1 VLAN mapping in DLAM
- L3-VPN provided by a dedicated L3 VPN PE with EoMPLS tunnels from PE-AGG
**E-LINE Service (EPL and EVPL)**

**Ethernet/IP Aggregation**

- DSL UNI (PVC or 802.1q) 1:1 VLAN mapping in DLAM
- Ethernet VLANs in the metro Ethernet aggregation network EoMPLS pseudowires from the N-PE

**MPLS/IP Aggregation**

- DSL UNI (PVC or 802.1q) 1:1 VLAN mapping in DLAM
- EoMPLS PW backhaul from PE-AGG/U-PE for ERS services for the DSL UNI and ERS/EWS for Ethernet UNI
E-LAN Services (H-VPLS)

**Ethernet/IP Aggregation**
- DSL UNI (PVC or 802.1q) 1:1 VLAN mapping in DLAM
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**MPLS/IP Aggregation**
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QoS
QOS Architecture Direction

Internet and Business Traffic Utilize Per-Subscriber QoS Model in Access, Aggregation and Core
Triple Play Services CAC Requirements

- VoIP telephony service
  - Subscriber line: no CAC required
  - The number of calls generally limited at the application level
  - Aggregation network: no CAC required
    - Generally provisioned with sufficient class bw to cope with peak during working and failure case

- TV broadcast service
  - Subscriber line: CAC required
  - Aggregation network: no CAC required
    - Generally provisioned with sufficient class bw to cope with peak during working and failure case

- Video on demand service
  - Subscriber line
    - For fixed number of channels per subscriber line: no CAC required
    - For variable number of channels per subscriber line/variable bandwidth cases: CAC required
  - Aggregation network: CAC required
    - Potential for congestion both in working and network failure cases
Video CAC

Topography-Unaware Off-Path CAC
- Embedded within the VoD server
- CAC decisions not synchronized with the network topologies

Topography-Aware Off-Path CAC
- CAC decision outsourced to Policy Server
- Policy server interaction with the network for topology synchronization

Topography-Aware On-Path CAC
- Dynamic adjustment to any topology change
- Requires network level connection admission control signaling: RSVP

Integrated CAC
- Integrated video CAC approach combines two methods
- VOD stream will be denied if business rules of either fail
- Prioritize blocking of free VOD vs. pay VOD in network failure scenarios

COPS: Common Open Policy Server
Broadcast TV and IP Multicast
## B-TV Transport Options and Characteristics

### Transport options in the aggregation network?
- L2—Ethernet switching
- L2 emulated—H-VPLS
- L3—P multicast

### What are the main benefits of IP multicast in the aggregation network?

### What are the main factors contributing to channel change delay?

<table>
<thead>
<tr>
<th>Bandwidth Efficiency</th>
<th>Fast Convergence</th>
<th>Service Separation</th>
<th>Extra Services</th>
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<tbody>
<tr>
<td>IP PIM SSM, SSM mapping</td>
<td>MPLS TE Fast IGP (BFD) Fast Multicast Convergence</td>
<td>Multi-VRF MPLS VPN Multicast VPN</td>
<td>Security Monitoring Load Balancing Anycast Sources</td>
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<tr>
<td>802.1q IGMP Snooping</td>
<td>802.1w RSTP</td>
<td>802.1q/ 802.1ad VLAN</td>
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<tr>
<td>H-VPLS IGMP Snooping</td>
<td>TE-FRR (Only Link)</td>
<td>L2-VPN</td>
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B-TV Delivery—L2 Aggregation

- PE-AGG IGMP snooping to optimize the multicast distribution
- Optimal multicast with any topology and in case of topology failure
- Resiliency can be provided at both L2 and L3 based on N-PE capabilities
B-TV Delivery—L2 Emulated Aggregation (H-VPLS)

- All channels distributed to all DSLAMs
- Multicast distribution not aligned with the topology
- Not optimal Multicast distribution in case of topology failure

N-PE Multicast
- IGMP Registration
- PIM-SSM, SSM Mapping

IP Unicast and Multicast Routing (Retail)
or
Multicast VPNs (Wholesale)

DSLAM Multicast
- IGMP Filtering
- IGMP Snooping
- IGMP Message Throttling
- IGMP Message Suppression
B-TV Delivery—L3 Aggregation

Aggregation Node Multicast
- Multicast VPN
- IGMP registration
- PIM-SSM, SSM Mapping

IGMP Snooping
- IGMP Filtering
- IGMP Snooping
- IGMP Message Throttling
- IGMP Message Suppression

IP Unicast and Multicast Routing or RFC 2547 bis MPLS VPN

DSLAM Multicast
- IGMP Filtering
- IGMP Snooping
- IGMP Message Throttling
- IGMP Message Suppression

Access
- Service VLAN
- 802.1q/PVC
- Residential
- STB
- DSL Access Node

Edge
- Service VLAN
- 802.1q
- Aggregation Node

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

Policy Plane (Per Subscriber)
Benefits of Distributed L3 Edge for Multicast

**Efficient Multicast Distribution**
- L3 enables shortest path to source
- L2 needs IGMP snoop, replicates every m’cast packet around ring
- Wasted bandwidth, less room for HSI and other services
- Extra processing stress on L2 forwarding engines

![Diagram showing efficient multicast distribution](image-url)
Benefits of Distributed L3 Edge for Multicast

Anycast Support

- No anycast support in aggregation network
- No shortest-path election to the source because mcast traffic only enter through the designated router
- All of above results in inefficient distribution multicast pkts

Ring-VPLS Implementation

IP Multicast Implementation

- PIM-SSM inherently supports anycast
- Shortest path election through IGP
- Load sharing between multicast source
- Instantiate multiple replication tree for same multicast destination
Benefits of Distributed L3 Edge for Multicast:

Source Specific Multicast (SSM) Prevents Security Threats

- SSM-Map not supported at the PE-AGG
- Attack launched from spoofed source address can create outage on ring
- H-VPLS aggregation network is vulnerable to spoofed sources

Ring-VPLS Implementation

- SSM enabled at the PE-AGG
- SSM-Map enforces source aware mapping
- Minimizes ability to spoof service
- Anycast works with SSM

IP Multicast Implementation
Node Failure and Unicast Traffic

- L2 network segmented due to node failure
- Asymmetric routing can blackhole unicast traffic

Ring-VPLS Implementation

L3 Implementation

No impact to unicast traffic. IGP converges around failed node
Channel Zapping Delay

- Common misconception is that IP multicast causes slow channel change
- Only when mcast request has to go to the regional headend is it $>100\text{ms}$
- Typical PE-agg router will serve thousands of subscribers and probability is that the next channel is already multicast to the PE-agg node
- The main culprit is waiting for the I-Frame—this can be solved by a frame cache approaches

<table>
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<th>Channel Change Latency Factor</th>
<th>Typical Latency</th>
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<tr>
<td>Multicast Leave for old Channel</td>
<td>50 msec</td>
</tr>
<tr>
<td>Delay for Multicast Stream to Stop</td>
<td>150 msec</td>
</tr>
<tr>
<td>Multicast Join for New Channel</td>
<td>50 msec</td>
</tr>
<tr>
<td>Jitter Buffer Fill</td>
<td>150-200 msec</td>
</tr>
<tr>
<td>Conditional access delay</td>
<td>0 msec – 2 sec</td>
</tr>
<tr>
<td>I-Frame Delay</td>
<td>500 msec</td>
</tr>
</tbody>
</table>
Channel Zapping Delay STB, Network and Encoding Events Summary

- User hits remote
- SW starts channel change
- STB sends leave (wire)
- Network Join time (approx. 100 ms)
- STB sends join (wire)
- 1st UDP Packet arrives to STB
- SW recognizes UDP pkt
- Start filling jitter buffer
- Jitter buffer full
- Wait for arrival of PSI, Seq Hdr, I-Frame
- STB starts decode
- Video is displayed
- Related to STB implementation
- Related to network delays
- Related to encoding
Network Availability
Metro Ethernet Aggregation Network Availability

- **MPLS/IP aggregation:**
  - MPLS TE/FRR
  - Fast IGP convergence/BFD
  - Multicast fast convergence
  - IP services have sub-second convergence
  - MPLS services have 50 ms convergence with MPLS FRR

- **Ethernet/IP aggregation:**
  - RSTP
  - Fast IGP convergence/BFD
  - Multicast fast convergence
  - IP services have sub-second convergence
  - Ethernet services have sub-second convergence for hub and spoke and 2–3 seconds convergence for rings