Cisco ASR 9000 Series: Carrier Ethernet Architectures

The initial phase of network migrations in the past several years was based on the consolidation of networks over the IP/Multiprotocol Label Switching (IP/MPLS) protocol suite. Service Providers are now looking to consolidate the physical media using Carrier Ethernet for their service infrastructure which provides cost benefits while simultaneously addressing the steep growth in bandwidth requirements from both residential and business customers in retail and wholesale business models.

Carrier-class Ethernet has become a fundamental requirement in the transformation toward IP Next Generation Networks (IP NGN) and their associated services. This paper describes the applicability of the Cisco® ASR 9000 Series as a critical element of the IP NGN Carrier Ethernet design for consistent transport of all services.

Figure 1. Service Optimized Packet Network

Introduction

The approach to building service provider networks is at a crossroads, with significant changes occurring. Common themes of these changes include convergence of infrastructure and services as well as integration of service offerings. The common denominator for this transformation is being consolidation over a converged Carrier Ethernet infrastructure. Service providers need highly scalable robust Carrier Ethernet aggregation and distribution platforms for successful network deployments, and they must offer always available service transport and resiliency.
The Cisco ASR 9000 Series is a next-generation, highly scalable, reliable, Carrier Ethernet optimized platform. It is equipped with massive switching capacity and a modular OS, Cisco IOS®-XR. A comprehensive and flexible set of Carrier Ethernet services and VPN capabilities makes the Cisco ASR 9000 Series best suited for a wide variety of residential, business and mobile transport service delivery applications.

The Cisco ASR 9000 Series provides architectural and functional enhancements that translate to distinctive advantages and incremental value for service providers by increasing the scalability, reliability and longevity that can help service providers reduce operating expenses (OpEx):

- The Cisco ASR 9000 facilitates native Ethernet bridged access integration with an IP/MPLS aggregation network by improving scalability of the Ethernet physical and logical interfaces and providing granular service-level agreements (SLA) enforced per logical interface. The Cisco ASR 9000 Series hardware and software design allow for significant increased scalability in both physical and logical interface dimensions.
- The Cisco ASR 9000 Series enables flexible options for interfacing with access networks and devices through a Multiplexed User-Network interface (Mux-UNI). The connectivity models are aligned with standards recommendations from the Broadband Forum (formerly known as DSL Forum) and the Metro Ethernet Forum (MEF). Recommendations from these standards enable the system to aggregate a multitude of access technologies such as DSL, cable, ETTX, Gigabit Passive Optical Network (GPON), WiMax and Mobile Radio Access Network (RAN) on a single Ethernet interface. An additional critical capability to support these deployment options is the support of scalable and robust hierarchical quality of Service (QoS) on a per service and per subscriber instance basis.
- The Cisco ASR 9000 Series enhances the flexibility and manageability of the aggregation network by enabling intelligent service multiplexing in the MPLS transport services and thus enabling Layer 2 and Layer 3 services across the same set of interfaces and network elements.
- The Cisco ASR 9000 Series supports comprehensive operations, administration and maintenance (OA&M) tools for end-to-end Carrier Ethernet service management including support for IEEE 802.3ah and IEEE 802.1ag Connectivity Fault Management (CFM) technologies as well as MPLS OA&M for service-aware end-to-end trouble shooting.
- The Cisco ASR 9000 Series optimizes the IPTV experience by providing efficient broadcast TV and video on demand (VoD) distribution with admission control and minimal service effect when aggregation network failures occur.
- The Cisco ASR 9000 Series enhances the scalability and resiliency of business VPNs enabled by a suite of Layer 2 and Layer 3 VPN features and modular Cisco IOS®-XR software.

Services

Most applications originate in environments where the requirement to be carrier-class is mandatory at both node and network levels. These requirements accompany the service when it is converged into Carrier Ethernet based-networks. Thus the Ethernet networks also must be able to deliver on the same carrier-class requirement at both the node and network levels for scalability, manageability and reliability.
Carrier Ethernet networks are tasked with not only replacing one mission-specific infrastructure used for a single application or service, but also supporting several different access technologies and services (as shown in figure 2) on many occasions in the same node. Consequently, all service-specific requirements imposed by each service must be delivered using the same Carrier Ethernet service transport infrastructure.

Services can be broadly categorized as residential and business services for retail and wholesale business models.

The Cisco ASR 9000 builds on the most common functional capabilities and connectivity models from the DSL Forum TR-101 and Metro Ethernet Forum 6/10 and extends these considerations to Fixed WiMAX and Ethernet to the home (ETTH), enabling implementation of all of these services with the same type of SLAs across different access technologies. Table 1 summarizes the service definitions for Carrier Ethernet networks offered by many types of service providers.

Table 1. Carrier Ethernet Service Definitions

<table>
<thead>
<tr>
<th>Market</th>
<th>Services</th>
<th>Access</th>
<th>SLA Type</th>
<th>SLA Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Internet Access</td>
<td>Ethernet, DSL, Cable and WIMAX</td>
<td>Transport</td>
<td>Dynamic access bandwidth, session and idle timeout, advertisements, post and pre paid (time and volume)</td>
</tr>
<tr>
<td></td>
<td>Voice over IP VoIP Telephony</td>
<td>Ethernet, DSL, Cable and WIMAX</td>
<td>Application</td>
<td>The number of VoIP appliances, Session Initiation Protocol (SIP) URLs and Public Switched Telephone (PST) numbers, active calls and VoIP call quality</td>
</tr>
<tr>
<td></td>
<td>VoD</td>
<td>Ethernet, DSL, Cable and WIMAX</td>
<td>Application</td>
<td>The number of set-top boxes (STB), stream quality, content and charging models</td>
</tr>
<tr>
<td></td>
<td>TV</td>
<td>Ethernet, DSL, Cable and WIMAX</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>Layer 3 VPN MPLS and Multicast</td>
<td>Ethernet, DSL, Cable and WIMAX</td>
<td>Transport</td>
<td>Access bandwidth, differentiated services (DiffServ) support, Layer 3 VPN topology and managed services (MPLS/Multicast VPN)</td>
</tr>
</tbody>
</table>
### Carrier Ethernet Network Architecture

From a network infrastructure point of view, it is apparent that a multitude of technologies must be involved to deliver on these broad requirements. Several previously disparate networks will be merged onto a single aggregation network. Service and feature specific platforms will form a multi-service edge, while the transport converges around a common IP/MPLS based Carrier Ethernet aggregation and distribution network.

**Figure 3.** Multi service network architecture
As depicted in Figure 3, the multiservice capable IP/MPLS based Ethernet aggregation and distribution nodes form the centerpiece of the IP NGN Carrier Ethernet design that represents the network layer of the IP NGN architecture. The capability of this infrastructure component to deliver on the carrier-class requirements for all the noted services becomes critical. It is also mandatory for this architecture to provide the consolidation benefits in terms of both capital expenses (CapEx) and operating expenses (OpEx).

**Aggregation Node Functions**

The IP NGN Carrier Ethernet design is composed of aggregation and distribution nodes deployed in various physical topologies, typically in rings or in hub and spoke configurations.

The aggregation node provides an intermediate aggregation and multiplexing layer between the access network and the edge network. The main functions of the Cisco ASR 9000 as an aggregation node follow:

- Advanced Ethernet service functions for interfacing with the access nodes and the business customer premises equipment (CPE), when the aggregation node provides directly business services:
  - Classification of port, untagged, 802.1Q, ranges and lists of 802.1Q and IEEE 802.1ad tagged Ethernet frames.
  - Encapsulation translation and rewrites: Push, pop and translate for 802.1Q or QinQ /IEEE 802.1ad tags.
  - Ingress and egress hierarchical quality of Service (QoS) policies for business and residential services (with service classification, scheduling, policing and marking) on the same access interface.
  - Security through ACL filters for Layer 2 and Layer 3 traffic, MAC address limits and storm control for broadcast, multicast and unknown unicast.

- The Cisco ASR 9000 Series routers performs scalable, transparent, virtualized, reliable and service aware carrier Ethernet aggregation and transport functions, based on IP/MPLS Layer 2 and Layer 3 technologies:
  - Layer 2 transport: Point-to-point Ethernet transport based on Ethernet over MPLS (EoMPLS) pseudowire (with backup pseudowire support for redundancy) or local VLAN and ports cross-connect and multipoint or point-to-multipoint with Hierarchical Virtual Private LAN service (H-VPLS:VPLS bridged topologies with pseudowires) or locally defined bridge domains, in addition, for controlling multicast distribution, the VPLS Virtual Forwarding Instances (VFIs) and the Ethernet virtual connection EVC local bridge domains support Internet Group Management Protocol (IGMP) snooping with proxy reporting.
  - Layer 3 transport: IP Unicast and Multicast edge with Multicast Connection Admission Control (CAC)
  - MPLS topology management based on MPLS Traffic Engineering with MPLS Traffic Engineering Fast Reroute (MPLS TE-FRR) as well as H-VPLS.

- The Cisco ASR 9000 offers advanced hierarchical QOS (per service and subscriber based):
  - Scalable H-QoS per subscriber with support for ingress and egress SLA enforcement
- Multilevel priority scheduling for voice and video applications with minimal jitter, latency and packet loss
- Priority propagation to ensure service integrity for voice and video throughout all hierarchy layers, even at peak hours with high traffic load
- The Cisco ASR 9000 also provides service aggregation functions for the DSL, Ethernet, GPON, Cable, Mobile RAN and WiMAX access but also supports direct Ethernet fiber based access to the business premises.

Figure 4. Cisco ASR 9000 Series Hierarchical QoS Implementation

Distribution Node Functions
The distribution node is the demarcation point between the aggregation network and the service edge node providing an Ethernet handoff to the Broadband Network Gateway (BNG) and Multi-Service Edge (MSE). At the same time the distribution node provides aggregation for the aggregation network EoMPLS and H-VPLS transport services and acts as an intermediate IP/MPLS forwarding node for the IPTV services. The main functions provided by the Cisco ASR 9000 as a distribution node follow:

- It performs flexible Ethernet service functions for interfacing with the edge BNG and MSE nodes:
  - Classification on 802.1Q, IEEE 802.1ad and QinQ
  - Encapsulation translation and rewrites: Push and pop tags
QoS support based on differentiated service code point (DSCP), MPLS experimental bit (EXP) and 802.1p classification with marking, policing and scheduling, ingress and egress SLA enforcement is accomplished by enforcing the maximum service rates for residential and business subscribers.

Cisco ASR 9000 performs scalable, transparent, virtualized, reliable and service aware carrier Ethernet distribution and transport functions, based on MPLS/IP layer 2 and layer 3 technologies:

- Layer 2 transport: EoMPLS pseudowire aggregation and switching, H-VPLS (VPLS mesh in the core with access facing attachment circuit pseudowires), and point-to-multipoint multicast distribution with H-VPLS (VPLS bridged topologies with pseudo- wire split horizon enabled or disabled)
- Layer 3 transport: IP, MPLS (IP over MPLS and IP Multicast over VPLS pseudo-wires) and MPLS or IP Multicast VPN transport support for retail and wholesale triple play(data, voice and video) services
- MPLS topology management based on MPLS TE and MPLS TE-FRR, H-VPLS with restricted topologies, MPLS inter-autonomous system technologies and EoMPLS pseudowire switching for operational segmentation between the aggregation and core networks

- In certain cases distribution-node functions may be collapsed with a aggregation-node functions if required to directly connect access nodes or business VPN CPE

Residential Services Delivery Architecture

The Cisco ASR 9000 can use access facing logical interfaces (UNI) in both Layer 2 and Layer 3 modes: in other words the same physical interface can have multiple Layer 2 and Layer 3 interfaces defined concurrently. For residential services aggregation at the aggregation node, there are three connectivity models that have been defined based on the DSL Forum TR-101 recommendations:

- Non trunk UNI, N:1 VLAN Model maps all subscriber services aggregated by the access node in a shared VLAN, providing to the Aggregation Network a shared VLAN for all subscriber and services traffic. This Model is recommended for DSL or Ethernet UNI.
- Trunk UNI, N:1 service VLAN Model uses each virtual circuit or VLAN on the UNI to map a certain service or group of services, each service (or group of services) being aggregated by the Access Node in a shared VLAN, providing to the aggregation network shared service VLANs. This Model can be used with DSL, WiMAX and 802.1q tagged Ethernet UNI.
- Trunk UNI, 1:1 Internet Access VLAN model uses different virtual circuit or VLAN for mapping to Internet access while shared VLAN is used for IPTV. The access node multiplexes the IPTV traffic into a shared VLAN and provides to the aggregation network per subscriber VLANs for Internet access and a shared VLAN for TV and VoD. This model can be used for DSL Multi VCs UNIs or DSL and Ethernet 802.1q tagged UNI.
- For DSL Forum TR-101 non compliant access nodes (primarily traditional DSL access nodes or Very High Bit rate DSL [VDSL] large and dense access networks) the residential subscribers bridged or routed CPE devices are connected with trunk UNIs, using DSL multiple virtual circuits or Ethernet (VDSL, PON or Ethernet) 802.1q tagged interfaces. These access nodes are required to cross connect the subscriber UNI virtual circuit or
Customer VLAN (C-VLAN) into per-subscriber and per-service provider VLANs or to tunnel the subscriber UNI C-VLANs into a per-subscriber line Service Provider VLAN (S-VLAN).

**Figure 5. Residential Services Delivery Architecture**

<table>
<thead>
<tr>
<th>Residential Services-Delivery Architecture</th>
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<tbody>
<tr>
<td>HSI, VoIP</td>
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<tr>
<td>N:1, 1:1 VLAN Model</td>
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<tr>
<td>HSI or IP service subnet</td>
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<tr>
<td>IP Model, VoD, IPTV Multicast</td>
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<tr>
<td>N:1 VLAN Model</td>
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</table>

**Residential High Speed Internet (HSI) Service**

The residential Internet access (and optionally VoIP telephony) services are delivered through the BNG, which provides the subscriber and service aware IP edge. The BNG implements subscriber authentication, authorization and accounting (AAA) with dynamic policy control for the transport SLAs. The transport from the aggregation Cisco ASR 9000 is based on pseudowires to the distribution nodes.

The residential traffic from multiple access nodes is aggregated in a single pseudowire, regardless of the access node UNI and connectivity model used, generating on the Ethernet UNI between the aggregation network and the BNG 802.1Q or QinQ encapsulations. Each pseudowire can be protected through a backup pseudowire to a redundant distribution node for node failure events. Optionally TE-FRR can be configured for fast recovery of intermediate link and node failures.
Residential Video Services

The residential broadcast TV and VoD (and optionally VoIP) services should be delivered through the aggregation Cisco ASR 9000 which provides the IP service aware edge. The Cisco ASR 9000 enforces service level transport SLAs. The TV and VoD transport in the aggregation network is based on two models:

- **IP**: The aggregation network transport data plane is IP and the control plane is based on the Interior Gateway Protocol (IGP) and Protocol Independent Multicast – Source Specific Multicast (PIM-SSM). This model provides efficient TV and VoD transport in the aggregation network, alignment between the transport and the physical topology, local service injection capabilities, on path CAC, optimal mechanisms for source redundancy and consistent sub second failure recovery based on IGP and PIM fast convergence. IPTV (VoD) traffic can also be transported over MPLS TE tunnels.

- **IP/MPLS with VPLS**: IPTV traffic can be distributed to the aggregation node Cisco ASR 9000 from the distribution node Cisco ASR 9000 using VPLS pseudowires (H-VPLS: hub and spoke or daisy chained ring VPLS), in this option IGMP snooping and proxy functions provides optimal multicast distribution along each hop of the Layer2 network.

Although Internet Access and TV and VoD services have different transport SLAs (for example different session timeouts, idle timeouts, authorization and accounting requirements), delivery of these services is based on different IP subnets on the client side, an IP subnet for Internet Access
and another IP subnet for TV and VoD. With bridged CPE devices, the home devices are directly part of these IP subnets, whereas with routed Network Address Translation (NAT) CPE devices the CPE provides the mapping function between the home devices and these IP subnets.

The residential Internet access and TV and VoD services delivery models can coexist and integrate any of the access node UNI and connectivity models as part of a specific network deployment.

**Figure 7.** Video Service Transport Architecture

**Business Services Delivery Architecture**

Business services delivery is based on two architecture models, the first relying on a centralized MSE and the second relying on the integration of the MSE function in the aggregation Cisco ASR 9000 node.

The Ethernet Layer 2 and Layer 3 VPNs (point-to-point and multipoint) are delivered using Metro Ethernet Forum (MEF 6/10) service multiplexed (xDSL, WiMAX and Ethernet access) and non multiplexed Ethernet UNIs (Ethernet access).
Centralized MSE Based Business Services-Delivery Model:

The centralized MSE based business services architecture places the service-related network forwarding and transport SLA enforcement functions in the MSE node from the edge network. The MSE maps subscriber QinQ or 802.1ad (for multiplexed Ethernet access UNIs) and QinAny (for non-multiplexing Ethernet access UNIs) frames to IP Virtual Route Forwarding (VRF) instances for MPLS VPN services, EoMPLS pseudowires for Ethernet line services and VPLS for Ethernet LAN services. (Note: QinAny defines a subinterface or service classification that matches a specific S-VLAN ID whereas the C-VLAN is ambiguous.).

The aggregation network provides transport services based on EoMPLS pseudowires, where multiple end subscribers (QinQ and QinAny) from the same or different access nodes are mapped in the same EoMPLS pseudowire and terminated-on the Ethernet interface between the aggregation network and the MSE.
Distributed Business Service delivery model:

The distributed aggregation node based business services architecture places the service-related network forwarding and transport SLA enforcement functions in the aggregation network. This is done by integrating the Layer 2 and Layer 3 VPN functions in the aggregation nodes. The aggregation node maps subscriber Ethernet ports, 802.1Q, QinQ/802.1ad (for multiplexed Ethernet to the Building [ETTB] Access Networks UNIs) and QinAny (for non-multiplexing ETTB access networks UNIs) customer interfaces to the Layer 2 and Layer 3 VPNs transport instances. The aggregation network transport for Layer 3 VPNs services is based on MPLS and Multicast VPNs with the end subscriber UNI being mapped to the VRF forwarding instances. The transport for Ethernet Line services is based on EoMPLS pseudowires where the end subscriber UNI is locally or remotely cross-connected into other UNIs or EoMPLS pseudowires. The transport for Ethernet LAN services is enabled by connecting the end subscriber Interfaces in the aggregation Node bridge domain functions with pseudowire transport to the H-VPLS instances from the distribution nodes (these nodes create the VPLS core mesh). The distribution nodes implement MPLS Network Node Interface (NNI) interfaces which can use inter autonomous systems, multi-segment pseudowires or VPLS auto-discovery between the aggregation and the core networks.
Wholesale Services Delivery Architecture

Wholesale services delivery models are defined to provide residential and business access to the retail service provider and include internet access wholesale with Layer 3 handoff based on Layer 2 Tunneling Protocol version 2 (L2TPv2) and MPLS VPNs. The BNG maps the Point-to-Point over Ethernet (PPPoE) and IP over Ethernet (IPoE) subscriber sessions to the corresponding wholesale L2TP tunnel or MPLS VPN VRF instance based on locally configured or remote network forwarding policies retrieved from the policy decision layer during the session authorization process. The Internet access wholesale with Layer 3 handoff from BNG may share the same EoMPLS pseudowire transport in the aggregation network with the retail Internet access services.

Optionally Internet access wholesale with MPLS VPN handoff can be extended to triple play services. The aggregation node connects the ISP TV and VoD service instances (shared VLANs) to MPLS and Multicast VPNs. The BNG Internet access PPPoE and IPoE sessions corresponding to the same ISP are connected in the same MPLS and Multicast VPN. The aggregation node IP edge functions optimize the ISP address management complexity related to the high number of access nodes.
Alternatively in some cases wholesale services with Layer 2 transport and handoff can also be used, also referred to as Ethernet bit stream wholesale with point-to-point and point to multipoint (for TV broadcast) distribution support. The Ethernet bit stream wholesale services cover DSL access and extend current regulations by supporting for multicast delivery. The Ethernet bit stream wholesale transport integrates all the residential and business DSL UNI models proposed for retail (i.e. shared VLANs and subscriber VLANs from the DSL access nodes).

The transport for the point-to-point services is provided with EoMPLS pseudowires, the Ethernet interface with the retail service provider being QinQ based, the S-VLAN identifying the access node and the C-VLAN reflecting the retail service provider DSL UNI model and connectivity preferences. The peering point with the retail service provider for the point-to-point transport service may be at the distribution node level or extended over the core network to another point of presence.

**Conclusion**

Carrier Ethernet aggregation networks are faced with unprecedented demand for bandwidth, scalability, reliability and multi-service capabilities for wireline, mobile, retail and wholesale services. The Cisco ASR 9000 Series meets these demands in scale and throughput while providing flexibility for different technology choices as part of the Cisco IP NGN Carrier Ethernet design supporting many business models that will enable carriers to expand their offerings in quality and quantity for years to come.
Cisco Services for Cisco ASR 9000

Through a lifecycle services approach, Cisco delivers comprehensive support to service providers to help them successfully deploy, operate, and optimize their IP Next-Generation Networks (IP NGNs). Cisco Services for the Cisco ASR 9000 Aggregation Services Router provide the services and proven methodologies that help assure service deployment with substantial return on investment, operational excellence, optimal performance, and high availability. These services are delivered using leading practices, tools, processes, and lab environments developed specifically for Cisco ASR 9000 deployments and post-implementation support. The Cisco Services team addresses your specific requirements, mitigates risk to existing revenue-generating services, and helps accelerate time to market for new network services.

For more information about Cisco Services, contact your local Cisco account representative or visit http://www.cisco.com/go/spservices.