Reference Architecture

Broadband Edge Network Design

Modified: 2016-04-14

Juniper Networks, Inc.
1133 Innovation Way
Sunnyvale, California 94089
USA
408-745-2000
www.juniper.net

Reference Architecture Broadband Edge
1.0

The information in this document is current as of the date on the title page.

YEAR 2000 NOTICE

Juniper Networks hardware and software products are Year 2000 compliant. Junos OS has no known time-related limitations through the year 2038. However, the NTP application is known to have some difficulty in the year 2036.

END USER LICENSE AGREEMENT

The Juniper Networks product that is the subject of this technical documentation consists of (or is intended for use with) Juniper Networks software. Use of such software is subject to the terms and conditions of the End User License Agreement ("EULA") posted at http://www.juniper.net/support/eula.html. By downloading, installing or using such software, you agree to the terms and conditions of that EULA.

Table of Contents

Solution Reference Architecture Overview: Broadband Edge 1
- Introduction 1
- About Juniper Networks Validated Solutions 1
- Target Audience 1

Broadband Edge Industry Trends 2
- Broadband Challenges 2
- Addressing the Challenges 3

Reference Architecture Components 4
- Components Overview 4
- Home and Access Network 5
- Aggregation Network 7
- Edge Network 8
  - Broadband Network Gateways 8
  - Logical Interfaces 10
  - DHCP Enhancements 11
  - Service Delivery Points 12
- Core 13
- Juniper Networks Universal Edge 13

Conclusion 14

About Juniper Networks 14

Solution Reference Architecture Overview: Broadband Edge

Residential broadband providers are experiencing explosive bandwidth demand driven by an ever-expanding array of home and mobile applications, especially online video. Increasing bandwidth demand and subscriber expectation for high-quality user experience is challenging service provider business models, as the network investment has outpaced revenue growth. Now, service providers are struggling to decrease operational and capital expenditures while providing the same level of service, and to identify innovative service offerings that will drive new revenue streams. The existing broadband edge architecture is distributed among a variety of routers, switches, and appliances, making management and service creation difficult.

The broadband edge demands a new architecture that can enable a high-quality user experience for subscribers and empower the provider to reduce expenses and drive new, innovative services that can increase average revenue per user (ARPU). The Juniper Networks Broadband Edge Reference Architecture is designed and verified to meet this challenge and improve the economics of the network edge.

Introduction

The Juniper Networks Broadband Edge solution enables providers to maintain traditional multiplay services with a simpler, collapsed service model that consolidates management and service activation points. The benefits of this approach include faster rollouts of differentiated service offerings and greater operational efficiency, which contribute to higher margins.

This Solution Reference Architecture document addresses:

- Industry trends that impact architectural decisions
- Design considerations that must be taken into account when planning a new network architecture
- Solution architecture covering the operational elements of the Juniper Networks Broadband Edge solution

About Juniper Networks Validated Solutions

Juniper Networks validated solutions are complete domain architectures that are expertly designed, fully tested, and completely documented to allow customers to deploy complex network systems with maximum assurance. Juniper Networks solution validation labs put all solutions through extensive testing using both simulation and live network elements to ensure comprehensive validation of all published solutions. Customer use cases, common domain examples, and field experience are combined to generate prescriptive architectures and configurations to guide customer and partner implementations of Juniper Networks solutions.

Target Audience

The primary audience for this guide includes the following technical personnel:

- Network Architects—Responsible for creating the overall design of the network architecture that supports their company's business objectives
- Sales Engineers—Responsible for working with architects, planners, and operations engineers to design and implement the network solution
- Juniper Networks Partners—Channel partners and system integrators that seek to design and build Juniper Networks-based broadband edge implementations

Broadband Edge Industry Trends

Broadband service providers are enabling our evolution toward a culture where everything is connected and our business and social lives are managed from a digital device. This trend toward universal connectivity is stimulating rapid network expansion, driven by subscriber growth, high-speed access networks, and bandwidth-hungry, media-rich applications such as online video.

At the same time, network operators want to increase the average margin per user (AMPU) in an environment that demands competitive pricing, and requires rapid and efficient new service introduction. Unfortunately, the traditional broadband edge network does not support this service agility or velocity.

Modern service-centric edge network architectures improve network economics, service agility, and service velocity. This creates the opportunity for operators to consolidate their separate business service, carrier Ethernet service, mobile backhaul, aggregation, and broadband edge networks into a single, scalable network edge that supports all of these functions.

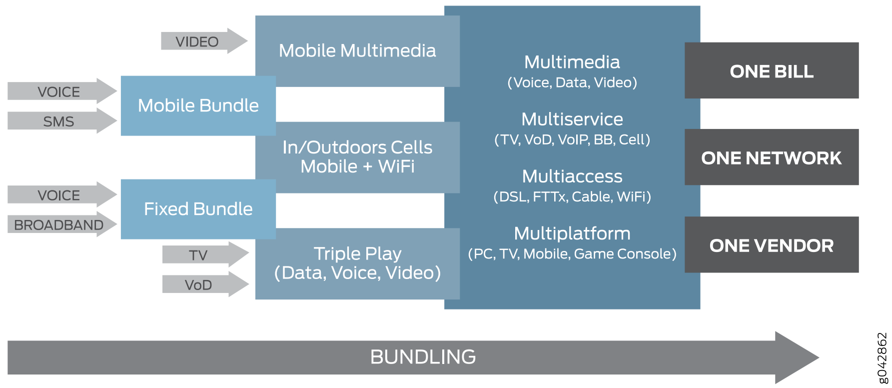
Broadband Challenges

As a result of massive subscriber growth, broadband network operators worldwide are realizing increased revenue. This revenue comes at a cost, however, as service providers are experiencing margin erosion due to expensive network buildouts and service introductions, as well as increased competition.

On top of these challenges, operational expenses are rising, because legacy edge architectures cannot efficiently handle this growth. Some of the structural problems of legacy broadband edge architectures include lack of automation and complex provisioning processes for subscribers and services, the inability to efficiently scale, and the use of single-service network elements.

Industry trends indicate that consumers prefer a bundled voice, video, and data service package and that they prefer getting a single bill from a trusted operator that can supply all of their service demands. Figure 1 on page 3 illustrates how this preference has developed. Under these circumstances, broadband network operators have evolved from connectivity providers to all-inclusive solution providers. This business model evolution requires a multiplay-capable network that supports Internet access, voice, data, and video-on-demand services, as well as broadcast services, and all with operational simplicity that allows faster, efficient service introduction without compromising reliability. The adoption of multiplay services at scale has faced a wide array of technical barriers that have resulted in long deployment cycles and expensive roll-outs for new services.

Figure 1: The Evolution of Residential Broadband Multiplay



Another challenge is the common practice of maintaining separate edge environments for each market segment (broadband, business, mobile). This separation of market segments is inefficient; the operator must pay for and separately maintain discrete edge networks and, in most cases, must also pay for full redundancy in each network “silo” to ensure “always on” services. The back-end support infrastructure for each network must also be duplicated, as management and operation of the various market segments is typically achieved by completely separate groups. Finally, the metro/aggregation layer of each network must contain a larger number of links into the network edge; this drives up the cost of doing business and erodes already thin margins.

Provisioning new services and subscribers is also an increasingly difficult challenge in traditional broadband networks. With a wide array of devices and provisioning points throughout the network, operators often find that new subscriber activation requires multiple interactions with the network and back-end support systems. These provisioning interactions often require multiple steps—the network team provisions the last mile and subscriber information while the back-office support personnel provision authentication and billing. Additional points of provisioning might be required depending on the type of service. This complexity is a roadblock to service innovation. The chance of errors introduced by the need to replicate new service profiles across the entire broadband network, potentially covering multiple access types, introduces configuration issues that slow time to revenue for new service offerings.

The same forces stifling innovation in the traditional broadband networks also impede the ability to easily scale network capacity and increase performance. The sheer number of devices that need to be configured, or even upgraded, to increase capacity and throughput, can be prohibitive and further erodes operating margins.

Addressing the Challenges

The answer to these challenges is the introduction of a scalable and flexible architecture that reduces operating and capital expenses, and enables service agility while maintaining support for legacy service offerings. The solution requires elements that can support multiple service offerings to enable a unified and consolidated broadband edge.

Reference Architecture Components

The architectural elements of the broadband edge design that enables element and service consolidation at the edge include elements of network design, support for legacy and modern access protocols, and seamless interoperability with the metro/aggregation network.

This section touches on each of these areas, working from the access layer inward to the broadband edge, covering key areas where design can be optimized to enable more efficient operations and cost savings. This overview summarizes key points of architectural design consideration in the larger broadband network.

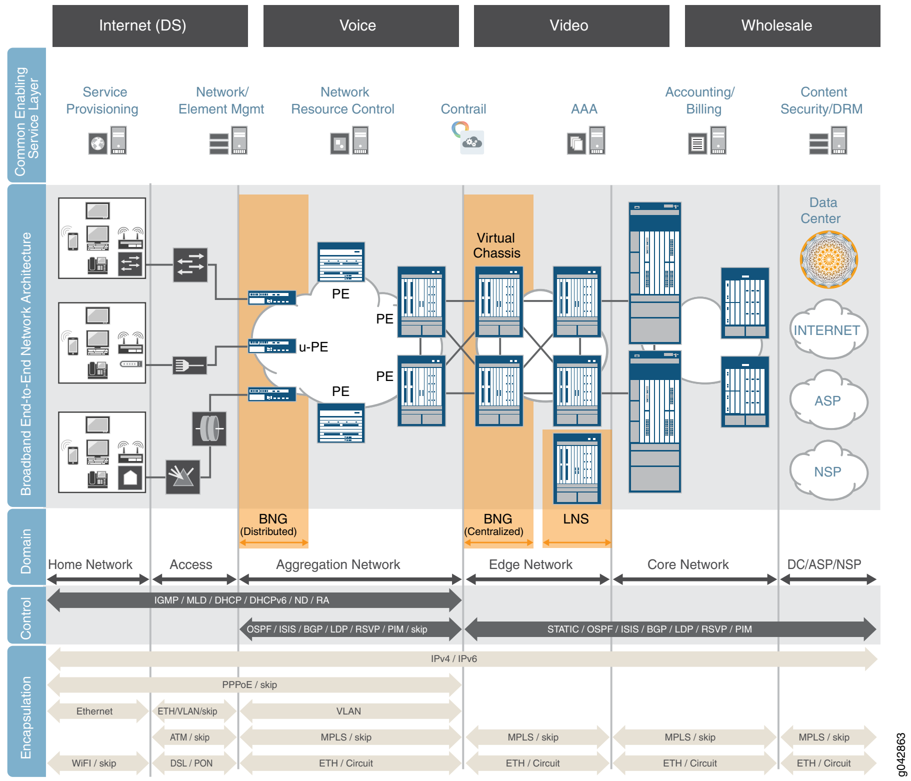
The components of the reference architecture are described in the following sections:

- Components Overview on page 4
- Home and Access Network on page 5
- Aggregation Network on page 7
- Edge Network on page 8
- Core on page 13
- Juniper Networks Universal Edge on page 13

Components Overview

The broadband edge is divided into several tiers of operation and configuration, as illustrated in Figure 2 on page 5. The home network and access layers provide the subscriber's entry point to the broadband network. The aggregation layer serves to multiplex the subscribers into a single link or group of links for transport efficiency. The broadband edge is the tier of the network where much of the service provisioning occurs. Subscribers are differentiated at this layer of the network and assigned to service profiles based on their authorized services. Usually, this differentiation is achieved through an exchange between the broadband network gateway (BNG) and the RADIUS server to authenticate and enable services dynamically per subscriber. The core provides transport, and various resources provide content (provider data center, video head end, and so on).

Figure 2: The Broadband Edge Architecture



NOTE: Juniper Networks Broadband Network Reference Architecture supports distributed, centralized, and hybrid BNG deployment models.

Home and Access Network

The home network serves as the residential subscribers' point of control for their broadband experience. The residential subscriber often purchases several service offerings that combine into something called multiplay (or triple play) services. These offerings often include high-speed Internet, voice over IP (VoIP), Internet Protocol television (IPTV), and video on demand (VoD). Home network devices include:

- Broadband modem: The line of demarcation onto the broadband network, which terminates as Ethernet or Coax, Passive Optical Network (PON) Optical Network Terminal / Optical Network Unit (ONT/ONU), or DSL. This is the cable/DSL/PON modem.
- Residential Customer Premise Equipment (CPE) router: This is the home router, or residential gateway.
- Wi-Fi Access Point: Residential users utilize either built-in Wi-Fi or a discrete access point to provide wireless access to home clients such as smartphones, printers, game

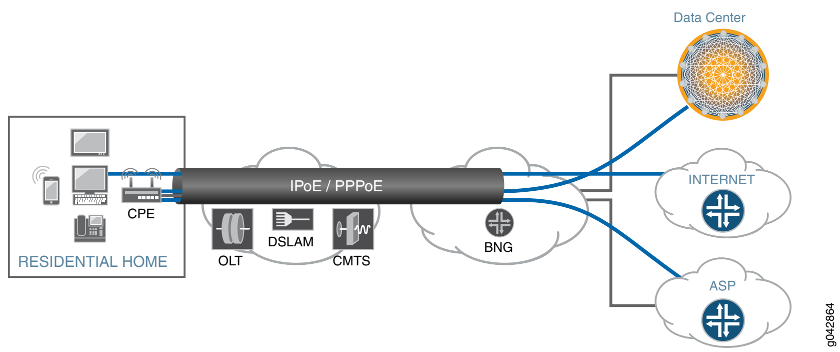
consoles, and other appliances. The Wi-Fi access function is often integrated into the home CPE routing gateway.

- Clients of the home network: The devices in the home that use the broadband service. These include home computers, set-top boxes, printers, game consoles, DVRs, media players, and video cameras, to name a few. This list continues to expand.

The home network connects to the access network. Many broadband access technologies exist for broadband access including digital subscriber line (DSL), cable access, and passive optical networking (PON). The key function in the access network is the multiplexing and demultiplexing of multiple subscribers (hundreds or thousands) through the aggregation network and to the broadband edge for service delivery.

The subscriber accesses the network via an access protocol. Traditionally, Point-to-Point Protocol over Ethernet (PPPoE) has been employed to permit subscriber access, although the current model leans more and more toward Internet Protocol over Ethernet (IPoE), which generally relies on Dynamic Host Configuration Protocol (DHCP). Both PPPoE and IPoE/DHCP are endorsed by the Broadband Forum. See Figure 3 on page 6 for an illustration of the WAN-facing interfaces.

Figure 3: WAN-Facing IP Interfaces in the Broadband Network

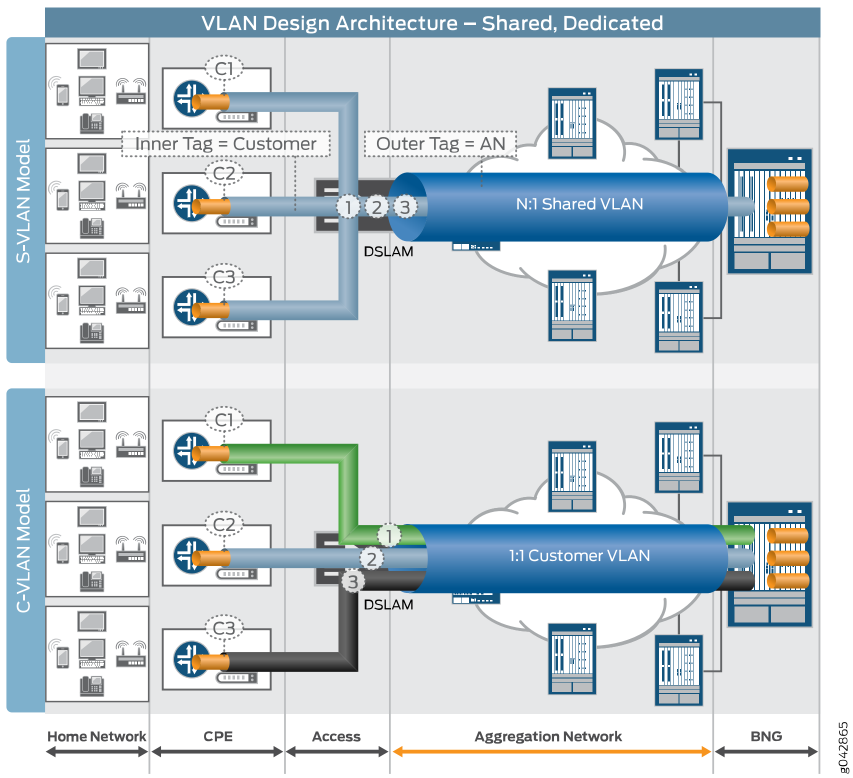


Transport mechanisms assist in establishing sessions between subscribers and services. Transport mechanisms enable several key functions of the broadband network to include establishment of the physical link and session, authentication, authorization, identification of the user, and network monitoring. Sessions can then be used to manage subscriber connection to the network.

While both PPPoE and IPoE are used today, the method used in forward-looking design is IPoE, as it is easily implemented.

In the access network, each subscriber has a discrete circuit, or connection, into the broadband network. At some point, all of these subscribers must converge onto a single service aggregation point (a single device or a cluster of devices) for transport to and from the services to which they are subscribed. The traffic must be aggregated onto a single transport while maintaining separation between subscriber traffic. This is done using virtual LAN (VLAN) aggregation at the access layer. There are a couple of choices for VLAN design. Service VLAN (S-VLAN) provides a dedicated VLAN for each service. In this model multiple subscribers share individual VLANs (video subscribers, for instance, would receive video services from a single IPTV VLAN). Customer VLAN (C-VLAN) uses a dedicated VLAN for each individual subscriber or household. This is often referred to as the 1:1 model because each VLAN is associated to a single customer as shown in Figure 4 on page 7.

Figure 4: VLAN Design Architecture: S-VLAN (Shared) Compared to C-VLAN (Dedicated)



The aggregation network in this solution architecture assumes a 1:1 C-VLAN model. The outer VLAN tag represents all traffic from the access node, and the inner VLAN tag represents each subscriber household. This design enables optimal subscriber scale on the broadband edge.

There are various methods of provisioning types of VLANs for aggregating user traffic. Bandwidth requirements often dictate the need to deploy both C-VLANs and S-VLANs, and the Juniper Networks Broadband Edge solution architecture supports both. Because of the wide array of services and bandwidth requirements of modern multiplay networks, we recommend the implementation of hybrid VLAN (H-VLAN) architecture to optimize real-time media and Internet traffic.

Aggregation Network

The various access nodes are often aggregated into fewer connections for optimal transport to the broadband edge. Aggregation can be done in several ways. In some instances, it makes sense to directly connect access nodes (DSLAM, OLT, and so on) into the broadband edge. A dual-homed topology can also be used, where each access node is redundantly connected into an aggregation node; the aggregation node itself is connected as a full or partial mesh, with multiple connections existing between each of the aggregation routers. Finally, a ring topology can be employed. In a ring topology, the aggregation nodes are connected redundantly to each other in a ring, forming a right and left redundancy path. Some access/aggregation designs employ optical rings and Dense Wavelength Division Multiplexing (DWDM) technology. In this design, access nodes are aggregated directly onto optical rings. The recommended topology is driven by cost and need for resiliency, although the ring topology offers the best mix of redundancy and cost optimization, providing redundant paths for traffic and fewer interconnections. A focus on simplicity should drive any effective aggregation network design, as this network tier serves only to aggregate subscribers to the edge network. The Juniper Networks Broadband Edge solution accommodates all of these aggregation options.

Edge Network

It is at the broadband edge that much of the reference architecture's functionality occurs. The broadband edge is the tier of the network where BNGs are used to perform subscriber management including session and circuit aggregation, authentication/authorization/accounting (AAA), policy and traffic management functions, among others. The BNGs also manage addressing and service attachment, and handle the multiplexing and demultiplexing of traffic to and from the individual subscriber.

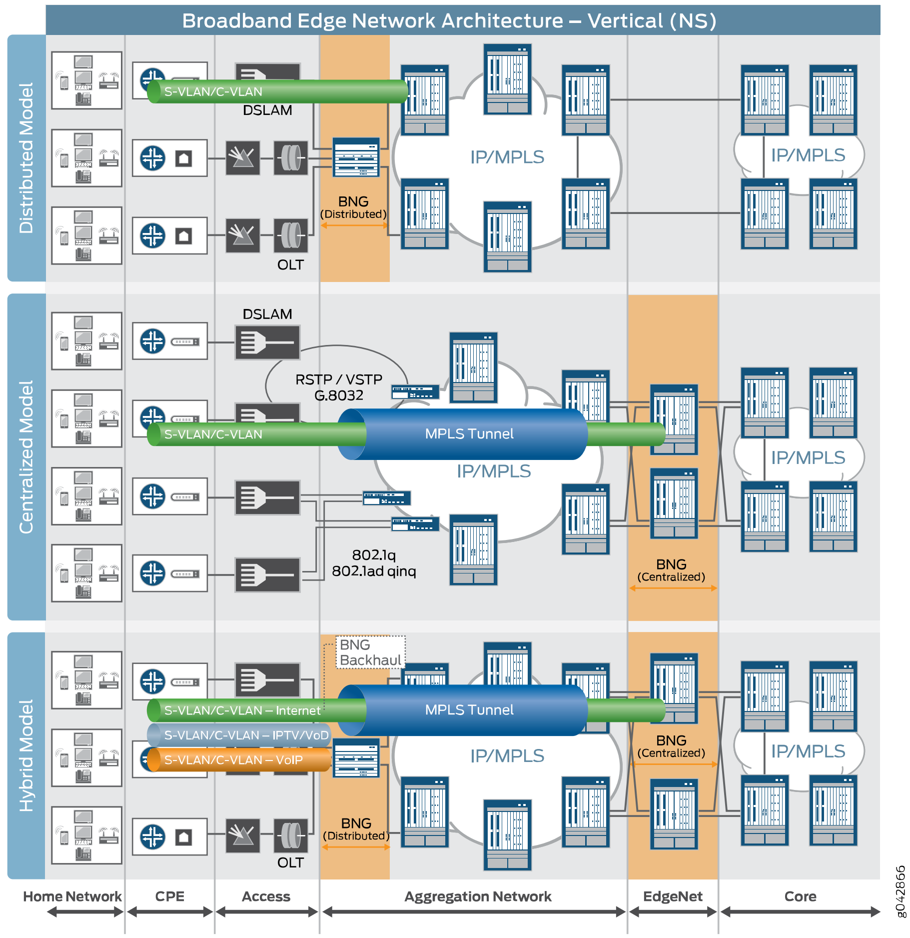
This section consists of the following subsections:

- Broadband Network Gateways on page 8
- Logical Interfaces on page 10
- DHCP Enhancements on page 11
- Service Delivery Points on page 12

Broadband Network Gateways

An important area of design consideration is the placement of BNGs in the network; they should be placed in a way that optimizes service activation and attachment. In a centralized BNG model, a BNG is placed in the point of presence (POP), close to the core network. A distributed model places the BNGs in COs much closer to the subscriber. In a hybrid model, BNGs are placed close to the subscriber and in the POP, depending on subscriber density and bandwidth requirements from the serving office. These three models are shown in Figure 5 on page 9. The recommended edge architecture is the hybrid model, as it enables the best mix of flexibility and service impact and can be tailored to fit both the service footprint and the traffic load easier than either the distributed or centralized models. In any case, the Juniper Networks Broadband Edge solution architecture and MX Series BNG accommodate all of these options.

Figure 5: Broadband Edge Network Architectural Models



Each of these models has trade-offs. The distributed BNG model increases device count as more BNGs are required, although the cost can be mitigated somewhat because the distributed BNG serves as a pre-aggregation router, minimizing interconnections into the aggregation layer. The centralized BNG model requires fewer devices at the network edge; however, this approach could result in potentially higher costs in the aggregation layer. The main benefit to the hybrid BNG model, where a mixture of centralized and distributed BNGs is employed, is flexibility. The hybrid model allows a central BNG to be efficiently employed in a low-subscriber density area or a new market. In areas with high density, a distributed BNG can be employed. Another value of a hybrid architecture, particularly when seamless MPLS is involved, is that the service edge can be placed in the location that is most appropriate to the service being terminated. This enables delivery of a unified metro architecture that might terminate different services in different models on the exact same infrastructure. For instance, it might be desirable to terminate high-speed internet access very close to the core on a centralized BNG, while services that have very strict latency and high bandwidth requirements, such as IPTV, VoD, and VoIP, can be terminated on a distributed BNG to enable direct distribution to the appropriate resource on the provider network. Juniper Networks MX Series 3D Universal

Edge Router portfolio supports all these models. Additionally, they support mobile and business services that enable network consolidation.

Logical Interfaces

The BNG utilizes logical interfaces to track subscriber attachment. The use of logical interfaces provides a handle, or anchor, for assigning policy and control functions such as per subscriber service filters and quality-of-service (QoS) policies. Subscriber logical interfaces are generally created following a successful authentication and authorization. Because logical interfaces are a limited resource both at the line-card level and at the platform level, the method by which subscribers are terminated on the BNG has consequences in terms of scalability of the BNG.

NOTE: **Scale testing results are highly dependent on the configuration being tested. Variables such as route scale, filter types and numbers, accounting and statistics, and policies/QoS can affect scaling results. Lab and proof of concept testing is highly recommended to validate customer configurations and to benchmark achievable scaling.**

The Juniper Networks Broadband Edge solution uses a VLAN demultiplexing access model, where a single logical interface is consumed, regardless of stack implementation or access-side configuration. Table 1 on page 10 highlights the differences among the various access models.

Table 1: Access Model Details

VLAN Architecture	Access Protocol	BNG Configuration	Logical Interface Type	IP Address Source	AAA
Customer VLAN	IPoE	DHCP local server	VLAN	Local pool or RADIUS	VLAN and/or DHCP
		DHCP relay	VLAN	External DHCP server	VLAN and/or DHCP
	PPPoE	PPPoE local server	PPP	Local pool or RADIUS	VLAN and/or DHCP
		PPP relay (L2TP LAC)	L2TP session	—	VLAN and/or DHCP
Shared VLAN	IPoE	DHCP local server	IP Demux or ACI-set VLAN	Local pool or RADIUS	VLAN and/or DHCP
		DHCP relay	IP Demux or ACI-set VLAN	External DHCP server	VLAN and/or DHCP
	PPPoE	PPPoE local server	PPP	Local pool or RADIUS	VLAN and/or DHCP
		PPP relay (L2TP LAC)	L2TP session	—	VLAN and/or DHCP

DHCP Enhancements

The architectural elements of the broadband edge design that enable consolidation of services at the edge include network design, support for legacy and current access protocols, and the interoperability with the aggregation network. Starting at the access layer of the network, one requirement for the new edge architecture is support for a mix of access protocols, including PPPoE and IPoE/DHCP.

The network's ability to identify a subscriber and attach the appropriate services involves identifying the user, authenticating and authorizing the user, and establishing a session over the logical interface. In traditional broadband networks these actions were performed using PPPoE. Now, providers are moving more toward the use of IPoE (which relies on DHCP), especially for voice and video service. See Figure 3 on page 6.

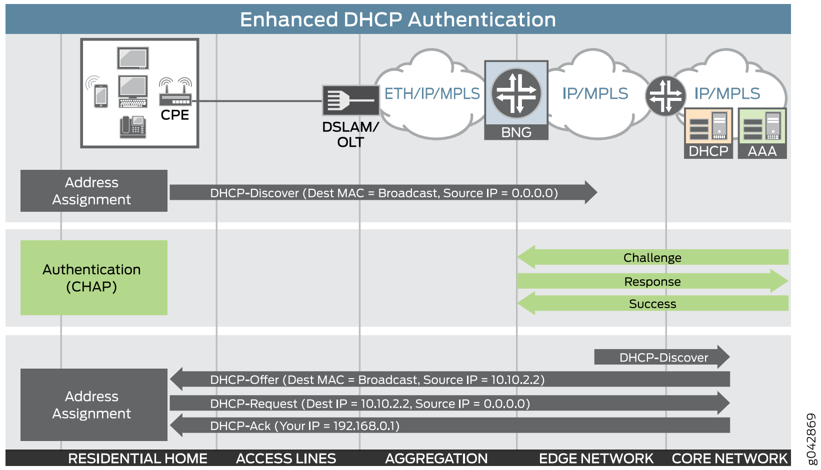
Although IPoE is missing one key aspect that is inherently supported by PPPoE (namely, an IP session monitoring and keepalive mechanism), it does provide benefits to the broadband provider and subscriber and is an appropriate substitute in some cases. *Broadband Forum TR-146 Subscriber Sessions* is a good reference for more information. It is important to note that widespread adoption of DHCP is also driven by the need to consolidate residential and business edge networks onto a single, universal edge. In light of that drive, support for DHCP to handle both residential and business subscribers is essential.

The Juniper Networks Broadband Edge solution incorporates a broad set of DHCP-specific enhancements that address many of the DHCP challenges already discussed, including:

- IPoE/DHCP session monitoring and accelerated session recovery
- DHCP session integration with AAA/RADIUS and policy layers—for example, policy and charging rules function (PCRF) and RADIUS change of authorization (CoA)
- Processing of subscriber access loop information encoded in DHCP control messages
- Multiple address management deployment models, such as DHCP local server, DHCP relay, and DHCP proxy

The Juniper Networks Broadband Edge solution also maintains concurrent support for PPPoE and DHCP-based subscriber attachment. Figure 6 on page 12shows the packet flow in the Junos OS DHCP authentication functionality.

Figure 6: Enhanced DHCP Authentication

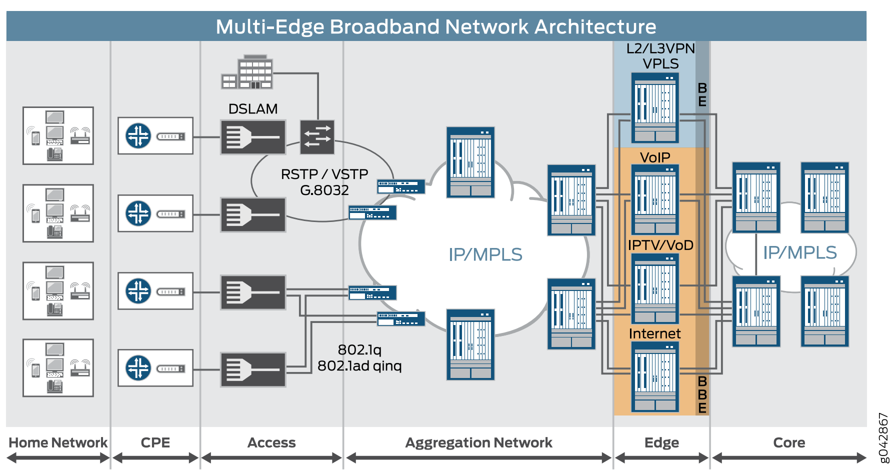


Service Delivery Points

Another architectural element and design consideration is the placement of service delivery points within a broadband network. A single-edge or multi-edge architecture can be used, and, for stateful redundancy, a virtual chassis design can be employed.

In a multi-edge architecture, a BNG is implemented per service. For example, one BNG might be implemented for high-speed internet access; another might be configured for IPTV and VoD. This enables physical separation of traffic profiles and requirements, although it imposes added expense in that each edge device must be connected redundantly to the backhaul/aggregation network as shown in Figure 7 on page 12.

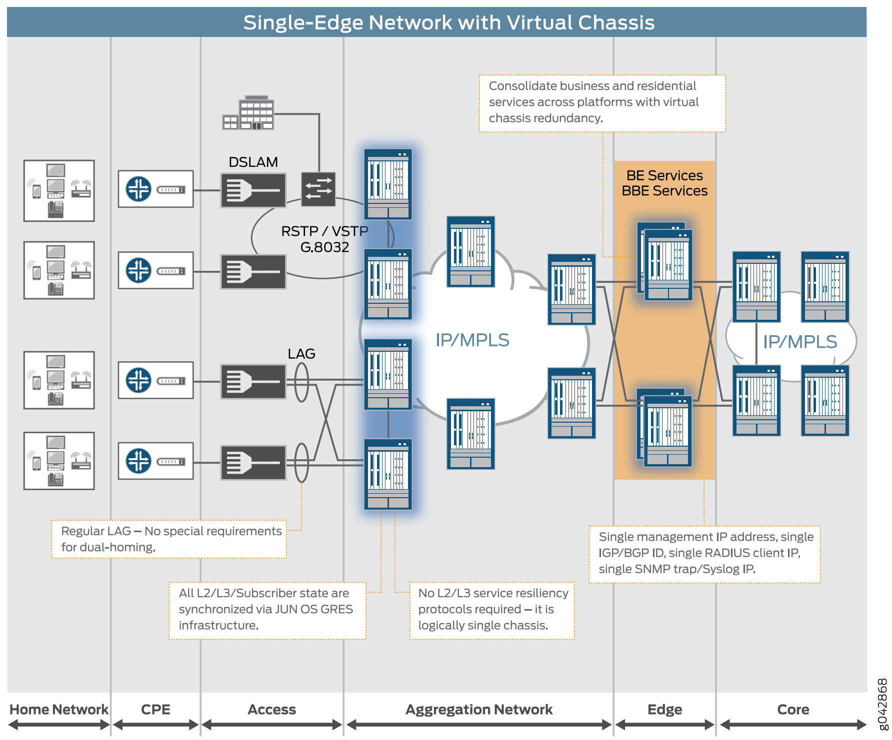
Figure 7: Multi-Edge Network Architecture



Alternatively, in a single-edge architecture, a single BNG supports all broadband services. The concept of unifying multiple services onto a single edge platform, shown in Figure 8 on page 13, simplifies network design and improves management and costs.

The MX Series supports both single-edge and multi-edge architectures, and recommends a single-edge with a virtual-chassis design for the agile and resilient deployment of all services. This approach optimizes CapEx and OpEx.

Figure 8: Single-Edge Architecture



Core

The design of the core network and resources is somewhat peripheral to the discussion, but it can impact design decisions. In many cases, MPLS is used as the transport for all core networks. One concept gaining favor is the use of seamless MPLS. Seamless MPLS enables the provider to design and operate a true end-to-end network that leverages the strengths and capabilities of MPLS at every layer. This approach is fully supported by the Juniper Networks Broadband Edge solution architecture.

Juniper Networks Universal Edge

The Juniper Networks Broadband Edge solution is part of a larger universal edge solution. The universal edge is a consolidated architecture that joins multiple edge networks into a single, unified edge design. While this reference architecture covers only the broadband edge segment, providers that operate in multiple business segments can multiply the cost and efficiency savings from one segment and leverage that optimization across each segment. Though many service providers handle these networks as discrete entities, with Juniper Networks Universal Edge, the edge of the network can serve all segments, reducing the need for redundant networks and contributing to lower operating and capital expenses. The broadband edge is an introduction to the universal edge for many providers.

Seeing this same level of cost and operational optimization across each of the business segments and unifying the operation of the edge network can revolutionize a business.

Even in cases where separate edge networks are maintained, the ability to use a single edge platform—the MX Series 3D Universal Edge Router—reduces OpEx by simplifying and streamlining sparing, maintenance, upgrade, and troubleshooting tasks.

Conclusion

The Juniper Networks Broadband Edge solution is a tested and validated solution that enables multiple efficiencies and improvements to the legacy broadband edge. The solution addresses multiplay services, increases operational efficiency, and enables service innovation and agility. This approach helps service providers improve margins, simplify service introduction, and place control of services into key areas of the network based on their impact on customer experience. The Juniper Networks Broadband Edge solution is the foundation for the universal edge architecture, reducing the need for operators to build and maintain separate networks to serve residential and business subscribers.

Migrating to a universal edge also brings efficiency and cost savings, as upgrade costs can be optimized and spread across both business and residential cost centers. Furthermore, the duplication of edge elements is eliminated.

About Juniper Networks

Juniper Networks is in the business of network innovation. From devices to data centers, from consumers to cloud providers, Juniper Networks delivers the software, silicon, and systems that transform the experience and economics of networking. The company serves customers and partners worldwide. Additional information can be found at www.juniper.net.

Related Documentation

- Solution Brief: Broadband Edge