1 IPv6 Drivers in Broadband Networks

With the exponential growth of the Internet and an increasing number of end users, service providers (SPs) are looking for new ways to evolve their current network architecture to meet the needs of Internet-ready appliances, new applications, and new services. Internet Protocol Version 6 (IPv6) is designed to enable SPs to meet these challenges and provide new services to their customers.

The life of IPv4 was extended by using techniques such as network address translation (NAT) and other innovative address allocation schemes. However, the need for intermediate nodes to manipulate data payload while employing these schemes posed a challenge to peer-to-peer communications, end-to-end security, and quality of service (QoS) deployments. IPv6 also addresses fundamental limitations in the IPv4 protocol that renders the latter incapable of meeting long-term requirements of commercial applications. Besides its inherent capabilities to overcome the aforementioned limitations, IPv6 also supports an address space quadruple of that of IPv4, by supporting 128-bit instead of 32-bit addresses (RFC3513). The huge IPv6 address space will enable IPv6 to accommodate the impending worldwide explosion in Internet use. IPv6 addressing provides ample addresses for connecting consumer home/Internet appliances, IP phones for voice and video, mobile phones, web servers, and so on, to the Internet without using IP address conversion, pooling, and temporary allocation techniques. IPv6 is designed to enhance end-to-end security, mobile communications, and QoS, and also to ease system management burdens, as the protocol is still evolving, with some of its capabilities still a work in progress by the Internet Engineering Task Force (IETF).

As the number of broadband users increase exponentially worldwide, cable, digital subscriber line (DSL), Ethernet to the home (ETTH), wireless, and other always-on access technologies, along with IPv6's huge address range, long-lived connections to servers, and permanent prefixes for home appliances, give more flexibility to SPs. Specifically, the addressing capacity of IPv6 has made it valuable to SPs, most of which are rolling out IPv6 support in their networks or aggressively evaluating its potential and value for service delivery. Outside the

Deploying IPv6 in Broadband Access Networks, By Adeel Ahmed and Salman Asadullah

United States, IPv6 adoption is being promoted on a national level, and countries such as Japan, Korea, China, India, and some European countries have taken lead roles in moving from testing and evaluation to actual deployment in broadband services and applications.

Cable, DSL, ETTH, and wireless services are the main broadband technologies that are widely deployed. In this book we discuss key aspects of IPv6-enabled broadband networks and explore differences from IPv4 deployments.

1.1 IPv6-BASED SERVICES

Until recently, IPv6-based services were considered primarily as differentiators that allowed SPs to exploit the large address space available in IPv6 for future growth planning and as a competitive advantage. However, as IPv6 has become more popular and familiar, SPs are adopting the protocol not only to offer new services to their customers but also for provisioning and managing a large number of network devices and applications. Governmental interest and promotion by means of incentives and favorable legislation is also a major driver for the growing adoption of IPv6 in SP and enterprise networks.

SPs in densely populated regions such as Asia and Europe are at the forefront of adoption and integration of IPv6 into their networks to address the increasing numbers of broadband subscribers and the greater scaling of their networks. For example, Nippon Telephone and Telegraph (NTT) in Japan is currently offering dual-stack commercial services to asymmetric digital subscriber line (ADSL) and fiber to the home (FTTH) subscribers. Dual-stack devices are capable of forwarding both IPv4 and IPv6 packets; hence, these FTTH and ADSL users can access the services with either an IPv4 or an IPv6 address, or both. In this deployment model, subscribers are offered /64 dedicated IPv6 prefixes but generally receive only a single static or dynamic IPv4 address.

Additionally, some SPs are offering integrated IPv6-based multicast and voice over IP (VoIP) service in addition to existing IPv4-based services, and are taking advantage of the larger IPv6 address space and other useful features. The multicast services consist of several video and audio streams available simultaneously to broadband subscribers. The content providers store the content based on users' interests and send this content as multicast streams to broadband subscribers. Today, with IPv4 service offerings, generally a single device attached directly to a gateway router (GWR) at the customer's premises receives the multicast stream. In similar IPv6 offerings, multiple devices may be attached to the GWR, each receiving a different stream at the same time.

For example, in Japan cable and satellite TV are not very popular, and users expect to receive video content through traditional broadcast TV programs. This provides an opportunity for content service providers to generate additional revenue by offering content not available through TV to broadband subscribers at reasonable prices. The content provider may multicast several channels of video and audio, and broadband subscribers will join various multicast groups of interest to receive content. Disney movies are an example of a video stream, and an audio stream could be karaoke. In this regard, this service offering is similar to a cable TV subscription.

In North American and the Asia Pacific region, IPv6 is being adopted primarily by large cable multiple systems operators (MSOs) to address growing subscriber-base and IP-enabled devices. Currently, cable MSOs use RFC1918 address space for cable modems and set-top-box management. RFC1918 provides 16 million addresses under the 10.0.0.0/8 prefix, plus 1 million addresses under 172.16.0.0/12 and 65,000 addresses under 192.168.0.0/16 prefixes. Factually, address utilization efficiency decreases with hierarchical topologies (see the HD ratio in RFC1715 and RFC3194), so the 9.8 million cable modems and set-top boxes could easily exhaust all 16 million RFC1918 private addresses. The exhaustion of IPv4 private address space among the cable MSO community has become a catalyst in the definition and standardization of the data over the cable service interface specification (DOCSIS) 3.0 standard, which introduces support of IPv6 in cable networks. Now, cable MSOs are planning to deploy IPv6 to manage this large number of cable modems and set-top boxes.

SPs are also offering IPv6 services over wireless links using 802.11-compliant WiFi hot spots. This enables users to take notebook PCs and PDAs along with them and connect to the Internet from various locations. One of the potential benefits of this service flexibility may be downloading digital pictures from a mobile phone with a digital camera to a home storage server.

Figure 1.1 depicts an end-to-end SP network with some of the most commonly deployed access broadband technologies, a core network and back-end provisioning, and network management servers. The access layer of the network features different terminologies for provider edge (PE) devices in the various access models; however, in all cases, PE devices function similarly by acting as head-end devices. The head-end devices connect to multiple downstream customer premises devices using different encapsulation techniques, protocols, and methodologies. In this book we explore the integration and deployment of IPv6 in the broadband access segment as well as in provisioning and network management servers. We also highlight some commonly used techniques for enabling the network core for carrying IPv6 traffic. Once the SP has enabled IPv6 in an access broadband, core, and on back-end provisioning and management servers, it may consider enabling IPv6 on a per application basis. For example, the SP may choose to manage the network devices using IPv6 as a first application.

1.2 BROADBAND ACCESS MODELS

With the exception of cable MSOs, two access models are prevalent in most access broadband technologies, such as ETTH, DSL, and wireless local area

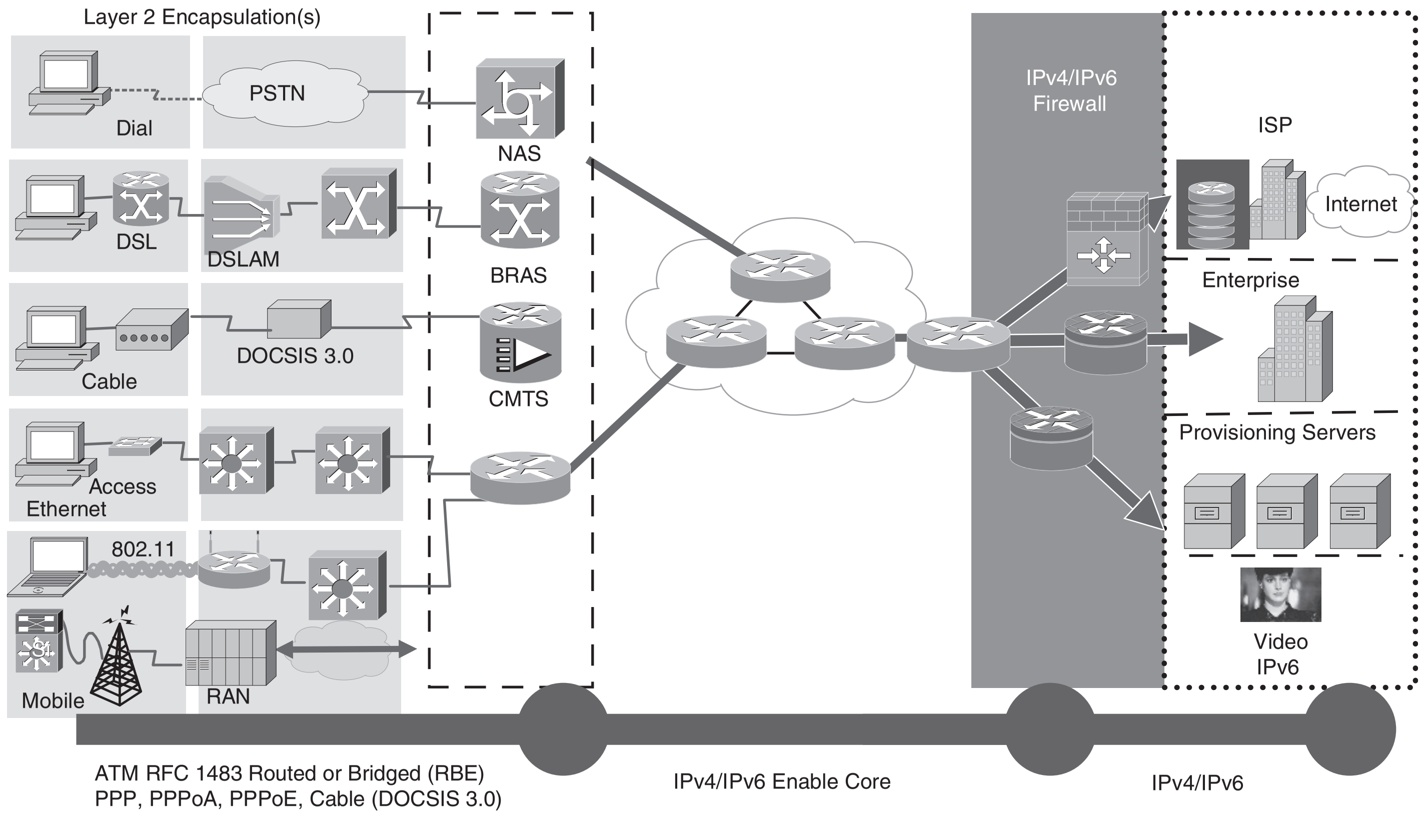

FIGURE 1.1 Typical end-to-end SP access broadband network.

networks (WLANs). In the first model the network access provider (NAP) and the network service provider (NSP) are owned and operated by the same entity. This is referred to as the ISP-operated model. In the second model the NAP and the NSP are owned and operated by two separate entities. This is known as the wholesale deployment model.

Generally, NAP is the entity that provides last-mile access services, and NSP is the entity that provides Layer3 services to customers. NAP and NSP operations are explained in detail in Chapter 4. Cable MSO architectures are very different from ETTH, DSL, and WLAN architectures and are covered in detail in Chapter 3.

1.2.1 ISP-Operated Deployment Model

In an ISP-operated model, a PE router [also known as an edge router (ER)], which is owned by the broadband SP, assigns the IPv4 address to the GWR. This deployment model is depicted in Figure 1.2. Assignment of the IPv4 address is done either by DHCPv4 or by static configuration. The IPv4 traffic is sent from the GWR to the PE using point-to-point protocol over Ethernet (PPPoE) (RFC2516), point-to-point protocol over ATM (PPPoA) (RFC2364), or routed bridged encapsulation (RBE) access methods, which are valid encapsulation candidates to offer IPv6 connectivity in a variety of access SP designs. Methods that are PPP based can leverage the IPv6 extensions to the authentication authorization and accounting (AAA) framework and the remote authentication dial-in user service (RADIUS) protocol (RFC3162) and fit in well with current IPv4 deployment models.

When deploying IPv6 in this framework, the same encapsulation techniques are used and the same behavior is achieved by ER assigning the IPv6 address to the GWR. The assignment of an IPv6 address is done either by using stateless address autoconfiguration (SLAAC), DHCPv6 using AAA and RADIUS, or static configuration. Depending on the agreement between the broadband SP and the user, this IPv6 address assignment could have a prefix length of /64 or shorter. The ER and GWR are upgraded to dual-stack routers in order to support both IPv4 and IPv6. The only scenario when GWR does not need to be

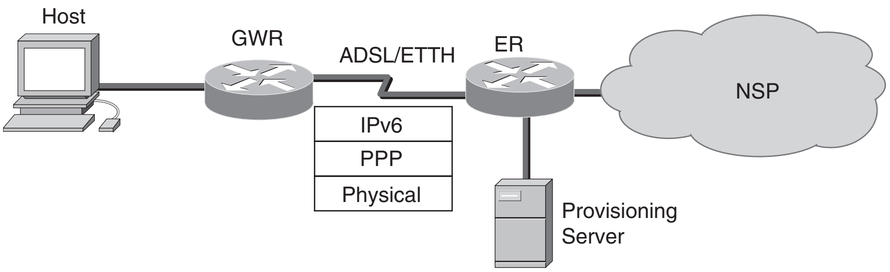

FIGURE 1.2 ISP-operated deployment model.

in dual-stack mode is when the host behind the GWR is running a PPPoE client and the IPv6 address is assigned directly to the host by the ER router, with the GWR acting only as a bridge.

1.2.2 Wholesale Deployment Model

In the wholesale deployment model the NAP only provides network access to users; it does not deal with addressing issues. NAP transports the user's IPv4 traffic from the GWR to the NSP ER [which acts as an L2TP network server (LNS)] by various means, such as Layer2 circuits [virtual local area networks (VLANs)], ATM permanent virtual circuits (PVCs), or frame relay virtual circuits (VCs), or by using other common encapsulation techniques (these PPP sessions can further be bundled be into an L2TP tunnel). The NAP's L2TP access concentrator (LAC) initiates a L2TP tunnel to the NSP's ER router. The LNS assigns IPv4 addresses to the devices (routers, PCs, etc.) located behind the GWR using DHCPv4 with AAA and RADIUS or by static configuration. Once the L2TP tunnel comes up, all traffic is forwarded to the NSP's ER over the L2TP tunnel. In a nutshell, the NSP's ER terminates these circuits and acts as a Layer3 gateway for all these users. For this reason, the NSP is actually responsible for assigning IP addresses to users. Figure 1.3 illustrates the wholesale deployment model operation.

In this model, if the NSP wants to provide content via multicast, it has to replicate that content to all subscribers. To preserve network resource one tries to do the replication as close to users as possible. In the case of an NSP reaching its customers through a wholesale NAP, the closest Layer3 device to the users is the NSP ER that terminates the virtual circuits. This means that the NSP will have to replicate the packets for all the virtual circuits with the users who requested it, and flood the NAP infrastructure with multicast replications. This is not a problem for the NSP; however, the wholesale NAP now has its network flooded with duplicate packets. This is not optimal, and it limits dramatically the capability of the wholesale NAP to scale support for the NSP's IP multicast service. Chapter 4 covers in detail new deployment models supported by IPv6 for addressing such scaling challenges.

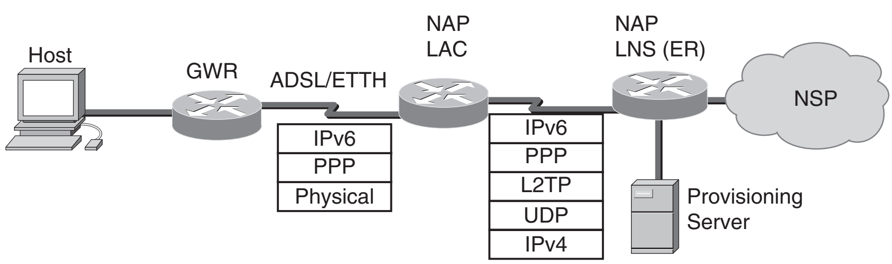

FIGURE 1.3 Wholesale deployment model.

When integrating IPv6 support in this model, the GWR and NAP's LAC are upgraded to dual-stack routers to support both IPv4 and IPv6. It is not necessary to upgrade the GWR to dual-stack capability when the host behind the GWR is running a PPPoE client, and the IPv6 address is assigned directly to the host from the NSP ER, with GWR acting only as a bridge. The NAP's LAC initiates a L2TP tunnel to the NSP's ER to forward traffic received from the GWR. The NSP ER assigns IPv6 addresses to the devices (routers, PCs, etc.) located behind the GWR using SLAAC, DHCPv6 using AAA and RADIUS, or static configuration. The GWR may receive a shorter than /64 prefix, depending on the NSP's policy and the customer's requirements. In this case the NSP's ER router is also upgraded to dual-stack status to support both IPv4 and IPv6.

1.3 SUMMARY

IPv6 enables SPs to offer new services as well as to enhance current services with a focus on servicing endpoints. IPv6 services may range from network addressing support for home appliances to peer-to-peer communication, such as Internet gaming, music and video file sharing, and IP telephony. With sufficient address space in the foreseeable future for several billion subscribers, appliances, and applications, IPv6 is the gateway to the future of the next-generation Internet. It is interesting to note that the world's population is projected to be 10 billion in 2050 and that up to 34 billion IPv6 addresses will be available to be assigned to each person as well as to many of the planets appliances, automobiles, buildings, cameras, control units, embedded systems, home networks, medical devices, mobile devices, monitors, output devices, phones, robots, sensors, switches, and VPNs. Thus, IPv6 holds the key to the success of the next-generation Internet.

REFERENCES

1. S. Asadullah and A. Ahmed, "IPv6 in Broadband," Cisco Systems, Inc. Packet Magazine, Fourth Quarter 2004.
2. S. Asadullah, A. Ahmed, C. Popoviciu, P. Savola, and J. Palet, "ISP IPv6 Deployment Scenarios in Broadband Access Networks," RFC4779, January 2007.
3. B. Lourdelet, "Application Note: IPv6 Access Services," Cisco Systems, Inc.
4. B. Lourdelet, "Application Note: DHCPv6," Cisco Systems, Inc.
5. Cisco Systems Inc., tutorial on IPv6 basics: "The ABC of IPv6."