IPv6: The Next Generation Internet Protocol

Purpose of this Paper

PAIX's legacy as an industry leader in the Internet exchange business has opened up unique opportunities to learn from customers as they deploy new technologies. With respect to IPv6, PAIX established a native IPv6 peering test bed in September 1997 for participants looking into this new protocol where they could deploy, test, audit, and easily transition into a production mode. Throughout this paper we will bring to light differing customer experiences and thoughts regarding their partial or full transition to IPv6.

This paper provides insight into IPv6, including some history and information about this new protocol, customer feedback, and overview of the transition from the current IPv4. It also highlights the need for Internet exchange points to proactively prepare for this migration to IPv6, making the transition to this new IP protocol quick and seamless.

For more information and in-depth technical knowledge there is a plethora of information on the Internet. Some of the more prominent sites are listed at the end of this paper under: **Where to Find More Information.**

Evolution from IPv4 to IPv6 and How IX's are Preparing for the Transition

Internet Protocol version 4 (IPv4), is currently the most widely used protocol for the Internet. It provides the functionality for interconnecting end systems across multiple networks. Internet Protocol (IP) is implemented in each end system and in routers enabling the proper routing of packets to different networks or subnets.

IPv4 is now about 20 years old and many of its limitations have been reached. One of the biggest limitations is the fixed 32-bit address space, which restricts the number of useable available IP addresses to four billion. With the world population expected to reach 9 billion in the not-so-distant future and the expected prolific use of network appliances and personal Internet devices, this initial allotment could be exhausted somewhere between 2005 and 2018. IPv6 is based on a 128-bit address space, which provides for a virtually unlimited number of addresses.

In addition to limited address space, other factors such as inadequate security features, lack of required functionality for new services, the fragile nature of Internet patches, and Network Access Translation's (NAT's) incompatibility with certain applications have been cited as reasons IPv4 needs to be replaced with a more modern protocol. Moreover, an ever-increasing multimedia and application-rich Internet environment plus complex client/server applications are speeding up the requirement for a more robust protocol.

Internet Protocol Version 6 (IPv6) is the next generation IP protocol. This new version of IP was developed in the early 1990's by the Internet Engineering Task Force (IETF)[1]. The original draft version of IPv6 was known as "IP Next Generation" (IPng)[2] and the core set of IPv6 protocols became an IETF standard in 1998. IPv6 was designed to fix the shortcomings of IPv4 and to be backward compatible with IPv4, making it an evolution from IPv4.

To prepare for this migration, Internet exchange points such as PAIX have incorporated IPv6 services into their Layer 2 peering switches. Today, almost 10% of PAIX's Palo Alto customer base utilizes the IPv6 protocol. This figure is expected to grow as more networks deploy IPv6 in either testing or production mode. PAIX, in anticipation of this trend, now offers IPv6 services on all of its switches, including those in *"***PAIX**^{SM}*"* sites.

To see which PAIX customers are currently using IPv6 go to: http://www.paix.net/participants.htm pick a location and look for the ISP's with a + in front of the company name. Clicking on that customer will bring up contact information.

A list of IPv6 Internet Exchanges can be found at: `http://www.v6nap.net/.`

What Companies Say About IPv6

Current IPv6 users are very positive about the future deployment of IPv6. However, they are also cognizant of the various challenges and drawbacks to its deployment. Early adopter confidence seems rooted in the feeling that the benefits of being first will help them in the long run. They expect the deployment of IPv6 to be slow and steady over the next 2-3 years with the IPv4 and IPv6 networks working side by side for quite some time. This is especially true in the Asia-Pacific region where there is a significant push to have complete IPv6 implementation within the next 3 years.

Because of its infancy, IPv6 still has a number of issues and concerns that need to be addressed. These concerns are widely attributable to the limited amount of IPv6 traffic and the unknowns that may arise as traffic increases across the networks. The full effect might not be realized until more networks have deployed IPv6. Some of the early adopters have voiced concerns over the potentially huge learning curve in the operations area for all the later implementers. They believe that the IPv6 latecomers, who are expected to be a large group, will hinder the transition because they will not have had the early exposure and/or the ability to test and implement over a long period of time.

In the United States, many firms do not accept the inevitability of migration to IPv6. Since the U.S. dominated the early development of the Internet using IPv4, U.S. companies acquired the highest proportional allocation of IP addresses. This has the expected effect of lowering the priority of conversion for this geographic segment.

[1] Overview of the IETF, http://www.ietf.org/overview.html, p.1
[2] IETF Organization, IP Version 6 Working Group (ipv6), http://www.ietf.org/html.charters/ipv6-charter.html, p. 1

And there are other reasons for delay. Economic, as well as hardware and software optimization concerns are preventing a quick conversion to IPv6. Many experts do not anticipate additional costs associated with a migration to IPv6. However, from a realistic perspective, it is likely that the migration will have some expense associated with it. IPv6 implementation can necessitate having separate routers and/or separate systems, which could result in added expenses. On the hardware and software side, which is addressed later in this paper, there are possible pitfalls associated with the stability of dual stack routers. This is where both protocols coexist on the same router, communicating between both IPv4 and IPv6 nodes and differentiating between IPv4 and IPv6 packets.

The feedback from both IPv6 users and other customers at PAIX was consistent with the information available from various other published sources. Not surprisingly, 80% of the current IPv6 users who responded were Japanese Internet companies. Each believes IPv6 is the protocol for the coming decades and will result in a more useful Internet. The majority of the PAIX IPv6 users also feel that by being early adopters they will be ahead of the game, giving them a tremendous jump on future opportunities and positioning themselves to meet future customer demand.

These early adopters are paving the way and are willing to do what it takes in the early stages to quickly get to production status. As Mike Leber, President of Hurricane Electric, says, “Being early adopters of IPv6 enables us to get a major edge on a potentially significant future customer demand.”

IIJ Japan’s early IPv6 adoption is a big benefit, according to Takamichi Miyoshi, Director of Internet Initiative Japan (IIJ). "Since August 1999, we (IIJ) have offered various IPv6 related Internet services while extending our IPv6 reach to four IPv6-capable IX’s in the United States, which includes PAIX IPv6.” He also notes that, “ By leveraging our accumulated experience in IPv6 operations, we continue to take the initiative to explore (other) IPv6 possibilities."

Much Debate

Clearly there is much controversy, confusion, and debate as to whether IPv6 is needed for the future growth of the Internet. While some feel IPv6 is "too little, too late," others say, “implement now.” Those who are of the “too little, too late” mindset are IPv4 users who believe that, with the addition of Network Address Translation (NAT) boxes, IPv4 works just fine. Conversely, there are those who feel that, due to the third generation, or 3G, (Wireless Generations) systems and applications that are fast becoming prevalent, sooner or later everyone will likely need to implement IPv6 anyway; that is if they want to keep up with future Internet technology.

PAIX customers that have not deployed IPv6 pointed out that they are in no hurry to do so given the current market turmoil and focus on revenue generation and cost reduction. The conversion to IPv6, as was stated earlier, may require some capital investment and

will not, in and of itself, generate additional immediate revenues. As a result, IPv6 is not high on their radar screens. Only when there is revenue will they deploy.

While the move to IPv6 in the United States is slow, Asia and Europe are embracing the new protocol. In fact, Japan and Korea's governments have mandated that they must be IPv6 ready by 2005. The large number of Japanese PAIX participants that have already transitioned over to IPv6 confirms this initiative.

Firms in China, Korea and India cite their shortage of IPv4 addresses as the primary reason for their rapid migration to IPv6. Unlike the United States these, and other Asian countries entered the Internet game relatively late. As a result, they were allocated fewer addresses. To quantify the difference in the IPv4 address allocation, countries like Korea and China received 23 and 38 million addresses respectively, while the United States was allocated 3 billion[3]. India, which held the first global IPv6 summit in early 2001, is actively promoting IPv6 deployment by legislating voice over IPv6 (VoIP6). Their deployment will begin with institutions first and later move on to the commercial side. Obviously this, coupled with the liberalization of the telecom and Internet industries in Asia, will generate the need for many more IP addresses. Implementation of IPv6 would virtually eliminate the inadequacy in the amount of available addresses, opening the door to future explosive growth in these Asian markets. Because of their later entrance, network providers in these countries have far less legacy infrastructure to replace making the transition even more cost effective than what the U.S. networks will experience.

Major industry leaders such as Cisco, Intel, 3Com, Ericsson, Telebit, Hitachi, Nortel, Microsoft, Compaq, HP, Linux, Sun, and Juniper are all encouraging the adoption of IPv6, but even then it will be quite some time before IPv6 accessible web sites prevail. (To see a list of current IPv6 Accessible Web sites, go to: http://www.ipv6.org/v6-www.html). This is a web site where anyone can publicly announce their IPv6 accessible server with a list of services. The only drawback (I think that's what you mean) is that currently it is only available for web sites that can be reached through an IPv6 capable client.

IPv6 Benefits

While this paper has focused so far on the advantages of IPv6 in the area of limited IP addresses, there are many new benefits IPv6 brings to the Internet. IPv6 also lends itself to meeting the needs of new high-performance parameters and quality of service (QoS) for applications like real-time audio and video streaming. IPv6 is designed to run efficiently on both high-performance networks (e.g. Gigabit Ethernet, OC-12, ATM, etc.) and low bandwidth networks (e.g. wireless). The following lists shows many of the other benefits or reasons to make the transition:

- Better security: embedded encryption and authentication

[3] Waiting, Waiting, and Waiting for IPv6, Jim Wagner, Internetnews.com, p 1, 2

- Easy, quick provisioning: automatic configuration and management of IP addresses allowing for less errors
- Improved routing efficiency: better network performance
- Cluster addressing and source routing: identifies topological regions and allows nodes to control routing more precisely
- Accommodation of any device connected to the Internet: mobility support, which allows a mobile host away from home to communicate directly with a node
- Plug & play is automatic & node discovery far superior to IPv4: allows for the ability to do more with dynamic configuration, unlike DHCP in IPv4
- "Always-on" technologies: 3G communications systems are being created for devices to be 'always-on', which requires a permanent IP address
- Reduced complexity of network deployment & administration: more efficient route aggregation; also eliminates costly boxes like NATs; easier capability to select or change ISPs
- Provides a platform for new Internet functionality for the future: support for next generation (3G) applications like wireless appliances and gaming

IPv6 also supports three address types, one of which is new for IPv6[4]:

- Unicast (Unicast)
- Anycast (Anycast) (new with IPv6)
- Multicast (Multicast)

For a more technical explanation of these addresses types, the articles: IPv6: The New Internet Protocol and IP Next Generation Overview (see references) are excellent sources.

IPv4 Compatibility and Transition

Compatibility with IPv4 is not a problem. In fact, IPv6 was specifically designed to work concurrently with IPv4, except where a node is configured as IPv6 only. Not only does this enable IPv6 packets to be "tunneled" through existing IPv4-routed networks, but it also sets the stage for a relatively seamless, gradual transition to IPv6.

Since the transition to IPv6 is expected to be slow, IPv4 and IPv6 will need to coexist together for a long time until IPv6 becomes the dominant network protocol. IPv6 users, like those at PAIX, achieve this with one of three methods[5]:

1. *Dual IPv4/IPv6 stack approach* – complete support for both protocols – clients, servers, and routers are running both protocols.

[4] IPv6: The New Internet Protocol, William Stallings, p. 14
[5] Transition to IPv6 in 2G and 3G mobile networks, Nokia Networks White Paper, p. 4

2. *Tunneling* – creates virtual IPv6 links over IPv4 routing infrastructure. IPv6 packets are encapsulated in IPv4 packets and then decapsulated at the other end of the tunnel
3. *Network Address Translation* (NAT) boxes – translates IPv6 addresses into IPv4 addresses and vice versa, allowing direct communications between IPv4 & IPv6 networks without requiring modifications to the hosts.

Much of the upgrade to IPv6 can be done with software alone, unless certain IPv6 applications are being used. Applications such as Multicast may require hardware upgrades or additional equipment.

When PAIX began offering IPv6 at its Palo Alto facility, special "free" test ports were provided. These ports allowed PAIX customers to test applications prior to committing to production status. To ensure a fully functional test bed, PAIX offered port bandwidths of 10mb, 100mb Fast Ethernet, 333mb Fractional Gigabit, and full Gigabit Ethernet. These customers have since all transitioned over to full production mode and now successfully exchange both IPv4 and IPv6 traffic. In order to ensure PAIX provides the highest level of Internet connectivity throughout all facilities, production IPv6 services are now available in every PAIX and "*Peering by **PAIX***" ISO Layer 2 switch fabric.

Applications

While many IPv6 applications are currently available, some are not yet considered to be in full production mode. Compared to a year ago, the growth in the applications area has been phenomenal. Applications for mail, chat, DNS, FTP, firewalls, games, news, multimedia, plus more can be found on these two websites:
IPv6 Applications: http://www.ipv6forum.com/navbar/links/v6apps.htm.
IPv6 Enabled Applications: http://www.ipv6.org/v6-apps.html.
There are other sites for the Asia and European applications that can be found on the Web.

Putting the Data into Perspective

All software has a life cycle, and IPv4 is approaching obsolescence. Eventually, U.S. companies are going to be forced to look for a more robust version of IP, and countries that entered the IP race relatively late will need access to millions or billions of IP addresses. This transition will probably need to happen sooner, rather than later. These driving forces will push anyone who wants to stay or be at the leading edge of technology to make the jump. Since the costs for converting to IPv6 are minimal, the main reasons for not converting must be the lack of human resources and the current "survival mode" that many companies find themselves in today.

Obviously, U.S. companies cannot afford to lag behind foreign firms, nor can they afford to be late to the party. Other countries understand that buy-in and commitment from the U.S. is an important step in global migration. So this appears to be the right time for

U.S.-based Internet companies to begin to exercise leadership in this area. Transition should be relatively painless, and it is still early enough in the game for U.S. companies to benefit from key learnings and still be ahead of the expected mass migration to IPv6.

On a global scale, the sooner Internet companies transition over to IPv6, the quicker they will be able to achieve greater efficiencies and develop more dynamic applications. These efficiencies and applications may have the potential of reduced costs and additional revenue generation.

One thing that will influence the U.S. and other global Internet companies to transition more quickly is for more Internet exchange points to provide easily accessible IPv6 ports. Doing so will create a much needed critical mass of IPv6-enabled Internet traffic and applications. In sum these changes, enabled at the exchange level, can shape the growth of IPv6 in the U.S. and abroad. This has been demonstrated at PAIX. Because PAIX offered IPv6-compatible ports on a test, and now production switch fabric, Asian and U.S. companies have been able to experiment and tune their networks.

Finally, over the past several months, the awareness of IPv6 and its enhanced applications and benefits has increased. The rollout of IPv6, while still slow, is gathering momentum. Some ISPs and exchange points are actively marketing their ability to manage IPv6 traffic. The bottom line is that the global Internet community will need to help those on the fence to commit to IPv6 through their use of this protocol, which will, in turn, result in increased flexibility, capability and room for network growth world wide. PAIX, in its continuing drive to remain the leader in Internet exchange point technology, has taken a large step in enabling global networks to cost-effectively and easily share IPv6 traffic. We believe efforts like this will help make the transition easier and more attractive for everyone.

References

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5. IP Version 6 (IPv6), by Robert Hinden of Nokia, last updated on *16 January 2002,* http://playground.sun.com/pub/ipng/html/ipng-main.html

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9. Transition to IPv6 in 2G and 3G mobil networks, Nokia Networks White Paper, Link to the whitepaper "Transition to IPv6 in 2G and 3G mobile networks". (PDF format, 1.35 MB)

10. The Move to IPv6, Technical Paper, Alcatel, 02 2002, www.alcatel.com, search for IPv6, *www.cid.alcatel.com/doctypes/techpaper/pdf/IPV6_tp.pdf*

11. PAIX Engineering Interviews, Mr. Stephen Stuart, VP of Engineering and Mr. Brad Horak, Director of Engineering

12. ISP Planet - IPv6: The Future is Now, Jim Thompson, August 7, 2001, www.isp-planet.com/technology/2001/ipv6_nowagain.html

13. ISP Planet – Waiting, Waiting, and Waiting for IPv6, Jim Wagner, July 3, 2002, www.isp-planet.com/business/2002/ipv6_wait.html

14. 'Latest IP version will be better geared to handle Net surge', eFE interview – C Mendiratta, Principal consultant, Cisco Systems, November 13, 2001, http://www.financialexpress.com/fe20011113/efetop5.html

15. What is the matter with IP Version 4?, 26th August 2002, http://www.it-director.com/article.php?id=3145

Where to Find More Information

The following sites should be very useful in getting more in-depth and technical information on IPv6 or just some useful information in general. By no means is this list the only definitive information available. In fact there is a wealth of information on the Internet; just go searching.

- **IPv6 Forum**: www.ipv6forum.com A world-wide consortium of leading Internet vendors, Research & Education Networks with a mission to promote IPv6
- **IPv6 Information Page**: http://www.ipv6.org/ where you can get information on other IPv6 accessible servers, find out what applications run over IPv6, and how to get help with deploying IPv6.
- **Internet Engineering Task Force (IETF**): http://www.ietf.org/ has the sole authority for developing IPv6 protocol standards. IPv6 Working Group: http://www.ietf.org/html.charters/ipv6-charter.html
- **Nokia:** www.nokia.com/ipv6, IPv6 information and white papers
- **KAME Project:** http://www.kame.net**,** a joint effort of several companies in Japan to provide a free IPv6 and IPsec stack for BSD variants to the world
- **WIDE Project:** http://www.wide.ad.jp/wg/active/14_ipv6.html, Japanese group working on IPv6
- **List of IPv6 Internet Exchanges:** `http://www.v6nap.net/`
- **IP Addresses:** organizations that assign IP addresses:

  ►**Americas:** ARIN, www.arin.net

  ►**Europe:** RIPE, www.ripe.net

  ►**Asia:** APNIC, www.apnic.net
- **TechWeb TechEncylclopedia** – a technical dictionary, http://www.techweb.com/encyclopedia/ a handy tool when you want to look up a technical word and find the definition
- **A Brief History of the Internet:** http://www.isoc.org/internet/history/brief.shtml, by those who made the history plus other educational information by the Internet Society (ISOC), a global professional membership organization, providing leadership in addressing issues that confront the future of the Internet, http://www.isoc.org