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Internet Technology in 2010: The Issue of IPv6 Adoption in the U.S.A.

Garry L. White
Texas State University, San Marcos

Jaymeen R. Shah
Texas State University, San Marcos

James R. Cook
Texas State University, San Marcos

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James R. Cook.
Texas State University – San Marcos

ABSTRACT

Computer industry literature suggests that IPv4 Internet addresses are likely to have been depleted by the year 2010, and at least Asia and Europe will be using the new IPv6 Internet addresses. Literature also suggests that the U.S.A. is lagging behind Asia and Europe with the implementation of IPv6. Empirical data supporting the fact that the U.S.A. is lagging behind is not available in the literature. This paper presents the issues regarding IPv6, reasons why Asia and Europe are implementing IPv6, and why the U.S.A. is lagging behind. Empirical data is presented to support the literature's suggestion that the U.S.A. is lagging behind. The consequences of this inactivity regarding the implementation of IPv6 by the U.S.A. are discussed.

INTRODUCTION

Today, the Internet uses IPv4 (Internet Protocol version 4) rules of communication and node addresses. However, IPv4 addresses are likely to be depleted sometime between 2005 and 2011 (Gwin, 2002; Salus, 2000; Watlton, 1999; Wieland, 2002). The Internet Engineering Task Force (IETF), a multinational non-commercial group, forecasts that the 32-bit IP addresses provided by IPv4 will be depleted by 2010 (Suomela, 2001). That is when many speculate the Internet will be close to 100% compliant with the new Internet protocol, IPv6 (Hwany, 2001; Talley, 1998).

The need for IP addresses has accelerated by the introduction of personal digital assistants, smart phones, and other intelligent/mobile devices with Internet access (Cope, 2001; Gwin, 2002). Many other devices requiring IP addresses will be consumer-oriented, such as coffee machines, smoke alarms, refrigerators, dishwashers, etc. (Salus, 2000). Each of these devices will need an IP address. The rate of depletion of IP addresses will accelerate as the use of Internet-enabled devices proliferate.

In addition to the issue of depletion of IPv4 addresses, deployment of IPv6 is critical for providing next generation network services. Such services are important for companies to enhance their operations in the net-centric and global business world. IPv6 services will be available very soon, if they are not already available, within countries in Europe and Asia (Gwin, 2002; Morrison, 2002; Quinn, 2000). However, there is not much information available in the literature regarding U.S.A.-based companies' plans for upgrading their network infrastructure to support IPv6. To learn more about this issue and answer the following questions, the authors conducted a survey of U.S.A.-based Internet Service Providers (ISPs) and non-ISP companies.

a) Do U.S.A.-based ISPs and companies believe that it is necessary and beneficial for them to incur expenditure for implementing IPv6?

b) Have U.S.A.-based ISPs and companies developed or are in the process of developing an organizational plan for implementing the required software and hardware upgrades for supporting IPv6?

c) Will U.S.A.-based ISPs' and companies' entire network infrastructure be capable of supporting IPv6 by 2006 or 2010?

IPv6 CHARACTERISTICS

Over the next decade the Internet will require a new version of the Internet Protocol to deal with the shortage of IP addresses, and to provide enhanced network services. To solve this address shortage and to provide better quality of service, the IETF developed IPv6 in 1994 as a replacement for IPv4.

IPv6 differs from IPv4 in the following five major areas:

1) IPv6 increases the IP address size from 32 bits to 128 bits, providing over 10**13 addresses (Watlton, 1999). It also supports more levels of addressing hierarchy, making routing more efficient (Hinden, 1996).

2) Header format is simplified and extension headers are included.

3) Quality of Service (QoS) capabilities provides easier management of real-time file-sharing and voice services (Wieland, 2002). IPv6 also provides enhanced support for multimedia applications on the Internet.

4) Authentication and Privacy Capabilities are included.

5) Automatic configuration of IPv6 allows a host on the Internet to generate a unique IP address for itself based on network topology. It also makes using roaming mobile hosts, such as Internet-enabled cellular telephones, easier (Marsan, 1999; Watlton, 1999).

BACKGROUND

Reasons why IPv6 is not already widely used on the Internet

In order for the Internet to function efficiently, universal standards need to be implemented and monitored. The IETF controls the development of standards and technical specifications for the Internet (Trumbo, 2000). However, IETF's recommendations are voluntary. There is neither a set date nor a deadline for all companies to convert to IPv6 like there was for the Y2K problem (White, 2003).

The problem of IPv4 address shortages has not been as severe as first predicted. Technologies have been developed to deal with the shortage of IPv4 addresses. Technologies and protocols such as Network Address Translation (NAT), Dynamic Host Configuration Protocol (DHCP), and Classless Inter-Domain Routing (CIDR) have been able to increase the number of hosts on the Internet with a limited number of IPv4 addresses (Watlton, 1999). NAT technologies link many networked devices to the Internet through a translation device with a single IPv4 address (Cope, 2001), breaking the limit of 3.7 billion IPv4 addresses (Weiser, 2001). DHCP assigns temporary IPv4 addresses to nodes, and CIDR aggregates IP addresses. These technologies have mitigated the need to migrate to IPv6 (White, 2003).

Migrating to IPv6 requires a significant amount of learning, training, and restructuring (DeMaria, 2002). Applications will need to be rewritten to deal with the increased size of an IPv6 address. Domain Name Servers (DNS) and complex applications such as databases, firewalls, browsers, and IP phones will need to be upgraded (DeMaria, 2002; Lawson et al., 2002; Steinke, 2001). These changes imply that the cost of changing to IPv6 is significant (Snyder, 2000).

Due to there being no deadline for converting to IPv6, high migration costs, and a smaller shortage of IPv4 addresses in the U.S.A. via NAT and CIDR, many network managers have decided to adopt a wait-and-see approach before implementing IPv6 (Cope, 2001).

The Debate

Snyder (2000) suggests that there is insufficient demand for IPv6, and its fundamental design is based on a shortage of 32-bit IPv4 addresses. The availability of techniques such as NAT technologies has helped in reducing

the need for unique IPv4 addresses. Fortune 500 companies are accustomed to using 30 to 40 public IPv4 addresses and using NAT for everything else (Snyder, 2000). Some believe that IPv4 provides corporations with all the network functionality they need, at a lower cost (Yoke, 2002), and the world is adequately served by IPv4 (Weiser, 2001).

However, there are problems with IPv4's use of NAT to increase the number of node addresses. There may be an inability to meet the need of very large networks that serve 50 to 100 million IP-enabled devices. Address translation also may result in a higher network capital investment and increased operational costs (Suomela, 2001). NAT disables many existing network applications that require unique addresses, such as H.323 conferencing (Quinn, 2000). When using NAT, problems may be encountered in deploying NAT across the network applications like voice over IP (VoIP) and other applications that require end-to-end transparency across the network (Ottensmeyer, 2002). NAT provides minimal security, and adds complexity to network configuration and management. NAT also introduces a potential single point of failure into the network. Further, use of technologies like NAT with IPv4 is only a short-term solution, which could hurt companies in the long run. For example, IPv6 location information can be used for routing, which results in faster routing decisions and slower growth in the size of routing tables compared to IPv4. Companies using IPv4 will have to contend with rapidly growing routing tables and the unavailability of location information for routing purposes, which will adversely affect the time required to route IPv4 packets (Wong, 2002).

Other problems with IPv4 are deficient global address space (Quinn, 2000) and the inability to provide quality service for real-time packets (Wieland, 2002). Problems with IPv6 deployment also include the lack of empirical evidence showing that IPv6 is better than IPv4 (Loshin, 2000).

The key application for IPv6

To help make the transition to IPv6, a key application is needed (Weiser, 2001). That key application is the wireless networks/data communications (Ladid, 2001a). Wireless communication vendors support IPv6. They have committed to IPv6 for their third-generation standards (Higgins, 2000; Loshin, 2000; Paulson, 2001; Marsan, 2000b). Providers of next-generation mobile digital telephony services point out that they will need IP addresses for millions of devices for data networking (Loshin, 1999). It is predicted that we will be in a totally integrated wireless world sometime between years 2012 and 2022 (Ladid, 2001b). Mobile data network vendors are the principal beneficiaries; and, therefore, are the motivators for implementing IPv6 (Sweeney, 2002).

However, the responsibility for IPv6 deployment rests, not with the wireless network industry, but with the Internet service providers. When customers request IPv6, the ISPs will provide it (Loshin, 1999). IPv6 usage will increase significantly when ISPs can make a profit from its implementation (Steinke, 2001).

IPv6 Support and Deployment

IPv6 is currently available in hardware and software. Networking hardware vendors like 3Com, Cisco Systems, Ericsson, Hitachi, Nokia, and Nortel Networks support IPv6 (DeMaria, 2002; Hinden, 2002; Lawson et al., 2002; Loshin, 2000). IPv6 stacks are available for operating systems from Apple Computer, HP, IBM, Linux, Microsoft, Novell, SGI, and Sun Microsystems (DeMaria, 2002; Hinden, 2002).

The IPv6 backbone exists. The 6bone is a collaborative global IPv6 test-bed network, which is operated under the oversight of the IETF. As of the year 2000, 6bone had approximately 400 networks across 50 countries (Higgins, 2000). Japanese telecommunication companies have been providing IPv6-based services since 1999. In 2002, Steve Deering, Cisco Systems Fellow and member of the Internet Architecture Board, predicted that between years 2002 to 2006, most ISP's will begin implementing IPv6. This is consistent with predictions made at the 2001 Global IPv6 Summit in Seoul, South Korea (Ladid, 2001b). It is predicted that by the year 2005, the European IPv6 backbone will be completed and telecommunication legacy systems will have been converted to support IPv6 (Ladid, 2001a).

The Internet Corporation for Assigned Names and Numbers (ICANN), the overseer of the domain name system for the Internet, recently announced that it has started adding IPv6 addresses to the DNS root server system.

The IPv6 support will initially be limited to two-country code domains, .jp for Japan and .kr for Korea, and will be followed by .fr for France (Hicks, 2004). This announcement by ICANN, which is funded by the U.S. Department of Commerce, suggests that the U.S.A. is lagging behind Asia and Europe in IPv6 deployment.

US vs. ASIA & EUROPE

In 2002, 70% to 74% of all IPv4 addresses had been allocated to organizations located in North America (Gwin, 2002; Wieland, 2002). Since there currently is an adequate number of IP addresses in the U.S.A. and a huge investment in IPv4 infrastructure, many U.S.A.-based companies fail to see the need for IPv6. Thus, these companies are indifferent to IPv6 implementation (Gwin, 2002; Higgins, 2000; Loshin, 2000).

Companies should realize that a network infrastructure upgrade is only one aspect of IPv6 services. The other aspect is application upgrade. Companies will need to alter application code and change hard-coded four-byte IPv4 address fields. This requires a significant amount of time and money. If companies plan to support both IPv4 and IPv6 on their networks, which may be necessary during the transition phase, it will be necessary for them to add code in their applications running on dual-stack hosts to implement the logic required to determine which IP version should be used to communicate with the application/client. This will increase the complexity and testing requirements (Ottensmeyer, 2002; Wong, 2002). These issues clearly suggest that it is imperative that U.S.A.-based companies and ISPs develop a detailed plan for their transition towards supporting IPv6.

While IPv6 has a low profile in the U.S.A., the Asian and European countries are active in promoting IPv6 (Wieland, 2002). For example, the European Commission's Information Society Taskforce has specifically cited IPv6 as a key need, and South Korea has set the year 2005 for completing full implementation of IPv6 (Morrison, 2002; Quinn, 2000). Why? Countries in Asia and Europe did not receive enough IPv4 address space. There is a growing need for more IP addresses in these countries, which exceeds what is now available (Higgins, 2000; Loshin, 2000). For example, in 2003, China had approximately 60 million Internet users, and over 200 million cellular phone users. However, it had less than 30 million IPv4 addresses available for the entire country, whereas Stanford University alone has 17 million IPv4 addresses (Lu, 2003; Schwartz, 2002). Thus, Asian and European countries are major proponents of IPv6.

Japan is a good illustration of what Asia is doing. Japan is the world leader in IPv6 development and commercial adoption. In Japan, almost all ISPs, including small rural ISPs, have implemented IPv6 and are providing commercial IPv6-based services (Ito, 2003). Japanese telecommunication companies, such as NTT Communications, KDDI, Japan Telecom and others have invested heavily in IPv6 implementations and are offering commercial IPv6 services (Ito, 2003; Marsan, 2000a). Many Japanese companies like Tokyo based ISID, a systems integration company, have already deployed IPv6 network for internal use (Lawson et al., 2002). IPv6 is now considered a basic technology, and its adoption is no longer considered new. Japan is already in the second phase of IPv6 deployment; focus has now shifted to developing network-oriented hardware and applications for the next generation Internet market, based on IPv6. Examples of IPv6 applications deployed in Japan include wireless Internet access from taxis and trains, IPv6 PlayStation Game from Sony, and IPv6 refrigerator from Toshiba. Sony has announced that starting in 2005 each of its consumer electronic devices will be IPv6 enabled (Dempsey, 2004).

The Japanese government has imposed a deadline for upgrading to IPv6 of 2005 (DeMaria, 2002; Lawson et al., 2002; Morrison, 2002). As part of its e-Japan Initiative to bring the country to the forefront of IT by 2005, the Japanese government has sponsored an IPv6 Promotion Council that helped in setting up several trials of the new protocol on various carriers' networks and promoting IPv6 implementation (Lawson et al., 2002). South Korea, Taiwan, China, and other Asian countries are also aggressively moving towards implementing IPv6.

Although IPv6 trial and deployment has occurred in Europe, it is not as widespread as in Asia. IPv6-based services have been available in Europe. For example, in the Netherlands, SURFNet5 has provided IPv6-based services to universities, industrial research centers, hospitals, and commercial enterprises since September 2001 (http://www.surfnet.nl/en/surfnet-publications). Thus, in the near future, the use of IPv6 is likely to proliferate in Asia and in some parts of Europe where governments, service providers, and other businesses are supporting IPv6 (DeMaria, 2002; Gwin, 2002; Lawson et al., 2002; Marsan, 2000a; Morrison, 2002; Paulson, 2001; Quinn, 2000).

Penetration of wireless devices is much higher in Asian and European countries. European and Japanese wireless companies look to IPv6 to support wireless technology (Paulson, 2001). As a whole, both Asia and Europe perceive early adoption of IPv6 as a way to surpass the U.S.A. as the world's Internet leader (Gwin, 2002).

SUMMARY

With the IPv6 developments in Asian and European countries, and an increase in the demand for IP-addressable devices (cell phones, game players, etc.), the prospects for IPv6 are improving (Passmore, 2002; Wieland, 2002). Equipment and operating system vendors are supporting IPv6 along with manufacturers of devices that use "wireless" and embedded devices (Lawton, 2001). However, many U.S.A.-based ISPs and companies are not heavily supporting IPv6, due to market demand in the U.S.A. for IPv6-based services being relatively low.

As the use of IPv6 increases in Asia and Europe, it may require U.S.A.-based companies and ISPs to implement creative solutions on their networks, so that hosts and applications on their networks can communicate with their clients' business partners' hosts using IPv6. This will increase the cost of operating IPv4 networks, as it will introduce added complexity in network administration and require more short-term fixes (Ottensmeyer, 2002). Substantial increase in cost and complexity of operating IPv4 networks may force companies to rapidly upgrade their networks to IPv6 without adequate planning, which could result in higher costs of network upgrade and maintenance.

Will U.S.A.-based companies have enough addresses to implement their wireless Internet capabilities? Current estimates do not take into account wireless' needs. As IP addresses begin to be used by devices such as appliances with Internet connections, the current availability of IPv4 addresses will be inadequate (Wickham, 2000). IPv4 address space is forecasted to be depleted between 2006 and 2011 (Marsan, 2001). To gain more knowledge and understanding regarding U.S.A.-based ISPs' and companies' plans and views regarding implementing IPv6, the authors conducted a survey, which is described in the following Section.

METHOD

Information Systems (IS) professionals and managers of U.S.A.-based companies were surveyed. The Association of Information Technology Professionals (AITP) provided one thousand potential respondents from their membership list. The survey instrument that was used to gather data for this study is presented in Appendix I. To maintain anonymity of respondents, they were not required to provide their name or their company's name. The authors hoped this would encourage respondents to provide accurate information about their companies' plan regarding infrastructure upgrade for supporting IPv6.

The survey instrument was distributed via e-mail to selected AITP members. Each e-mail contained a brief message explaining the purpose of the study and a hyperlink to access the Web-based electronic survey instrument. The electronic survey instrument was designed with the intention of ensuring that it was easy to use, contained clearly stated questions, and required about five minutes to complete. The survey was made available to the respondents for five days. At the end of the survey period there were a total of 74 valid responses, 26 respondents from ISP companies and 48 from non-ISP companies. Data collected from this survey was analyzed using SPSS software.

RESULTS

Table 1 shows the percent distribution of the position type of each respondent. Fifty-five percent of the respondents were in technical positions and forty-five percent were in managerial positions. Approximately thirty percent of the respondents identified themselves as corporate managers, and fourteen percent indicated their position as IT/Network manager.

Table 1: Position Type of Respondents.

	Frequency	Percent
Technical position (55.5%)		
Programmer	11	14.9%
Junior Analyst	1	1.4%
Software Engineer	10	13.5%
Project Leader	13	17.6%
Other Tech positions	6	8.1%
Management Positions (44.5%)		
IT Manager	2	2.7%
Net Manager	8	10.8%
Corp Manager	22	29.6%
Corp Administrator	1	1.4%

Table 2 shows the percent distribution of the business type of each respondent. Forty-six percent of the respondents were either from a financial business or a health care business. Twenty-six percent indicated another type of business not listed.

Table 2: Business Types.

	Frequency	Percent
Manufacturing	5	6.7%
Transportation	3	4.1%
Distribution	3	4.1%
Telecommunication	1	1.3%
Financial	16	21.6%
Consulting	3	4.1%
Retail	2	2.7%
Health Care	18	24.3%
Construction	3	4.1%
Government	1	1.3%
Other	19	25.7%

Results of the survey, for each survey question, are presented in Appendix I. The three result columns contain data analysis for all respondents, ISP companies, and non-ISP companies. Discussion regarding the results presented in the following paragraphs is based on the data for all respondents.

Availability of adequate IP addresses is critical in a networked computing environment. Inadequate IP addresses can cause serious disruptions in employees' work and business operations due to their inability to connect to the corporate network. The survey results revealed that almost fifteen percent and seven percent of all respondents (almost twenty-three and twelve percent for ISPs) believed their companies will run out of IPv4 addresses by the year 2005 and 2010, respectively. Approximately thirteen percent of the respondents indicated that their companies will run out of IPv4 addresses in the year 2011 or later. Thus, about twenty-two percent (thirty-five percent for ISPs) of all survey respondents supported the timing suggested in the literature regarding the depletion of IPv4 address space.

Based on the results of the survey, it seems that very few companies are developing plans for deploying IPv6 services. Approximately seven percent of the respondents indicated that either their company has already developed, or is in the process of developing, a detailed plan for providing IPv6 services. Almost twenty-nine percent of the respondents indicated that their companies have not started developing a plan for providing IPv6 services. Twelve percent of the respondents indicated there is no need for their companies to develop a plan for providing IPv6 services. These results suggest that many IT managers and professionals are not aware of the extent of planning required for technology upgrades and staff training required for providing IPv6-based services. When these companies decide to upgrade their companies' technology infrastructure to IPv6, they will realize that it

requires more than shutting down the network for a few days, and that it involves a significant amount of time, money, and effort to fully implement the upgrade necessary to support IPv6-based services (Ottensmeyer, 2002; Kennedy, 2001).

Time and cost required for infrastructure upgrade were cited most often as the two most critical factors for providing IPv6-based services. Few respondents indicated that personnel training and vendor coordination are critical for providing IPv6-based services.

The survey results suggested there is a lack of consensus regarding the benefits of deploying IPv6-based services. Twenty-six percent of all the respondents (almost thirty-nine percent for ISPs) indicated their clients and companies would benefit by using IPv6-based services. However, almost nineteen percent (almost twelve percent for ISPs) suggested otherwise. Approximately fifty-five percent did not know whether or not the use of IPv6-based services will benefit their company or clients. This suggests that there is a lack of awareness among IT professionals and managers about the capabilities and benefits of IPv6, and the extent to which their clients and their companies will benefit from its use. This may be one of the reasons why the U.S.A.-based companies are reluctant to invest their time, money, and effort in upgrading their technology infrastructure to support IPv6. Thus, it may be necessary for IETF, IPv6 Forum, North American IPv6 Task Force, and leading software/hardware vendors, such as Microsoft and Cisco Systems, to disseminate among IT professionals, information regarding the capabilities and benefits of IPv6 services. This may aid in accelerating the adoption of IPv6 in the U.S.A.

Approximately fourteen percent and seven percent (fifteen percent for ISPs) of the respondents indicated their companies plan to offer IPv6-based services by the end of year 2005 and 2010, respectively. Twenty-four percent of the respondents indicated that their companies have no plans for offering IPv6-based services. Almost forty-seven percent of the respondents indicated that staff members from their company have not attended any IPv6 seminars or conferences. This seems to suggest a lack of commitment from the top management of these companies for moving towards implementation of IPv6.

Overall, the results suggest that the majority of the U.S.A.-based companies may not be planning to migrate to IPv6 by the year 2010. The consequences of this for U.S.A. consumers and companies may include: 1) higher charges for IPv6 services because of a lack of competitive pressure on service providers, 2) lack of support for advanced communication technologies, and 3) lower quality of service (QoS) compared to that achieved by using IPv6.

DISCUSSION

The results of this study suggest there is a lack of motivation and enthusiasm among U.S.A.-based companies and ISPs to upgrade their network infrastructure to support IPv6 standards and services. It seems that the U.S.A-based companies and ISPs are not developing plans for migrating to IPv6. Managers in these companies do not seem to be aware of the implications of not upgrading their network infrastructure to support IPv6. It is only a matter of time, as the world evolves toward IPv6, that U.S.A.-based companies and ISPs will need to implement IPv6.

At the current time, most of the U.S.A.-based ISPs and companies are reluctant to discard their huge investment in IPv4 infrastructure and make a significant investment in technology upgrade. The main argument in support of this decision is the lack of payback from the upgrade to IPv6, due to limited IPv6 traffic existing within the U.S.A. (Wong, 2002). Further, as the number of 3G mobile users increase and reach a critical mass, it will become inevitable for companies and ISPs to support IPv6 services (Ottensmeyer, 2002). Thus, it seems that the U.S.A.-based ISPs and companies stand to lose if they do not implement IPv6. Foreign ISP's may come in and offer IPv6-based services first, which may erode U.S.A.-based ISPs' and companies' market share. Currently, commercial IPv6-based services are being offered in the U.S.A. by only one company, Verio – a wholly owned subsidiary of the Japanese telecommunications giant, NTT Communications (Marsan, 2000a; Villano, 2003).

U.S.A.-based ISPs and companies seem to lack motivation and enthusiasm for upgrading their technology infrastructure to support IPv6. This is likely the result of a depressed global economy, decreased budget spending on network build outs and upgrades, availability of adequate IPv4 addresses in the U.S.A., and a lack of visibility about the near-term demands for profit from IPv6-based services (Hammond, 2004).

Steve Deering (Deering, 2002) has suggested that ISPs will adopt IPv6 between the years 2002 and 2006. If the U.S.A.-based ISP's fail to implement IPv6 during this period, they stand to lose out to foreign ISP's (White, 2003). Latif Ladid, President of the IPv6 Forum, said at the 2001 Global IPv6 Summit in Seoul, South Korea, "the longer the upgrade is postponed, the costlier it will be and more complex transition compared to Y2K" (Ladid, 2001b). The question is: will the U.S.A.-based ISP's and companies implement IPv6 by 2010? Both the survey and the literature indicate the answer is NO! When much of the world is using IPv6 in 2010, the U.S.A. may be lagging behind, with a majority of the companies using IPv4 and struggling with the depletion of IPv4 address space.

The results of the survey suggest that most of the U.S.A.-based companies and ISPs are not planning to implement IPv6 infrastructure upgrades by year 2010. However, the following factors should be considered:

1) Rapid increase in 3G mobile users. 3G mobile networks use IPv6. As 3G mobile users increase and reach a critical mass, it will require companies to support IPv6 services (Ottensmeyer, 2002). Sprint Corp., in its response to the U.S. Department of Commerce's task force on transitioning to IPv6, indicated that IPv6 is inevitable for mobile networks (Hammond, 2004).

2) Early adoption of IPv6 by Asian and European countries.

3) Globalization of markets causing a significant increase in business communication with business partners in Asian and European countries.

4) Endorsement of IPv6 from government and research agencies, and hardware, software, and wireless vendors. For example, in June 2003 the U.S. Department of Defense announced that any IT purchases made after October 1, 2003 must be IPv6-capable (Poe, 2004). This mandate was to support its goal to migrate its entire network to IPv6 by 2008. Security and mobility offered by IPv6 were cited as two major reasons for the Department of Defense's decision to migrate to IPv6. In March 2004, major tests were successfully conducted on the Moonv6 IPv6 backbone network. Moonv6 is a joint operation of the University of New Hampshire's interoperability lab, the U.S. Department of Defense, the North American IPv6 Task Force, and the Internet2 university consortium. Moonv6 tests were designed and conducted to promote deployment of IPv6 in the U.S.A. (Marsan, 2004).

5) Growing use of peer-to-peer applications, grid computing, VoIP and other applications that are better supported by IPv6 features, such as end-to-end transparency, QoS, and enhanced security and mobility, may also accelerate migration to IPv6 in the U.S.A. For peer-to-peer applications, IPv6 is necessary, as these applications cannot be supported by IPv4 with NAT (Ladid and Bound, 2003).

The authors anticipate that these aforementioned factors will provide the necessary impetus for U.S.A.-based companies and ISPs to upgrade their technological infrastructure to support IPv6 services before the year 2010.

APPENDIX I

Survey Results: IPv6 adoption by U.S.A. companies

1.	Is your company a U.S.A. based ISP?	Yes 35.1%	No 64.9%	
		Total N=74	**ISP's N=26**	**non-ISP's N=48**
2.	Your company provides service to clients in the:			
	a. U.S.A	74.3%	76.9%	72.9%
	b. International	2.7%	0.0%	4.2%
	c. Both a and b	23.0%	23.1%	22.9%

3.	Which is the highest IPv4 class address registered to your company?			
	a. A	10.8%	7.7%	12.5%
	b. B	12.2%	21.3%	6.3%
	c. C	24.3%	15.4%	29.2%
	d. Don't know	52.7%	53.8%	52.1%
4.	When does your company anticipate running out of IPv4 addresses?			
	a. 2002-2005	14.9%	23.1%	10.4%
	b. 2006-2010	6.8%	11.5%	4.2%
	c. 2011 or later	13.5%	7.7%	16.7%
	d. Don't know	64.9%	57.7%	68.8%
5.	When do you anticipate your company to provide or use IPv6 services?			
	a. 2002-2005	13.5%	11.5%	14.6%
	b. 2006-2010	6.8%	15.4%	2.1%
	c. 2011 or later	2.7%	0.0%	4.2%
	d. Don't know	52.7%	53.8%	52.1%
	e. No plans for IPv6	24.3%	19.2%	27.1%
6.	What is your company's status about the planning process to provide IPv6 services?			
	a. Already have a detailed implementation plan	2.7%	3.8%	2.1%
	b. Currently developing a detailed implementation plan	4.1%	3.8%	4.2%
	c. Have not started developing a detailed implementation plan	28.4%	30.8%	27.1%
	d. Company does not need to develop a detailed implementation plan	12.2%	7.7%	14.6%
	e. Don't know	52.7%	53.8%	52.1%
7.	Which is most critical to successfully provide IPv6 services by your company?			
	a. Time required for infrastructure upgrade	21.6%	15.4%	25.0%
	b. Cost of infrastructure upgrade	20.3%	26.9%	16.7%
	c. Personnel training	2.7%	7.7%	0.0%
	d. Vendor coordination	2.7%	3.8%	2.1%
	e. Client training	0.0%	0.0%	0.0%
	f. Others:_____	5.4%	7.7%	4.2%
	g. Don't know	47.3%	38.5%	52.1%
8.	Has staff members from your company attended seminars/conferences on IPv6?			
	a. Yes	24.3%	30.8%	20.8%
	b. No	47.3%	46.2%	47.9%
	c. Don't know	28.4%	23.1%	31.3%
9.	Has your company been involved with the standards development process for IPv6?			
	a. Yes	6.8%	11.5%	4.2%
	b. No	68.9%	61.5%	72.9%
	c. Don't know	24.3%	26.9%	22.9%
10.	Will the use of IPv6 services benefit your clients or company?			
	a. Yes	25.7%	38.5%	18.8%
	b. No	18.9%	11.5%	22.9%
	c. Don't know	55.4%	50.0%	58.3%

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