TITLE: **NAV6TF PCIPB INPUT PART II**

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Executive Summary

This report is the North American IPv6 Task Force's (NAV6TF[1]) second input to the Presidents Critical Infrastructure Protection Boards' (PCIPB) Draft Release September 2002 Report on a structure and call for input for U.S. Cyber Security from Richard Clarke. This report leads to the suggestion that the U.S. Government begin a plan to adopt IPv6 as a core network infrastructure technology for National Business, Economic, Social, and Political reasons, in addition to the formal NAV6TF response to the Cyber Security Draft [2]. The report will also make a set of recommendations how the U.S. Government could lead the deployment for IPv6 within the U.S.

The emergence of the Internet as a fundamental technology for commercial and social activity has been most apparent since the creation of the World Wide Web in the mid 90's. The Internet has grown rapidly in the past five years, to a scale well beyond that which the original Internet designers envisaged over twenty years ago. It is imperative that the U.S. Internet be able to grow to meet the future demands of commerce and society, for business, for learning, to enable new markets to be realized, and to enrich the lives of U.S. citizens. IPv6 is also important to the U.S. DoD as a network infrastructure and as a technology enabler to support secure and robust state of the art military operations tomorrow.

The Internet relies on a data communication method called the Internet Protocol (IP) to transfer data between machines on the network, be that data Web pages, e-mail, online gaming or otherwise. All Internet applications communicate using IP; it is the basic enabler of every service on the Internet; it is thus critical that IP is able to scale on the Internet.

Future network growth requires that Internet-enabled devices can be assigned and use a globally unique IP address, in a similar way to the telephone numbers that identify individual phones. The current version of IP, IPv4, has been in existence for over twenty years, but has a limited address space, not even enough for one IP address per person on the planet. Its successor, IPv6, in development by the IETF for eight years, offers relatively unlimited address space. The IPv6 core standards were completed in 1999, and vendors started shipping commercial IPv6 products in earnest in 2000. As a result a number of early IPv6 deployments already exist, notably in Japan.

The scarcity of IPv4 address space, for example for both commercial and home users, restricts the applications that can be run for both business and home networks. A technique known as Network Address Translation (NAT) allows multiple devices to be "hidden" behind one or more real IPv4 addresses, but NAT breaks the end-to-end principle of the Internet, preventing the evolution of next generation applications that demand IP address space, and connectivity into business

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[1] http://www.nav6tf.org/

[2] IPv6 Response to National Strategy to Secure Cyberspace Final V2.0

http://www.nav6tf.org/slides/Response_NAV6TF_Secure_Cyberspace_Final_V2.pdf

premises and home networks (e.g. from IP-enabled mobile handsets). IPv6 delivers that address space, and is thus a key factor for the well being of the future U.S. Internet.

The wireless Internet will most likely lead the IPv6 evolution, wireless devices with IPv6 will be used in the home, the workplace, in cars, and in consumer electronic devices. As IPv4 lead to wired networks in business and in homes, leaving mainframes behind, likewise IPv6, in relative terms, will leave the wired Internet behind in time too. IPv4 has been in use for over twenty years, yet the World Wide Web was not conceived until ten years after the introduction of IPv4. By deploying IPv6, new, innovative applications will be realized, some that can be developed now, but many will follow in years to come, as the U.S. Internet evolves.

This report overviews IPv6, describing the features of IPv6 that will be key enablers for new applications and services. It describes the road forward for IPv6, including the requirement to integrate IPv4 and IPv6 services as the gradual overall transition to IPv6 occurs. There is no IPv6 “flag day” as there was for Y2K, but the earlier that IPv6 transition is begun, the less costly that transition will be in the long run, and the sooner IPv6’s benefits can be exploited in the U.S.
IPv6 is the only solution that provides the vastly increased IP address space and new features that will allow the U.S. Internet to grow and to scale into the next decade and beyond. The base IPv6 protocols are ready now, but deployment, which should be lead by market forces, requires a number of factors to be addressed, as recommended by this report.

1. IPv6 and the future Internet

At the dawn of the 21st century, information and communication technologies (ICT) are revolutionizing the functioning of the economy and society, and are triggering new ways of producing goods, trading, and communicating. The further development of ICT into the 21st century will have a wide-range and long lasting impact not only on the economy, but also on every aspect of people’s lives, leading to radical transformations and far-reaching changes. Indeed these changes are not just about technology, they are primarily about creating wealth and generating new business opportunities, sharing knowledge, bringing communities closer together and enriching everyone’s lives.

According to population estimates from the US Census Bureau, the world will be home to about 9 billion people in 2050. Whatever the economic constraints may be, we must clearly plan technically for all of these people to have the potential for Internet access. It would not be acceptable to produce a technology that simply could not scale to be accessible by the whole human population, under appropriate economic conditions. Furthermore, pervasive use of networked devices will probably mean we will see many devices per person, not just one.

1.1. Internet communication and addressing

To a user of the Internet, computers are addressed by their domain name, e.g. in the Web context you would use www.hotmail.com as the web address of Hotmail, or someone@hotmail.com as the e-mail address of Hotmail e-mail user. While such domain names are easier for people to remember, the networked devices – such as web servers, e-mail servers or home PCs – communicate using a numeric address format and a protocol called the Internet Protocol (IP). As a loose analogy, domain names and IP addresses can be compared to people’s names and their telephone numbers. The Internet Protocol requires that communicating devices, anywhere on the Internet, have unique IP addresses, so that data packets can be carried (routed) between the devices across one or more Internet Service Provider (ISP) networks.

The current version of IP, IPv4, has been in use for over twenty years. However, when IPv4 was designed in the 1970's, the vast growth in the Internet was not foreseen, and at the time the Web was still many years away from conception. As a result, and given the limitations of hardware at the time, the original Internet designers only chose to use 32 bits to represent IPv4 addresses. Those 32 bits allow 2^32, or just over 4 billion, IPv4 addresses. While the Internet of the late 1970's contained only a handful of hosts, mainly in the U.S., the Internet today has reached over 600 million regular users[3].

There are not, at present, enough IP addresses for every person on the planet. When one considers that homes, offices, cars and other environments may all contain many IP-enabled devices in the near future, the pressure on IPv4 address space is evident, given any one device on the network may wish to connect to any other (e.g. a computer system at a car dealership may remotely check the status of IP-enabled sensors in a car, to monitor performance and predict future problems). That pressure is heightened because IP addresses are never fully utilized, because allocations per ISP or per site were too generous in the 1980's, and most generous in North America.

IPv6, in development since the early to mid 1990's, has now matured to the state where vendors are delivering early commercial products (e.g. Apple, Cisco, Fujitsu, Hewlett Packard, Hitachi, IBM, Microsoft, NEC, Juniper, Sony, Sun Microsystems, and Toshiba) and initial deployments are being made. IPv6's major advantage is that it uses 128-bit addresses, enough to offer a globally unique IP address to any device wanting it for the foreseeable future. Given that all Internet communications use IP, the importance of the availability of IP address space for all cannot be stressed enough.

1.2. IPv6 address allocations

An IPv6 prefix represents a hierarchical, aggregated block of addresses for a network, in a similar way to a telephone area code aggregating all telephone numbers in a city area (only the computer network may be spread over any distance, e.g. where a network prefix is used by a national or even multinational organisation).

The worlds three Registries – RIPE, APNIC and ARIN – share a common IPv6 address allocation policy. While this policy is subject to change, it currently offers a top-level provider (ISP) up to 32 bits of address space (i.e. the equivalent of more than the whole current IPv4 address space for a single IPv6 provider), and a site receives 16 bits of network address space, which should be ample for the vast majority of organisations. For reference to the current IPv6 allocations see previous supplied paper to PCIPB "Projected Impacts of IPv6"[4].

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[3] http://cyberatlas.internet.com/big_picture/geographics/article/0,1323,5911_151151,00.html

http://www.nua.ie/surveys/how_many_online/

[4] Projected Impacts of the Internet Protocol version 6 (IPv6) on the USN and USMC Enterprise – Michael P Brig SPAWAR

http://www.nav6tf.org/slides/IPv6ImpactReport.doc

The availability of IPv6 address space should, through market forces, lead to IPv6 addresses being cheap (compared to IPv4) if not free to the end user. Many ADSL users currently pay a fee to have a single, static IPv4 address for their home network (typically $40 per month). A home user with IPv6 can receive an entire block of IPv6 addresses (rather than just one IPv4 address), The combination of the availability of multiple globally reachable IPv6 addresses for a home network, along with broadband access (e.g. ADSL), enables a whole new range of remote home applications such as Distributed Gaming, On-line metering, or Community of Interest.

1.3. The digital divide

Most significantly IPv6 can help bridge the digital divide that currently exists between the developed world (in particular the US, where IPv4 address space was in good supply in the early years of the Internet) and emerging Internet nations in Eastern Europe, Africa and Asia. IPv6 promises a level playing field for Internet Protocol application development and deployment where IP addresses are readily available the world over, not a luxury for a privileged minority.

Bridging this divide is now a global objective. But the uneven diffusion of technology is nothing new. There have long been huge differences among countries. The bitter irony of the Internet phenomenon is that while in theory the global network of networks is open to all, the vast majority of the world's population remain cut off from its economic and educational benefits. Only 8% of the world population has access to the Internet, compared to 20% for the phone system. Likewise not all of our U.S. citizens have access to the U.S. Internet either.

Affordable technologies more appropriate to developing economies could include solar-rechargeable batteries that would allow mobile phones to be used even in areas lacking electricity lines. The Internet could achieve a far better penetration through wireless access technologies, due to their dual benefit of being faster to deploy in any area (wide-scale cabling is not required) and of "giving wings" to the Internet with their mobility.

The PC era will be overtaken by the non-PC world (PDAs, Smart Cell Phones, personal network devices, etc). The Docomo I-Mode[5] advanced mobile data communication initiative in Japan achieved more than 30 Million users in just two years of deployment and is perceived by its users as the Japanese Internet. Now, adding IPv6 to it would give the developing world immediate access to not only the Internet, but to many next generation applications currently under development. If we fail to provide access to digital technology to countries in the developing world we are, essentially, denying them an opportunity to participate in the new economy of the 21st century.

1.4. Enabling next generation applications

The risk of global IPv4 addresses becoming critically scarce between 2005 and 2007, coupled with the uneven distribution of the address space between North America and the rest of the world, is sufficiently serious for action to be taken now and swiftly, as the promotion of IPv6 deployment by Europe[6] and Japan[7] (and other countries in Asia). While IPv4 addresses may never be completely

[5] http://imodelinks.com/desktop/faq.html

[6] http://www.eurov6.org/

exhausted, their availability will become increasingly scarce, particularly for large-scale requirements (such as those of mobile operators). Scarcity implies an undesirable cost to those wanting IP addresses.

Without sufficient global IP address space, applications are forced to work with mechanisms that provide local site addressing – loosely the equivalent of the early days of telephony where users had to interact with one (or more) operators to place a call. Such mechanisms (i.e. Network Address Translation or NAT) restrict the end-to-end transparency of the Internet. While NAT has to some extent delayed the pressure on IPv4 address space for the short term, it places severe restrictions on application communication. While a client behind a NAT device can communicate out to servers on the Internet (the "client-server" communication model), that same client cannot be guaranteed to be accessible when external devices wish to establish a connection to the client (as typified by the "peer-to-peer" communication model).

The need for always-on environments (such as residential Internet through broadband, cable modem, or Ethernet-to-the-Home) to be globally reachable precludes NAT-style IP address conversion, pooling, and temporary allocation techniques, and the "plug and play" always-on consumer Internet appliance requirements further increases the address pressure. IPv6 will remove the requirement for the use of NAT because global addresses will be widely available.

IPv6 reintroduces the ability to provide end-to-end security that is not always readily available through a NAT-based network. The plug and play feature of IPv6 makes IP device deployment, for example in the home, much easier for vendors – end users should not need to configure their network appliances (and with IPv4, users would have to configure NAT routers, which is unacceptable for commodity deployment). IPv6 will introduce prefix delegation which permits home users to configure their network as its own network domain; this capability with plug and play will provide home users the ability to manage their own network with less reliance on their ISP.

1.5. IPv6 benefits

Viewed from a technical perspective, IPv6 has many benefits, including the following:

- Larger address space for end-to-end global reachability and Internet scalability.
- Simplified IPv6 data packet header for extensibility and performance
- Support for routing and route aggregation, making Internet backbone routing more streamlined and efficient (the IPv4 Internet backbone contains data routing information for over 130,000 networks; with IPv6 this number could be dramatically reduced).
- Serverless ("stateless") IP autoconfiguration, easier network renumbering, and much improved plug and play support. This is the most important future benefit for the Department of Defense and Home Land Defense communications.
- Prefix Delegation of IPv6 addresses to support renumbering and autoconfiguration.

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http://www.ipv6tf.org/

[7] http://www.v6pc.jp/en/index.html

http://www.v6pc.jp/en/showcase/showroom/index.html

- Security with mandatory implementation of IP Security (IPSec) support for all fully IPv6-compliant devices (IPSec implementation is not mandated in IPv4). The *use* of IPSec is not mandatory, but the mandatory implementation requirement of IPsec permits the user to have the option for secure communications.
- Improved support for IP Mobility inherent in IPv6
- Enhanced Multicast Networking Support
- Enhanced Anycast Networking Support

These benefits can be mapped to opportunities for improved business models, new applications, new technology use models, and system markets.

2. IPv6 deployment evolution

At present, IPv6 is gradually being introduced. However, this process needs to be accelerated to prevent the current IPv4 shortcomings from hindering the further development of the Internet, to ensure a more open and competitive arena for the provision of a new generation services, and to avoid much higher transition costs if that process is delayed. It is important that acceleration take place in the U.S.

2.1. IPv6 standards development

The IPv6 standards, as implemented by vendors, are designed, tested and approved by the Internet Engineering Task Force (IETF)[8]. The IETF is a vendor-neutral organisation that spans the globe and that has working groups (WGs) in a wide range of areas. The WGs relevant to IPv6 include:

- *IPv6* – the core IPv6 protocol definitions, the core set of which was finalized in 1999.
- *V6ops* – working on IPv4-IPv6 integration, transition scenarios, and transition tools.
- *Mobileip* – including work on Mobile IPv6
- *Multi6* – defining mechanisms for Internet sites to efficiently connect to multiple ISPs.
- *DNSext* and *DHC* – including IPv6 naming and statefull addressing functionality

To date there are over 40 IETF standards (RFC documents) on IPv6, with a similar number in the draft (design development) stage.

Standards bodies for wireless data services are preparing for the future, and IPv6 provides the end-to-end addressing required by these new environments for mobile phones and residential Voice over IP (VoIP) gateways, with integrated autoconfiguration (plug and play), QoS, and security features. Mobile IPv6 improves on IPv4 in many ways, including the option to exchange data directly between mobile devices, rather than routing all data via a “home agent” device – the removal of such “triangular routing” is a major advantage for IPv6.

Raising awareness of IPv6 is a separate issue. While the IETF sets standards, it does not mandate policy, perform advocacy, or drive deployment. The Internet Society (ISOC)[9] has an

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[8] The Internet Engineering Task Force: http://www.ietf.org/

[9] The Internet Society: http://www.isoc.org/

important educational role, while the IPv6 Forum[10] is a key advocacy and deployment catalyst for IPv6 technology. To allow U.S. industry to take advantage of IPv6, it is important that awareness of the technology and education in its use where appropriate, be promoted and made available.

2.2. IPv6 deployment around the world

Japan took political leadership in the design of the roadmap to IPv6 when back on September 21, 2000 in the policy speech by Prime Minister Yoshiro Mori to the 150th Session of The Diet the Japanese government mandated the incorporation of IPv6 and set a deadline of 2005 to upgrade existing systems in every business and public sector. Japan sees IPv6 as one of the ways of helping them leverage the Internet to rejuvenate the Japanese economy.

Large-scale deployment networks and vendor implementations have been widely promoted. The IP research community has been supported by government initiatives. The Japanese initiative was very crucial to the Asian regions. Korea followed suit on February 22, 2001 by announcing plans to roll out IPv6. China and Japan have declared jointly in their 7th Japan-China regular bilateral consultation toward further promotion of Japan-China cooperation in info-communications fields such as IPv6.

An IPv6 research activity exists within Internet2[11] and specifically within the Abilene[12] network initiative, who just broke the land speed communication data records over a 10 Gbit/sec network using IPv6.

The business case for IPv6 in the U.S. is not yet felt, as the technical case is not that apparent, though most of the design of IPv6 and vendor implementations has been done in the U.S. The U.S. was, of course, first in the "land rush" for IPv4 address space, so is not yet in as critical a position as Asia or parts of Europe.

However, IPv6 infrastructure can and is being deployed today in the market on intranets and at access points on the edge of the Internet, in particular in the Asia. Deployment is in the initial stage; users can use commercially supported vendor IPv6 implementations that began shipping in earnest in 2000. IPv6 implementations are available for many major router, server, and client products. These can be used to begin the infrastructure deployment, and can interoperate with existing IPv4 infrastructure elements. Application developers can begin porting IPv4 applications to IPv6, and undertaking innovative new IPv6 ventures (e.g. VoIP, Gaming, and Mobility).

IPv6 deployment initially must take place as a series of infrastructure test beds to assess and determine how to move IPv6 into production and mission critical deployments. The pre-

[10] The IPv6 Forum: http://www.ipv6forum.org/

[11] http://www.internet2.edu/

[12] http://abilene.internet2.edu/

infrastructure environments are critical to the deployment of IPv6. Non-mission critical production IPv6 networks can probably begin before mission critical deployment. Then some IPv6 deployment will happen simply because that technology will not work with the current IPv4 band-aids and limitations, not present in the IPv6 architecture.

2.3. IPv4 and IPv6 integration

While IPv6 offers a bright future for the Internet, IPv4 will not go away overnight. As IPv6 is being deployed today, it is done so alongside IPv4. The first IPv6 deployments began in 1996, from which emerged the U.S. lead 6bone IPv6 test bed network[13], now spanning over 50 countries and 1000 sites. Commercial IPv6 deployments are being prepared now, lead by Japan, and in countries where IPv4 address allocations have been historically lower (in particular in Asia). They have less of a choice than we do in the U.S., and will proceed with some risk to move forward.

A smooth coexistence, supporting integration of IPv4 and IPv6 during the transition is advocated. It is possible for IPv6 site networks to be connected via an IPv4 ISP network, by "tunnelling" the IPv6 data in IPv4 data packets. This will enable customers to leverage their existing investment of today's IPv4 services, while preparing for a seamless transition to IPv6 as additional IPv6 devices come online. The IETF has devised a wide range of transition and integration techniques, enabling providers to pick those methods best suited to them. The Industry is encouraged to continue to aggressively bring the cost and performance benefits of emerging technologies, such as IPv6, online as standards-based solutions.

2.4. *IPv6 U.S. Business and Economic Case*

2.4.1. Current Internet State

Citizens of a "TRUE" information society should be able to communicate electronically with each other and access the information services associated with daily life. The economy would highly leverage e-commerce and therefore be dependent upon information technologies and the security of information technologies. Voting and other government services would be remotely accessible. Educational institutions would provide distance learning services remotely. These statements closely describe today's U.S. society. Unfortunately, the scalability and capability limitations of the current standard IPv4 protocol make this impractical. Only the adoption of the IPv6 protocol for the Internet can bring about a "TRUE" global information society for the benefit of all. To deploy IPv6 there is required a smooth transition to IPv6 and coexistence with IPv4. Most implementations today support a Dual IPv4/IPv6 stack and that will permit several models of IPv6 deployment and adoption and variable rates of that adoption. Many IPv6 deployments are "native", i.e. IPv6 runs concurrently with IPv4 as services, rather than islands of IPv6 connected by means of the existing IPv4 Internet. Such infrastructures are starting to appear, mainly in Japan. It is now timely for the U.S. to take action to gain a competitive advantage.

2.4.2. Technology Leadership

The United States has a long tradition of technological leadership in the international community. This leadership continues to be an important factor in the growth of the U.S. economy and

[13] The 6bone project: http://www.6bone.net/

maintenance of the U.S. as a world super power. Internet technologies, products, and services have propelled much of the U.S. economic expansion since the Internet was commercialized ten years ago. U.S. educational institutions are investing in IPv6 technologies and education to maintain U.S. leadership. IPv4, IPv6, and similar IT technologies are fundamental to many information technologies and markets. The U.S. Government should fund the DoD to support the adoption of IPv6, to provide leadership in support of force transformation and enable new and improved network centric warfare capabilities. Lessons learned in the DoD can be shared with federal, state, and local governments to minimize the impacts of the transition. The DoD can provide technology leadership to develop technologies to collect the IPv6 communications intelligence of adversaries, disrupt IPv6 communications of adversaries, and secure DoD IPv6 communication. IPv6 also provides capabilities to significantly improve the ability of government agencies to share information and collaborate for purposes such as homeland security and defense.

2.4.3. Competitiveness

Many U.S. corporations and organizations will suffer if the U.S. is slow to accept IPv6 and it becomes the Internet protocol standard soon. Many processes, procedure, policies, products and services must be reengineered to support IPv6. That process alone could take several years to complete. Without IPv6, many new and innovative technologies are not practical or deployable to a large scale. These include massive remote sensing & control, home networking, VoIP, and prolific peer-to-peer networking. Educational products will need to be developed. Workers will need to be trained. Competitors abroad have already begun to develop and upgrade their products and services to support IPv6 since foreign markets for this technology are more mature and stable than in the U.S. A number of foreign governments are mandating IPv6 adoption by 2005 and are providing financial and tax incentives.

IPv6 would improve the competitiveness and security of small and medium businesses. Small and medium businesses have difficulty obtaining cost-effective IPv4 resources for an Internet presence. Monthly fees of $40 or more are being charged by some Internet Service Provides (ISPs) for each IPv4 address. With IPv6, a similar monthly fee would provide many times more addresses and therefore improve the Internet presence of small/medium business. The security and robustness of these businesses could be improved by distributing Internet services across many servers and securing each server for its specific service. In this manor, an attack on a company's web server might take down the companies' web presence but would probably not affect the companies email since email and web services are hosted on separate servers.

If regions such as Japan and China move to IPv6, the U.S. on-line business risk a decrease in use; hence revenue loss, if U.S. web sites from corporations can't be reached anymore from these growing regions due to the lack of IPv6 deployment in the U.S.

2.4.4. Security

IPv6 provides an opportunity to create standards based end-to-end security service for all Internet traffic with IPsec. IPsec is mandated in all fully compliant IPv6 products. IPsec is mandated but does not have to be used if not needed. IPsec is available in some cases with IPv4 products but for a number of reasons is not practical for large-scale deployment with the IPv4 Internet. Opportunities exist to produce more secure products and services as long as IPv6 and IPsec are utilized. A growing number of U.S. vendors implement both IPv6 and IPsec in their products and services, but there is still a large number that don't. An additional benefit of IPv6 is source identification. This is a requirement of e-commerce and security in general. Many remote attacks over the Internet today are difficult to counter and prosecute because they originate from behind

NAT devices. NATs allow more than one computer to share a single IPv4 address. Source identification enables authentication, which is a component of IPsec when enabled.

2.4.5. New business opportunities and markets

An IPv6 device connected to the IPv6 Internet is theoretically capable of communications with any other IPv6 device. This enables any-to-any communication, but also favours the creation of community of interest focusing on business services and security. This is true all over the world. Today, only about 8% of the world population has access to the Internet while 20% have access to the telephone network. This is a huge and growing market opportunity. U.S. companies and businesses need to expand the size and diversity of their markets. IPv6 enables a robust and scaleable e-commerce capability and opens new worldwide markets to U.S. businesses. IPv6 enables new applications and services which for one reason or another are not practical or scaleable with the IPv4 Internet. These include but are not limited to remote sensing and control, VoIP, peer-to-peer gaming, mobile internet, and home networking. US vendors and businesses should develop these and other new and innovative applications for the commerical and government markets.

2.4.6. Economic Stimulation

The U.S. Government should consider funding areas of IPv6 Research and Development (R&D) and test beds as a means of jump starting U.S. technical leadership in this important market segment. This would grow the infant U.S. market for IPv6 products and services and encourage further IPv6 adoption in the U.S. IPv6 test beds are considered essential to the deployment process for any organization before IPv6 can reach full production status.

The U.S. government should also consider providing tax incentives to U.S. businesses to accelerate IPv6 product development and adoption. This has been successfully accomplished in Japan. In addition, the U.S. Government should consider advocating an IPv6 compliance date for systems to be IPv6-Ready. But, the immediate need is to get an advertised schedule of IPv6 services elaborated for the adoption of IPv6 in the U.S., and a formal statement by the U.S. Government that IPv6 is critical to the U.S. as an IT technology.

2.4.7. Cost of Adopting IPv6 and eventually retiring IPv4*.*

- Investments in reengineering processes, policies, processes, porting products and services.
- Increased operations cost during the transition period.
- Increased security risks during transition period.
- Increased training costs during the transition.
- Costs associated with the eventual retirement of the current IPv4 protocol standard and legacy systems.

2.4.8. Cost of not Adopting IPv6 and remaining with IPv4.

- Inability to deploy new and innovative information technologies, products, and services.
- Growing isolation from the International community of vendors, customers, partners, allies, and users only connected via the IPv6 Internet.
- Lost revenue, market share, jobs for U.S. corporations and other institutions.
- Inability to fully defend U.S. interests due to the lack of a DoD IPv6 offensive information warfare capability.
- Inability to properly secure network infrastructure and services.

2.5. IPv6 U.S. Social Issues

2.5.1. Culture Shifts

Users have pervasive devices available to them.
Instant access to communication and information improves productivity.
Always-on stresses the demand on address space

Much of the growth of the Internet since the mid 1990s has been possible due to address sharing. As late as 1997, the average consumer in the U.S. spent less than 30 minutes per day connected to the Internet and usually in a single block of time. With the emergence of wireless devices, consumers are more often connected for short bursts to acquire targeted information, which means that addresses become more statically associated with a user, or managing the churn in the address pool becomes a significant operational challenge. In addition, new applications such as Microsoft's Windows Messenger (tm) expect to be 'callable' for direct peer-to-peer audio/video correspondence, which leads to the need for static association of the address for the devices, which it runs on. Consumer product manufacturers are actively enabling networking on their entire product line. With the resulting simplified device interconnect; powerful new applications will be enabled. These applications are no more predictable than face-to-face meetings in Asia, North America, and Europe over three days would have been prior to the invention of air travel. In any case, the vast number of new devices on the network will seriously impact the demand for address space. Rather than multiple consumers sharing a single address over time, each consumer will now have multiple devices needing addresses, many of which will require a static mapping to enable the embedded application to be contacted by clients or peers.

2.5.2. Have and Have-not's Scenarios

Education

We only need to look at the current IPv4 Internet to understand the impact of have vs. have-not's. For example, North America has been allocated about 30% of the IPv4 address space for non-defense purposes. This amounts to about half of the currently allocation from the global pool. As a result of early inclusion, Higher Education institutions in the U.S. are generally free to explore the potential of new applications. At the same time, most primary and secondary institutions were connected to the Internet at a later time and as a result are left with the need for sharing a small address pool (sometimes as small as a single address). This means they are only able to participate in a subset of the potential new applications. Even for existing applications, they are unable to use voice or video messaging to communicate directly between peers at different institutions.

Medical

Over the history of mankind, advances in medical care can be directly linked to sharing of information and best practices. in the current era where instant global distribution of detailed images and vital statistics is technically possible, the impediment to significant new advances is the complexity of the process to accomplish that task, which is in turn directly related to the complexity of the network. This complexity distracts the researchers and practitioners from their primary task, which is both unfortunate and unnecessary.

While it is not possible for technology to solve policy issues, it can simplify managing the policy as defined. What technology must not do is complicate the process of that management. An example would be the decision about who has access to sensitive information is a policy issue, but the ability to identify and authorize access in a distributed manner is a place where technology can simplify.

The state of IPv4 with NAT Internet requires using intermediaries to transfer information between the authorized end parties. These intermediaries require policy authorization from both ends, which slows the process and today generally requires human intervention. The result of including a third party is that timely distribution of information is subject to prior arrangements, which will seriously impact information distribution in times of emergency.

Employment

As the percentage of the labor pool that is comfortable with use of computers and the Internet grows, productivity will continue to increase. Those productivity gains will be capped by the limitations on information flow that IPv4 NAT imposes on applications. In the parts of the world where IPv6 is embraced, there will be no such caps. New applications will continue to improve the accessibility and richness of detail, enabling those parts of the global workforce to outstrip the productivity of their stalled peers.

Additional employment benefits would include the developers of the new suite of applications and service providers designed to simplify business and personal lives. We are already seeing some of this in Japan, where location awareness is coupled with live access to a current yellow-pages service to allow finding the nearest service of a particular type, or finding the path to a particular business location. In North America, Hertz provides a derivative of this in its 'Never Lost' (tm) service, but the offline database quickly becomes stale and ends up leading the user to a long since closed business.

2.5.3. U.S. Have-Not Potential

A "TRUE" INFORMATION SOCIETY MUST BE CAPABLE OF INTERCONNECTING IT'S CITIZENS AND ENABLE THEIR ACCESS TO THE REMOTE INFORMATION NEEDED IN ALL ASPECTS OF LIFE, BUSINESS, SECURITY, ETC. THIS TRULY CAN'T BE DONE WITH IPV4 BUT CAN WITH IPV6.

The China Ministry of Education has grasped this and find themselves in the position of have-not with respect to the Internet The education network in China serves 320 Million students and claim that they could use 72 /8's if they could get them. All of China (education and commercial) currently have just over 1 /8

North America has a total population of less than 300M ARIN manages 75 /8's.

India has a comparably large population, and currently has less than 1 /8.

Once those large segments of the global population move out of necessity to IPv6, the U.S. will be in the position of a 'have not'., if the U.S. has not adopted IPv6. This is not an ideal situation for the U.S. from a business perspective either; hence, the social impact has an impact on U.S. economics.

2.6. IPv6 U.S. Political Affect

The U.S. future leadership in Internet technologies is challenged by the earlier adoption and time-to-market of next generation internet protocols (IPv6) by other nations seeking and officially declaring to become the most advanced IT nations in the world (Japan in particular) substantiated by 2005 Japan investments, tax incentives, and Japanese industry aggressiveness. China will have the largest-scale IPv6 production network in the world by 2005 emulating their leadership in mobile phone network (no.1 spot with 180 Million users vs. 150 Million for the U.S.)

The U.S. economy will pay a higher last-minute (similar to a flag-day) transition price if it does not take an early smooth and graceful integration approach to IPv6.

IPv6 will create "Winners and Losers" around the world, with probably a majority of losers in the U.S., unless IPv6 is adopted as a network infrastructure and a transition defined.

The Internet is one of the U.S. top exports in the world. Now, will the U.S. addopt IPv6 too? The net impact of the Internet on the GNP is way too high to gamble with it.

The U.S. will be confronted for the first time in its history with the risk of an aging technology causing the U.S. to be a trailing IT nation. The impact will be felt in the flight of capital seeking innovative technologies with future potential either in Asia or in Europe.

When the Internet .com bubble burst it was painful, but that pain will pale by creating a YV4 (no IPv6 but only IPv4 with NAT and other band-aids) problem, by not embracing IPv6 as the clear technology to move towards now in the U.S. Not doing this will cause the U.S. economic and political ramifications that will have a cost far greater than the funding and leadership time from the U.S. Government to be a catalyst to embrace IPv6 in the U.S.

We also do not want to be without what the bad guys have and not be able to interoperate with our friends. This would also put us at a clear political disadvantage that is classic in the Machiavellian model, where our friends must compromise to support us and our enemies can use our lack of capabilities to exploit us to win over our friends.

3. The road forward to IPv6

The future of network services lies in convergence, of voice, video and data to a unified IP architecture. Such integration will have significant benefits, and open up new opportunities for business and to offer services for residential users in the U.S. For example, the combination of VoIP, wireless LAN and SIP (Session Initiation Protocol) technologies could have a significant business impact: In the near future, a user will be able to run VoIP through an IP-enabled handset over a wireless local area network to a local SIP gateway which communicates via IP to another SIP gateway at the recipient's site. In such an environment there is no conventional "phone call" that has to be billed and paid for; the communication is purely IP-based.

With IPv6 everywhere, mobile users can get a seamless Internet experience and wireless operators will be just another type of ISP, albeit one that carries a significant proportion of voice traffic. Users can connect to whatever web sites they choose, log in to their corporate intranet (and be reached from that network), do VoIP, get streaming audio/video, and use whatever network applications they need. They will not be constrained to the limited set of value added network

services the wireless operators will offer through their own portals. As a base protocol for a converged network, IPv6 is a significant enabler.

In the initial phase of GPRS/UMTS with a few millions of terminals, IPv4 is a perfectly reasonable solution, but to offer a scalable service that will cater for hundreds of millions of terminals, IPv6 is an imperative. By rapidly adopting IPv6, the U.S. Mobile industry has a unique chance to investigate and pioneer the future, together with all other Internet related players, whether they are fixed, cable, xDSL, ISPs etc. In so doing they will acquire a competitive edge which can be explored and exported.

There should be no reason for address space exhaustion in IPv6, and no need to resort to expensive and inefficient, non-scalable workarounds like schemes based on NAT. With simplified network renumbering methods, IPv6 will make network mergers easier to achieve, and the availability of the global address space of IPv6 will reduce the pressure for sites to use local private addressing and NAT (which can cause problems when two sites merge that use the same private IP address space).

While wireless operators may be the leading IPv6 adopters, IPv6 will also reach into all aspects of social life – the home, the workplace and schools and universities. It will enable end-to-end user services that have as big an impact on society as the business services will have on commerce. However, IPv6 is only an enabler. For the full social benefit broadband access to the home must become commonplace; at present xDSL and Cable Modem deployment is in its infancy, but combinations such as xDSL with wireless LANs in the home will – in conjunction with IPv6 addressing – open up avenues for consumer-electronics manufacturers and household appliance vendors to offer innovative new services.

While end-user and business requirements for advanced network services expand exponentially, IPv4 will not be able to cope. In the IPv4 world severe problems and limitations exist with band-aids such as NAT, and although these band-aids and extensions may prove valuable in the very near term, they ultimately will limit connectivity, interoperability, and performance in the long term for enterprises that are increasingly network-dependent.

As the transition to IPv6 takes place progressively and at different speeds by different industrial sectors, the need will arise to develop IPv6 transition and integration guidelines that will recognize that the coexistence of IPv4 and IPv6 will last many, many years, that the phasing out of IPv4 will be soft and gradual and that there will not be a magic date imposed on any particular industry (as was the case with Y2K) to move to IPv6, but rather that there will be an incentive to act before it becomes *too* late and *too* expensive.

It is now widely recognized – as exemplified by the position statements of the vast majority of router, host and mobile operators - that IPv6 will become critical to the operations and continued efficiency of day-to-day business activities in the new economy, and that there is ultimately no substitute for IPv6 when emerging multimedia, interactive, and transaction-oriented network applications start requiring high levels of connectivity.

The requirement for IPv6 implies a need for coordinated trials and tests of new IPv6-enabled devices – routers, hosts, PDAs, etc – which are more likely to succeed via both harmonization of standards and readily available interoperability events (such as those offered by University of New

Hampshire[14], TAH[15]I, and ETSI[16]). The trials and roadmap processes are critical for IPv6 systems developers and implementers.

For IPv6-enabled services to be deployed in a timely manner, it is of key importance to structure, consolidate and integrate U.S. efforts on IPv6, to ensure that the necessary base of skilled human resources are available, that the research effort is sustained, that standards and specifications work is accelerated and that all sectors of the new economy likely to be impacted by IPv6 are fully aware of potential benefits accruing from the adoption of IPv6. U.S. Government funding towards advanced test bed deployment should be made available, and advertised appropriately. Where secure networks require cryptographic key exchange, the avenues for PKI deployment should be explored.

A concerted effort is hence required that will enable the competitiveness of the U.S. to be strengthened. Standards activity needs to be harmonized, while application developers, and organisations tendering for new IP-based services, should consider the IPv6-ready status and future proofing of the services they intend to deploy. Regulation frameworks need to be investigated, such that IPv6 deployment is allowed to proceed unhindered via natural market forces.

It is expected that the NAV6TF activities should continue, and that they should be linked to a U.S. IPv6 Task Force initiative, to further the determination of best practice for future IPv6 deployment.

4. Recommendations

In light of the above, a series of recommendations pertaining to the implementation of IPv6 by all relevant ICT sectors in the U.S. is given below. These recommendations are seen as key measures to be taken to accelerate the pace of the introduction of IPv6 in the U.S. on a wide scale.

4.1. Actions for U.S. Government

- A call to application providers to support a Dual IPv4/IPv6 stack to begin to deliver IPv6 services coexistent with IPv4. Though the goal should be that applications are agnostic regarding IPv4 or IPv6.
- Determine funding required by the DoD to begin fast track towards IPv6 adoption.
- Increase U.S. support towards the integration of IPv4 and IPv6 in the networks and services associated with the public sector, in the context of public applications requiring the use of new Internet next generation tools and technologies. The integration of IPv6 in existing e-government, e-learning and e-health services and applications towards IPv6, will notably offer users greater reliability, enhanced security and privacy, and user friendliness,

[14] http://www.iol.unh.edu/

[15] http://www.tahi.org/

[16] http://www.etsi.org/

in a more open and dynamic environment. IPv6 future-proofing should be considered in application procurements

- Establish and launch educational programs on IPv6 tools, techniques and applications, so as to significantly improve the quality of training on IPv6 at professional level, and create the required base of skills and knowledge.
- Promote the adoption of IPv6 through awareness raising campaigns and co-operative research activities, by small and medium size enterprises, ISPs, wireless service providers, and network operators, so as to educate the stakeholders, boosting their technological know-how and strengthening their ability to operate on a U.S. if not International basis.
- Continue to stimulate the wide spread use of Internet across the U.S. and encourage the integration of IPv6 through the creation of a favourable, stable and government support programs and by avoiding fragmented approaches, mandatory deployment time-lines or excessive fees. Broadband access to the home and to small and medium size enterprises is a key requirement to maximize the benefit of future end-to-end, converged network services.
- Strengthen the financial support towards national and regional research networks, with a view to enhance their integration in U.S. IPv6 wide networks and increase the operational experience on novel Internet services and applications based on the use of IPv6. It should be understood that the move towards native IPv6 is a major step for the U.S. to keep its dominant position in the Network Communications Industry.
- Provide the required incentives towards the development, trials and testing of native IPv6 products, tools, services and applications in the new economy sectors such as consumer electronics, telecommunications service provisioning, IT equipment manufacturing, construction, transportation, public education and health, banking, insurance and trade.
- A formal statement or release from the PCIPB and/or from the President regarding IPv6 within the context of technology evolution as was done in Europe and Asia would be very beneficial as a catalyst for IPv6 momentum in the U.S. within government, DoD, and in the private sector. IPv6 benefits all of three of those environments as a national interest.
- Establish a National IPv6 Council tasked with:
    - ➢ The assessment, at national, state, and local municipality level, of current developments and rate of adoption with IPv6, as well as with the formulation of guidelines and dissemination of best practices relating to the efficient transition towards IPv6. The IPv6 Council should be guided by the imperative need for harmonization and by the economical benefits achievable through the wide spread IPv6 technology in all ICT sectors and should duly take into account the requirements for an all inclusive information society as well as the digital divide dimension.
    - ➢ Developing measures aiming at the alignment of IPv6 integration schedules favouring a cohesive IPv6 adoption and ensuring that the U.S. gains a competitive advantage on the Next Generation Internet.
    - ➢ Ensuring the active participation of national experts in the work of U.S. and International standards and specification bodies tasked with IPv6 matters.
    - ➢ Drawing the attention of potential IPv6 systems or application developers to funding opportunities available through a U.S. research and development incentive.
    - ➢ Lead from the Council IPv6 and Security Interest Groups at the State and Local municipality levels for consumers to access for support and education.
- Government Web sites that are IPv6 enabled for IPv6 users to access.

4.2. Actions for U.S. Industry

- Fully participate in the R&D activities to be supported in the context of a U.S. IPv6 program, with a view to put in place an integrated and structured set of IPv6 activities, covering the full range of IPv6 aspects, from basic research through the development of service enablers and associated software suites, to the large scale trialling and testing of IPv6 features, for a diversity of applications, in a U.S. wide environment.
- Actively contribute towards the acceleration and alignment of on-going IPv6 work within standards and specifications bodies and urgently develop key guidelines permitting the rapid integration of IPv6 infrastructures and interoperability of IPv6 services and applications, especially in the context of IPv6 wireless mobile communications, but also for VoIP and areas such as home networking.
- Where appropriate, develop roadmaps for the design, development and deployment of IPv6 services, equipment and networks, to include technologies such as AAA, DNS, xDSL, etc.
- Support and fully participate in interoperability events organized notably by the IPv6 Forum in conjunction with the NAV6TF, which provide opportunities for the collective testing of different IPv6 implementations and applications.
- Contribute actively to the work of the NAV6TF, and ensure the collective increase of IPv6 awareness and permit its members to individually derive their own perspective of the IPv6 business case and their own IPv6 integration strategy.
- Devote efforts towards the establishment of a U.S. wide, vendor independent, training and education program on IPv6.
- Consider in their manufacturing plans that the majority of mobile devices, and a growing number of household and consumer-electronic devices will require some form of IP connectivity and that the simplest way to offer these devices the fullest range of services is to have a unique globally routable IPv6 address available for all network-enabled components.
- Seek to develop innovative IPv6-enabled devices, e.g. biometric security devices, "IP in a chip" embedded systems components, in-car sensor devices. Seek to design and implement innovative peer-to-peer applications where appropriate, e.g. peer-to-peer gaming in the entertainment industry.
- Take early steps to obtain adequate IPv6 address allocations and where appropriate, and to either accelerate the offer of IPv6 capable services or consider on a priority basis how best to rapidly evolve towards IPv6.
- Address the multi-vendor interoperability issues impeding the wide-scale deployment of PKI and to conduct extensive trials with IP security in IPv6 and the parallel implementation of a PKI.

4.3. Action for U.S. Industry Associations

Recognized Standards Bodies:

- Standard Development Organisations (ITU, 3GPP/3GPP2, ETSI, IETF, IEEE, etc),
- Industry Forums: (3G.IP, ASP Consortium, DSL Forum, IMTC, IPv6 Forum, MPLS Forum, MSF, MWIF, OIF, OMG, SDL Forum, TM Forum, TOG, UMTS Forum, World Collaboration CPR, etc) and industry Associations (EICTA, ETNO, EURESCOM, EUCONTROL, GSM Europe, ISP associations, White Goods Associations, etc),
- coupled with an ITU-T initiative[17]

[17] ITU-T initiative: http://www.itu.int/ITU-T/tsb-director/forum/

It is critical that all standards-related initiatives and activities are harmonized for the timely and efficient introduction of common, interoperable IPv6 deployments, being lead by Tasks Forces under the IPv6 Forum (like the NAV6TF).

- Consider opportunities for partnerships on IPv6 projects for joint development/collaborative work (within and outside the U.S.)
  - Common standards
  - Education and knowledge exchange
  - Market intelligence
  - Marketing and promotion
  - Profiling and implementation agreements
  - Interoperability and conformance testing
- Feedback from market and forums to Standards Development Organizations for:
  - Requirements
  - Finished standards
  - Gaps analysis
  - Time-to-market Requirements

Examples of activities to encourage are collaboration between IETF, 3GPP and 3GPP2 to join forces with the IMT2000 initiative, studies of ENUM requirements, IPv6 address assignment policy discussions between the Regional Registries, and feedback to the IETF/3GPP on Mobile IPv6 requirements.

4.4. Action for Academia and R&D

- Assure IPv6 is part of learning curriculum for students and interns. It is important that institutions of learning at all levels begin to add IPv6 to any education on networking, the Internet, and Security.
- Adopt IPv6 as the network layer for research of new paradigms and models. It is important that R&D in academia begin to use IPv6 as the network layer in the assumptions, abstraction, and implementation of new technology research.
- Transition to IPv6 as the protocol for communications within the network campus. Academia as other parts of the U.S. society need to begin a transition to IPv6 and stronger security models for faculty, students, and researchers.

4.5. Action for Individuals

- Learn and understand the security guidelines as suggested by the PCIPB Cyber Security Document. The many guidelines, pointers, and forums provided by the Cyber Security document can be learned by simply going to a web page or a site for education. Individuals need to educate themselves when possible from this information.
- Ask your provider for IPv6 addresses for your home, business, or network function. Once you understand the benefits of IPv6 go to your ISP or provider for your network and request IPv6 address space and applications from them.
- Determine which products can support IPv6 in your environment. Every piece of network software and hardware (Firewall, Print servers, etc) need to eventually support IPv6.
- Join Cyber Security learning sites and IPv6 learning sites. Join sites to be set up where you can learn more about IPv6 in addition to securing your environment and how to protect your privacy.

- Send mail to your software and hardware providers for your individual network components to support IPv6. If you cannot get IPv6 on your software or hardware as required request that you want it from the vendors of those products.
- Request from your provider the ability to perform peer-to-peer application enablement and security, without Network Address Translation. Inform your provider that you would like to enable true peer-to-peer communications and in a secure manner using IPv6 from your home, business, or other network functional location (e.g. Mobile Phone, PDA, IP Tablet).
- If you are unable to access IPv6 in a reasonable time frame and products inform your Congressman and Senator, IPv6 Web Sites, and IPv6 Interest Groups through email. If you cannot get responses to your requests you need to complain and inform your public officials representing you and interests groups who are supporting the adoption of peer-to-peer secure communications through the use of IPv6.

5. Glossary

3G	Third generation mobile communications system.
ADSL	Asynchronous Digital Subscriber Line. Offers high-speed connectivity to the Internet over existing copper telephony wiring.
Always-on	Devices remain connected to the Internet when powered up (e.g. ADSL), rather than establishing temporary connections (e.g. dialup). Because devices need a unique IP address continuously, the rise in always-on devices demands more IP address space.
APNIC	The Asia-Pacific regional registry (equivalent of RIPE NCC).
ARIN	The Americas regional registry (equivalent to RIPE NCC).
Broadband access	High-speed Internet connection technologies, e.g. xDSL and cable modems
Cable modem	High-speed Internet access via cable television service line.
Client-server	A communication model where connections are initiated one-way, from clients to servers.
DNS	Domain Name Service. Used to map between Internet domain names (e.g. www.ipv6forum.org) and IP addresses (for use by the network).
End-to-end model	Devices communicating on the Internet do so directly without any intervening translation devices; such devices fate-share their connection.
GPRS	General Packet Radio Service. Allows Internet access from a mobile device running IP(v4) over the wireless telephony network.

IETF	Internet Engineering Task Force. Define global Internet standards,
I-Mode	Popular interactive Internet telecommunications system in Japan
Interoperability	The ability of two devices, usually from different vendors, to work together.
IP	Internet Protocol. The underlying technology by which all Internet data communication is carried out.
IPv4	Internet Protocol version 4. The current protocol.
IPv6	Internet Protocol version 6. The new protocol.
IPv6 prefix	A block of IPv6 addresses that may be used by an ISP or a site network
ISP	Internet Service Provider. Provides network/access services.
ITU	International Telecommunications Union.
LAN	Local Area Network. A local data network.
NAT	Network Address Translation. Allow multiple computers to connect to the Internet via a limited number of global IPv4 addresses. Restricts end-to-end principle of the Internet.
PDA	Personal data assistant, e.g. a handheld PC.
PKI	Public Key Infrastructure. Used to exchange keys used for data encryption.
Peer-to-peer	Communication model in which client devices may communicate directly, initiating the data exchange in either direction, without a server system.
RFC document	The document format used by the IETF to describe Internet standards.
RIPE NCC	The organisation (regional registry) that assigns IPv6 top-level prefixes in Europe.
SIP	Session Initiation protocol. Used for VoIP.
Static IP address	An IP address allocated to a device that does not change, thus allowing the device to be consistently found at that address. Important when running Internet services to that device.
Tunnelling	Using one version of IP to carry (deliver) data from another version of IP, currently most usually IPv6-in-IPv4 to link two IPv6 networks over the commodity IPv4 Internet.

UMTS	The third generation mobile communications system.
VoIP	Voice over IP. Using an IP network to carry voice data.
Wireless LAN	A local network communication over an air interface. The current 802.11b standard allows 11Mbit/s maximum throughput over a wireless LAN.
xDSL	The set of Digital Subscriber Line technologies, including ADSL.