White Paper

IPv6-Empowering Generation Next IP-Communications

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Abstract:

IPv6 networks becoming more reality and commercial deployments happening around the globe, there have been tremendous movements in emerging towards the direction and common infrastructure based on Internet protocol version 6. In this paper we provide the comprehensive wave towards IPv6 networks its standards, business drivers and applicability areas along with a business case and strategies for deployment.

Table of Contents

IPV6 BACKGROUND AND EVOLUTION

The Internet Protocol was introduced in the ARPANET in the mid-1970s. The version of IP in common use today is IP version 4 (IPv4). Although several protocol suites (including Open System Interconnection) have been proposed over the years to replace IPv4, none have succeeded because of IPv4's large, and continually growing, installed base. Nevertheless, IPv4 was never intended for the Internet that we have today, either in terms of the number of hosts, types of applications, or security concerns.

In the early 1990s, the Internet Engineering Task Force (IETF) recognized that the only way to cope up with these changes was to design a new version of IP to become the successor to IPv4. The IETF then formed the IP next generation (IPng) Working Group to define this transitional protocol to ensure long-term compatibility between the current and new IP versions, and support for current and emerging IP-based applications.

Work started on IPng in 1991 and several IPng proposals were subsequently drafted. The result of this effort was IP version 6 (IPv6), described in RFCs 1883-1886; these four RFCs were officially entered into the Internet Standards Track in December 1995. Table-1 below shows IPv6 Evolution paths.

August, 1990	Projected exhaustion of Class B address space by Mar 1994
July, 1992	IETF issues formal call for IPng proposals
July, 1993	IESG takes on responsibility for making IPng recommendation
August, 1993	IETF area formed to consolidate IPng activities
July, 1994	IPng recommendation(RFC 1752) is SIPP with 128-bit addresses

Table -1

IPV6 FEATURES AND ADVANTAGES

IPv6 is designed as an evolution from IPv4 rather than as a radical change. Ease of transition is a key point in the design of IPv6. IPv6 is designed to interoperate with IPv4. Specific mechanisms (embedded IPv4 addresses, pseudo- checksum rules etc.) were built into IPv6 to support transition and compatibility with IPv4. According to the IPv6 specification, the changes from IPv4 to IPv6 fall primarily into the following categories:

- **Large Address Space**

The IP address size is increased from 32 bits to 128 bits in IPv6, supporting a much greater number of addressable nodes. The large address space of IPv6 has been designed to allow for multiple levels of sub-netting and address allocation from the Internet backbone to the individual subnets within an organization.

- **Efficient and hierarchical addressing and routing infrastructure**

IPv6 supports large hierarchical addresses which will allow the Internet to continue to grow and provide new routing capabilities not built into IPv4. It has anycast addresses which can be used for policy route selection and has scoped multicast addresses which provide improved scalability over IPv4 multicast. It also has local use address mechanisms which provide the ability for "plug and play" installation.

- **New Header Format**

Some IPv4 header fields have been dropped or made optional to reduce the necessary amount of packet processing and to limit the bandwidth cost of the IPv6 header.

- **Improved Support for Extensions and Options**

IPv6 header options are encoded in such a way to allow for more efficient forwarding, less stringent limits on the length of options, and greater flexibility for introducing new options in the future.

- **Better support for QoS**

A new quality-of-service (QOS) capability has been added to enable the labelling of packets belonging to particular traffic "flows" for which the sender requests special handling, such as real-time service.

- **Built-in security**

Extensions to support security options, such as authentication, data integrity, and data confidentiality, are built-in to IPv6.

- **Stateless and Stateful address configuration**

To simplify host configuration, IPv6 supports both stateful address configuration, such as address configuration in the presence of a DHCP server, and stateless address configuration (address configuration in the absence of a DHCP server). With stateless address configuration, hosts on a link automatically configure themselves with IPv6 addresses for the link (called link-local addresses) and with addresses derived from prefixes advertised by local routers.

- **New protocol for neighboring node interaction**

The Neighbor Discovery protocol for IPv6 is a series of Internet Control Message Protocol for IPv6 (ICMPv6) messages that manage the interaction of neighboring nodes (nodes on the same link). Neighbor Discovery replaces the broadcast-based Address Resolution Protocol (ARP), ICMPv4 Router Discovery, and ICMPv4 Redirect messages with efficient multicast and unicast Neighbor Discovery messages.

IPV6 DRIVERS

Below mentioned are the some of the drivers and applicability areas of IPv6:

a) Mobile IP:

- Mobile nodes must be able to move from router to router without losing end-to-end connection
- Home address: Maintains connectivity
- Care-of address: Maintains route-ability
- Mobile IP will require millions or billions of care-of addresses

b) Peer-to-Peer Networking

- Every host is a client and a server
- That is, a consumer and a producer
- The Internet has evolved into a “Services in the Middle” model
- Information and services flow primarily toward the user
- Present online gaming mostly client/server

c) Internet-Enabled Devices

- Internet-enabled appliances

  1. Dual Mode Handsets
  2. IP enabled Digital Cameras
  3. Digital Network Refrigerator

- Internet-enabled automobiles

  1. Already available in many luxury cars
  2. Interesting research being conducted in Japan

- Smart sensors
- Bioelectronics

BUSINESS CASE

The details of technology are not interesting to most people, but the potential applications are interesting. However, forward-thinking people in industry are focused on the business case and the applications that IPv6 will deliver in the future.

As next-generation Internet technology is deployed, the advances in security and quality of service necessary to support advanced telemedicine at any broadband-equipped location will become readily available. Medical diagnosis and treatment will benefit from a global pool of linked health care expertise.

One of the most exciting developments is the vast number of mobile medical devices that will be available. IPv6 will allow the medical community to create a system of sensors and health screening devices that can be used anywhere at any time. Patients with known conditions will be remotely monitored and tested, and remote mobile medical networks will be quickly set up in response to emergency situations.

Federal agencies have already begun planning and using efficiency-enhancing technologies such as radio frequency identification in the supply chain and are exploring how IPv6 can transform the business of government. Applications such as logistics tracking, cargo container screening and cradle-to-grave product tracking will benefit from IPv6’s advanced capabilities.

Conserving energy and alleviating traffic congestion have long been goals of government. But in recent years, living and working “greener” has taken on new importance. Many IPv6 applications will help federal agencies and their employees become more environmentally responsible. Building IPv6-based sensor and control networks will provide as much as 30 percent greater efficiency in managing and operating buildings. The use of IPv6 to support teleworking and secure remote access will enable agency officials to travel less and work from home or close-in telework centers.

The advanced security and mobility capabilities enabled by IPv6 will help organizations get the right information to the right people at the right time during emergencies, without compromising sensitive data. IPv6 will provide the necessary tools for agencies to continue operating during disasters and to improve their overall mission effectiveness.

The transition to IPv6 could be viewed as an extremely technical — even esoteric — exercise. But the advanced IPv6 applications developed and deployed in the next 30 years will yield real-world benefits. They include better access to telemedicine, increased readiness to respond in emergency situations and more efficient supply chain management, to name a few. With IPv6, government can improve the quality of public services via enhanced security, mobility, access to information and ability to collaborate.

RFC’S & STANDARDS

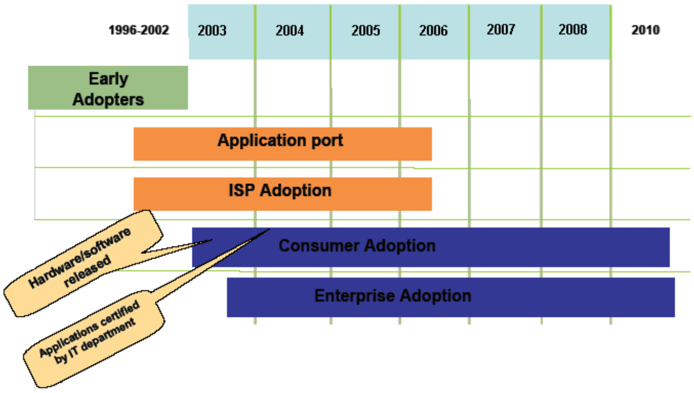
- RFC 1981, *Path MTU Discovery for IP version 6*
- RFC 2373, *IP Version 6 Addressing Architecture*

- RFC 2460, *Internet Protocol, Version 6 (IPv6)*
- RFC 2461, *Neighbor Discovery for IP Version 6*
- RFC 2462, *IPv6 Stateless Address Auto configuration*
- RFC 2463, *Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6*
- RFC 2464*, Transmission of IPv6 Packets over Ethernet Networks*
- RFC 2472, *IP Version 6 over PPP*
- RFC 2474, *Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers*
- RFC 2675, *IPv6 Jumbo grams*
- RFC 2767, *Dual Stack Hosts using the "Bump-In-the-Stack" Technique (BIS)*
- RFC 2878, *PPP Bridging Control Protocol*
- RFC 2893, *Transition Mechanisms for IPv6 Hosts and Routers*

DEPLOYMENT STRATEGIES

- Deploying IPv6 over IPv4 tunnels: These tunnels encapsulate the IPv6 traffic within the IPv4 packets, and are primarily for communication between isolated IPv6 sites or connection to remote IPv6 networks over an IPv4 backbone. The techniques include using manually configured tunnels, generic routing encapsulation (GRE) tunnels, semiautomatic tunnel mechanisms such as tunnel broker services, and fully automatic tunnel mechanisms such as IPv4-compatible and 6to4.
- Deploying IPv6 over dedicated data links: This technique enables isolated IPv6 domains to communicate by using the same Layer 2 infrastructure as for IPv4, but with IPv6 using separate Frame Relay, separate optical links, or dense Wave Division Multiplexing.
- Deploying IPv6 over MPLS backbones: This technique allows isolated IPv6 domains to communicate with each other, but over an MPLS IPv4 backbone. Multiple techniques are available at different points in the network, but each requires little change to the backbone infrastructure or reconfiguration of the core routers because forwarding is based on labels rather than the IP header itself.
- Deploying IPv6 using dual-stack backbones: This technique allows IPv4 and IPv6 applications to coexist in a dual IP layer routing backbone. All routers in the network need to be upgraded to be dual-stack with IPv4 communication using the IPv4 protocol stack and IPv6 communication using the IPv6 stack.

IPv6 ADOPTION & TIMELINES –Fig-1



PUBLIC POLICY FACTORS

Migration to IPv6 is more than a technology problem, however. It involves policy issues concerning Organization's role in moving the Organization toward IPv6, as a national standard which presumably will advance commerce and make the Organization more competitive. These decisions need to be made at the executive level, and do its best to implement it.

BUSINESS IMPLICATIONS

The following points give an analytical business model of the Internet IPv6 protocol, focusing on the intrinsic technical properties of the protocol.

- The challenge in making IPv6 ubiquitous is that we need, say, 10,000 people to dedicate themselves for a year or two to make new applications, or to port current applications, or to add IPv6 to devices that aren't usually associated with the Internet (like cars, kitchen appliances, RFID tags, mobile phones, etc.). To motivate an army of developers to drop what they doing and start (awkwardly at first) to make v6 apps these developers will have to have stories that will make them think that there is a potential payoff down the road.
- The migration to IPv6 will be an evolutionary process. Users will not abandon their existing reliable IPv4 networks overnight; instead, a prolonged transition period can be expected. Many industry pundits (including DoD experts) predict that this period could easily last five to ten years. During this transitional stage, a whole new set of challenges will emerge. Routers, switches, servers, and sometimes even end-users' workstations will need to handle double duties - supporting both IPv4 and IPv6.
- Up until now, most IPv6 testing has occurred in some lab environments and has

focused on the fundamental conformance, performance, scalability and functional aspects of the IPv6 protocol. However, the initial deployment scenarios for IPv6 will not consist of pure IPv6 networks; they will probably be unwieldy hybrids that include both versions of IP. The next phase of IPv6 testing must address these mixed environments in order to ensure the success of the next decade of networks.

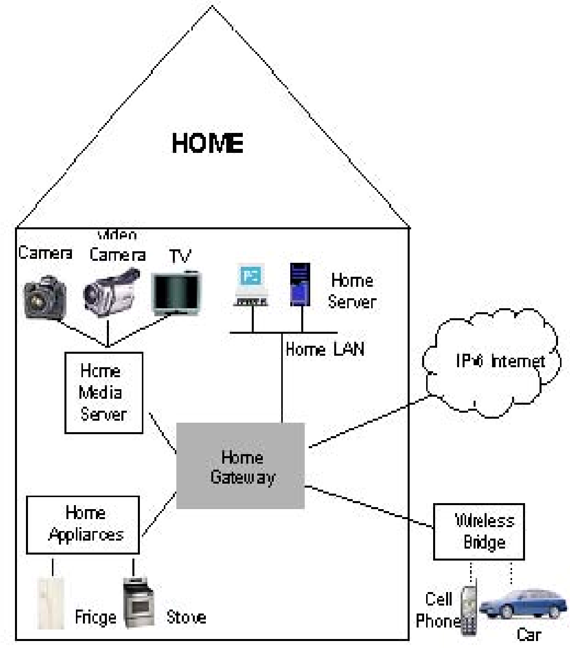
- Equipment vendors are in a constant struggle to keep up with the massive number of changes in the industry’s RFCs and drafts. Discontinuous changes abound, such as the transition from IPv4 to IPv6, which requires a complete code re-write in some cases. How is an equipment vendor supposed to keep up? Vendors face a number of choices. Hiring ever increasing numbers of R&D staff, unfortunately, is not an option in our new age of cost- conscious, rapid time-to-market development mandates. Rather than outsource overseas, why not try to outsource “in house?”

NETWORK EVOLUTIONARY PATHS

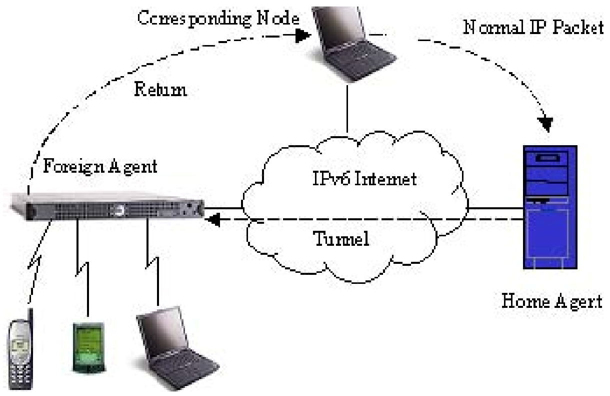
New technologies such as IEEE 1394, 802.1a/b/g and Bluetooth for both mobile and home use are being deployed in large numbers. As these processors make their way into more and more devices, it is ever more likely that these devices will be network ready. Televisions are being produced with embedded cable connectivity, as well as advanced networking ability as part of the Digital Living Network Alliance. Mobile telephones use this technology to take the place of remote controls in selecting programming for viewing. Content is distributed throughout residence using centralized gateways that store and forward audio and video data. That same data is then available via an Internet connection to household members as they travel on business. The average consumer has no desire to configure multiple devices, in multiple locations, using multiple tools. Simplicity has been proven to be key to success in the consumer market.

Therefore, devices are coming hardwired for IP connectivity, because consumers are not willing to perform these complex management tasks. The solution is to embed IPv6 technology into new devices. IPv6 offers such a large address space that it is likely devices and appliances of the future will contain IPv6 network processors and be stamped with IP addresses that act as serial numbers. Imagine the Refrigerator that has sent you an email telling you it ordered replacements for the menu items you selected and put in the microwave before leaving home. Imagine the microwave then sending a reminder that you have programmed dinner for seven this evening, and asking if you have managed to avoid that last-minute meeting, so it can begin the heating program.

And then imagine sending a reply back to that microwave from your automobile telling it to accelerate things by a half-hour, because you've managed to leave the office early. Home networking will drive the use of IPv6, both in residential gateways and appliances. Refer Fig-2 below appliances on IPv6 networks & mobility.



Mobile computing from below Fig-3 is one of the most talked about technologies. With the explosion of mobile devices that need always-on connectivity, it is imperative that protocols be developed that allow for IP connectivity regardless of the physical location of a device. The problem is that IP was not meant for roaming devices. The answer to this problem was the development of the mobile IP standard in RFC2002 [IP Mobility Support]. This standard defined the concept of a Home Agent (HA) and Foreign Agent (FA), together with a Mobile Node (MN), And Care-of-Address (COA). The basic concept as shown in the diagram below, is that each MN has a HA. When a MN goes away from the HA, it registers with an FA. The FA then contacts the mobile nodes HA. When a Corresponding Node (CN) wishes to contact an MN, it sends the data packets to the HA. The HA then tunnels the packets to the FA, which delivers the packets to the MN.



Since RFC2002, there have been additional specifications in the IETF updating and expanding the role of mobile devices in IP networks (e.g.: RFC2290 [Mobile-IPv4 Configuration Option for PPP IPCP], RFC2794 [Mobile IP Network Access Identifier Extension for IPv4], or RFC3220 & RFC3344 [IP Mobility Support for IPv4]). These additions provide for the enhanced security and protection of session-related data to and from these devices.

While the IETF has been concerned with Layers 2 and above in the wireless arena, the IEEE has been fleshing out the set of standards for wireless communications not only protection, but performance, as well. Wireless networking has grown from a LAN extension application to regional and long-haul services in areas where it is impractical or undesirable to implement wired infrastructure. Geographies and subscribers unimagined by the intrepid ARPA pioneers are getting connected to a global IP infrastructure, straining the IPv4 address space even further. Because these protocols are so new and will incorporate a potentially huge number of devices with embedded IP addresses, it is very likely that Mobile IP will be heavily deployed using the IPv6 protocol.

CONCLUSION

IPv6 may be new, but this technology is expected to grow and eventually usurp its older and more restricted IPv4 cousin. This evolution will take place over time, and both technologies will likely coexist for years. Nevertheless, IPv6 will offer service providers an opportunity to tailor offerings to customers, launch innovative services, and generate new revenues. By capitalizing on IPv6's improved security, QoS options, mobility Autoconfiguration, and peer-to-peer capability, service providers can create a powerful suite of next-generation Internet services and stimulate new revenues.

In addition to offering service providers and their customers better security, mobility, and peer-to-peer support, IPv6 will address the escalating need for Internet addresses—a requirement largely now restricted to Europe, Japan, and Asia Pacific. The growing worldwide demand for IP addresses are due to the increase in mobile devices; the growth of broadband access; the convergence of voice, data, and video; the proliferation of potential IP-enabled devices; and the burgeoning popularity of VoIP. Not surprisingly, IPv6 market interest is strongest today in Europe, Japan, and Asia Pacific, but demand can also be found in national research networks and governments, many of whom have programs to test and promote IPv6. In North America, IPv6 is recognized as a technology requirement as organizations, including the U.S. DoD, specify support of the protocol in current RFCs.

GLOSSARY

ARP	Address Resolution Protocol
ARPA	Advanced Research Projects Agency
BIS	Bump in the Stack
COA	Care of Address
DARPA	Defense Advanced Research Projects agency
DHCP	Dynamic Host Configuration Protocol
DoD	Department of Defense
FA	Foreign Agent
GRE	Generic Routing Encapsulation
HA	Home Agent
ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPCP	Internet Protocol Control Protocol
LAN	Local Area Network
M-IP	Mobile-Internet Protocol
MN	Mobile Node
MPLS	Multi Protocol Label Switching
NGN	Next Generation Networks
QOS	Quality of Service
R&D	Research and Development
RFC	Request for Change
RFID	Radio Frequency Identification

REFERENCES

- http://www.ipv6.org/
- http://www.anml.iu.edu/ipv6/resources/whyipv6.html
- http://www.usipv6.com/CES_Presentations/CES_Gary_Hemminger.pdf
- www.marketresearch.com/map/prod/1265022.html
- www.apan.net/meetings/busan03/materials/ws/nrw/IPv6-Deployment-Taiwan-Lee-8-28-2003.ppt