IPV4 to IPV6 - Transition and Benefits

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Abstract—IPv6 is the next generation protocol for the Internet, designed to support continued Internet growth in number of users and functionality. The current version, IPv4, was developed in the 1970's and provides the basis for today's Internet interoperability. IPv4 suffers some limitations that may be inhibitors to growth of the Internet, and use of the Internet as a global networking solution.

Requirements for more address space, simpler address design and handling at the IP layer, better quality of service support, greater security, and an increasing number of media types and internet-capable devices have all contributed to drive the development of Internet Protocol version 6 (IPv6).

IPv6 is a new version of IP which is designed to be an evolutionary step from IPv4. It is a natural increment to IPv4. It can be installed as a normal software upgrade in internet devices and is interoperable with the current IPv4. Its deployment strategy is designed to not have any flag days or other dependencies. IPv6 is designed to run well on high performance networks (e.g. Gigabit Ethernet, OC-12, ATM, etc.) and at the same time still be efficient for low bandwidth networks (e.g. wireless). In addition, it provides a platform for new internet functionality that will be required in the near future.

IPv6 is designed to solve many of the problems of the current version of IP (known as IPv4) such as address depletion, security, auto-configuration, research and extensibility. Its use will also expand the capabilities of the Internet and enable a variety of valuable and exciting scenarios, including peer-to-peer and mobile applications.

IPv6 includes a transition mechanism which is designed to allow users to adopt and deploy IPv6 in a highly diffuse fashion and to provide direct interoperability between IPv4 and IPv6 hosts. The transition to a new version of the Internet Protocol must be incremental, with few or no critical interdependencies, if it is to succeed. The IPv6 transition allows the users to upgrade their hosts to IPv6, and the network operators to deploy IPv6 in routers, with very little coordination between the two.

This paper seeks to enlighten Kenyan companies and institutions on the reasons why they should move from IPv4 to IPv6 and inform them of what methods are available to enable the transition without affecting their networks. This is because all companies all over the world are encouraged to do so since IPv4 addresses are expected to be exhausted by august 2011. This means that they shall be forced to move to IPv6 at one given point but the earlier the better. It is also in response to IPv6 world day on 8 June, 2011, where Google, Facebook, Yahoo!, Akamai and Limelight Networks will be amongst some of the major organizations that will offer their content over IPv6 for a 24-hour "test flight". The goal of the Test Flight Day is to motivate organizations across the industry; Internet service providers, hardware makers, operating system vendors and web companies to prepare their services for IPv6 to ensure a successful transition as IPv4 addresses run out. "Please join us for this test drive and help accelerate the momentum of IPv6 deployment" Quote from internet society.

Keywords—ICT, manufacturing, organization.

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INTRODUCTION

To deal with the long-anticipated IPv4 address exhaustion, IPv6 (known first as IPng (Internet protocol next generation) and then as IPv6) was developed by the Internet Engineering Task Force (IETF), and is described in Internet standard document RFC 2460, published in December 1998. Like IPv4, IPv6 is an Internet Layer protocol for packet-switched internetworking and provides end-to-end datagram transmission across multiple IP networks.

While IPv4 allows 32 bits for an Internet Protocol address, and can therefore support 2^{32} (4,294,967,296) addresses, IPv6 uses 128-bit addresses, so the new address space supports 2^{128} (approximately
3.4 ×1038) addresses. This expansion allows for many more devices and users on the internet as well as extra flexibility in

allocating addresses and efficiency for routing traffic. It also eliminates the primary need for network address translation (NAT), which gained widespread deployment as an effort to alleviate IPv4 address exhaustion [1].

Without sufficient global IP address space, applications are forced to work with mechanisms that provide local addressing. The exhaustion of IPv4 addresses has been long anticipated, and various techniques have been introduced to extend the life of the existing IPv4 infrastructure, including Network Address Translation (NAT), Dynamic Host Configuration Protocol (DHCP), and Classless Inter-Domain Routing (CIDR). Network Address Translation (NAT) allows multiple devices to use local private addresses within an enterprise while sharing one or more global IPv4 addresses for external communications. While NAT has to some extent delayed the exhaustion on IPv4 address space for the short term, it complicates general application bi-directional communication. IPv6 eases the complexity of providing end-to-end security. IPv6 removes the common motivation for the use of NAT since global addresses will be widely available [2].

While these techniques provide a workaround for the lack of address space, they fail to meet the requirements of the Internet's end-to-end architecture and peer-to-peer applications. Additionally, residential broadband Internet requires always-on, always-contactable global addresses, which are unsupportable with current IP address conversion strategies, pooling, and other temporary allocation techniques [1].

The true transition of the global Internet from IPv4 to IPv6 is expected to span many years. During this period of transition, many organizations introducing IPv6 into their infrastructure will operate in a dual-stack environment supporting IPv4 and IPv6 concurrently, possibly for the foreseeable future.

There is not a one-size fits all transition strategy for IPv6. The incremental, phased approach allows for a significant period where IPv4 and IPv6 can co-exist using one or more transition mechanisms to ensure interoperability between the two protocol suites.

IPV6 FEATURES AND BENEFITS

IPv6 was designed to build on the existing features of IPv4 and provide new services and capabilities.

There are several features and benefits IPv6 is intended to provide which include:

Larger address space

IPv6 increases the IP address size from 32 bits to 128 bits. Increasing the size of the address field increases number of unique IP addresses from approximately (4.3×10^9) to (3.4×10^{38}).

Improved efficiency in routing and packet handling

IPv6's very large addressing space and network prefixes allow the allocation of large address blocks to ISPs and other organizations. This enables an ISP or enterprise organization to aggregate the prefixes of all its customers (or internal users) into a single prefix and announce this one prefix to the IPv6 Internet.

Within the IPv6 address space, the implementation of a multi-leveled address hierarchy provides more efficient and scalable routing. This hierarchical addressing structure reduces the size of the routing tables Internet routers must store and maintain.

Though the IPv6 header is larger, its format is simpler than that of the IPv4 header. The IPv6 header removes the IPv4 fields for Header Length (IHL), Identification, Flags, Fragment Offset, Header Checksum, and Padding, which speeds processing of the basic IPv6 header. Also, all fields in the IPv6 header are 64-bit aligned, taking advantage of the current generation of 64- bit processors.

Support for auto-configuration and plug and play

The need for plug-and-play auto-configuration and address renumbering has become increasingly important to accommodate mobile services (data and voice) and Internet-capable appliances. IPv6's built-in address auto-configuration feature enables a large number of IP hosts to easily discover the network and obtain new, globally unique IPv6 addresses. This allows plug-and-play deployment of Internet-enabled devices such as cell phones, wireless devices, and home appliances.

The auto-configuration feature also makes it simpler and easier to renumber an existing network. This enables network operators to manage the transition from one provider to another more easily.

Support for embedded IPSec

Optional in IPv4, IPSec is a mandatory part of the IPv6 protocol suite. IPv6 provides security extension headers, making it easier to implement encryption, authentication, and virtual private networks (VPNs). By providing globally unique addresses and embedded security, IPv6 can provide end-to-end security services such as access control, confidentiality, and data integrity with less impact on network performance.

Enhanced support for Mobile IP and mobile computing devices.

Mobile IP, defined in an IETF standard, allows mobile devices to move around without breaking their existing connections an increasingly important network feature [3]. Unlike IPv4, IPv6 mobility uses built-in auto-configuration to obtain the Care-Of-Address, eliminating the need for a Foreign Agent. In addition, the binding process allows the Correspondent Node to communicate directly with the Mobile Node, avoiding the overhead of triangular routing required in IPv4. The result is a much more efficient Mobile IP architecture in IPv6 [4].

Elimination of the need for network address translation (NAT)

NAT was introduced as a mechanism to share and reuse the same address space among different network segments. While it has temporarily eased the problem of IPv4 address shortage, it has also placed a burden on network devices and applications to deal with address translation. IPv6's increased address space eliminates the need for address translation, and with it, the problems and costs associated with NAT deployment.

Support for widely deployed routing protocols.

IPv6 maintains and extends support for existing Interior Gateway Protocols (IGPs) and Exterior Gateway Protocols (EGPs). For example, OSPFv3, IS-ISv6, RIPng and MBGP4+ have been well defined to support IPv6.

Increased number of multicast addresses, and improved support for multicast.

IPv6 multicast completely replaces IPv4 broadcast functionality, by handling IPv4 broadcast functions such as router discovery and router solicitation requests. Multicast saves network bandwidth and improves network efficiency.

Quality of Service (QoS)

The UDP and TCP protocols are used for streaming and other multimedia services on internet. Because the usage of these services are increasing day by day IPv6 have a flow level field in its header which make better and special handling for packets from source to destination. Data traffic is identified in the IPv6 header; support for QoS can be achieved even when the packet payload is encrypted with IPSec and ESP.

TRANSITION TO IPV6

No general rule can be applied to the IPv4 to IPv6 transition process. In some cases, moving directly to IPv6 will be the answer.

Other transition plans will enable a gradual interoperability between IPv4 and IPv6 as transition evolves. Here, ISPs and enterprises will prefer to preserve the heavy investments made to deploy IPv4 networks [5].

Some studies foresee that the transition period will last between today and 2030-2040. At that time, IPv4 networks should have totally disappeared.

A number of strategies have been developed for managing this complex and prolonged transition from IPv4 to IPv6 including the NGTrans working group. The following subsections describe several of these strategies.

Dual-stack

This approach requires hosts and routers to implement both IPv4 and IPv6 protocols. Applications choose between using IPv4 or IPv6, with the application selecting the correct address based on the type of IP traffic and particular requirements of the communication.

Today, dual-stack routing is the preferred deployment strategy for network infrastructures with a mixture of IPv4 and IPv6 applications that require both protocols.

This strategy has several limitations, however: all routers in the network must be upgraded to IPv6; routers also require a dual addressing scheme, an IPv4 address must be available for every dual-stack machine, dual management of the IPv4 and IPv6 routing protocols and sufficient memory for both the IPv4 and IPv6 routing tables.

IPv6 over IPv4 tunneling

The term “tunneling” refers to a means to encapsulate one version of IP in another so the packets can be sent over a backbone that does not support the encapsulated IP version. For example, when two isolated IPv6 networks need to communicate over an IPv4 network, dual-stack routers at the network edges can be used to set up a tunnel which encapsulates the IPv6 packets within IPv4, allowing the IPv6 systems to communicate without having to upgrade the IPv4 network infrastructure that exists between the networks.

A variety of tunneling mechanisms are available for deploying, they include:

- *Configured Tunnels* **-** *when network administrators manually configure the tunnel within the endpoint routers at each end of the tunnel. Any changes to the network like renumbering must be must manually reflected on the tunnel endpoint. Tunnels result in additional IP header overhead since they encapsulate IPv6 packets within IPv4 (or vice versa).*

- *Automatic tunneling* **-** *refers to a technique where the routing infrastructure automatically determines the tunnel endpoints. Tunnel endpoints are determined by using a well-known IPv4 anycast address on the remote side, and embedding IPv4 address information within IPv6 addresses on the local side.*

Protocols Translators

The term "translators" refers to devices capable of translating traffic from IPv4 to IPv6 or vice and versa. Translation is necessary when an IPv6 only host has to communicate with an IPv4 host. This mechanism is intended to eliminate the need for dual-stack network operation by translating traffic from IPv4-only devices to operate within an IPv6 infrastructure [6]. This option is recommended only as a last resort because translation interferes with objective of end-to-end transparency in network communications. Use of protocol translators cause problems with NAT and highly constrain the use of IP-addressing.

Imbedding of IPv4 addresses in IPv6 addresses. IPv6 hosts will be assigned addresses that are interoperable with IPv4, and IPv4 host addresses will be mapped to IPv6 [8].

IPv6 new opportunities

IPv6 opens up new opportunities in infrastructure and services as well as in research opportunities.

New infrastructure

As new internet appliances are added into the IP world, the Internet becomes a new infrastructure in multiple dimensions:

- ✓ IPv6 can serve as the next generation wireless core network infrastructure. Various capabilities in security, addressing and tunneling have enabled mobility applications.
- ✓ Additional sensor devices can be connected into the IPv6 backbone with an individual IP address. Those collective sensor networks will become part of the fabric in IPv6 network infrastructure.
- ✓ "Smart" networks with sufficient bandwidth and quality of service make the Internet available for phone calls and multimedia applications. We expect that next generation IPv6 network will replace traditional telephone network to become the dominant telecommunication infrastructure.
- ✓ As virtualization is widely deployed in both computing data centers and network services, the IPv6 functions become mandatory in security, in flow label processing, and so on. Next generation data centers and network services will evolve around the IPv6 platforms.
- ✓ IPv6 can create a new virtual private network (VPN) infrastructure, with inherently built-in tunneling capabilities. It also decouples security boundaries from the organization perimeter in the security policy. We expect that network virtualization is possible with IPv6 VPN on demand provisions and management.
- ✓ Inside a computer, the traditional I/O bus architecture might be replaced by a pure IP packet exchanged structure. This scheme might further improve the network computing infrastructure by separating the computing and storage components physically [9].

New services

The basic features and new functions in IPv6 provide stimulation to new services creation and deployment. Here are some high-level examples.

- ✓ Presence Service (can be developed on top of Location Based Service (LBS). For example, in pure LBS, movie theaters can post attractive title advertisements to a patron's mobile device when entering the movie zone. In PS, users can setup additional preferences and other policy attributes. As a result, the underlying network services can be aware of user preference and privacy requirements. So, rather than pushing the advertisement to all patrons in the movie zone, those advertisements have to be filtered and tailored accordingly to "do-not-disturb" or "category-specific" preferences.
- ✓ Anonymous Request Service (ARS) can be developed by exploiting the new IPv6 address allocation functions. For example, a location address can use a random but unique link ID to send packets in reporting ethical or policy violations within an enterprise or in government services.
- ✓ Voice and Video over IP (which we call V2oIP in IPv6) will replace traditional phone service and provide video services over IPv6.
- ✓ Always On Services (AOS) allows V2oIPv6 to be ready for service with ease of use. Communication sessions can be kept alive and active using IPv6 mobility functions as well as the IPv6 QoS capability. The "always on" availability is independent of location, movement, or infrastructure.
- ✓ On-demand Routing Services (ORS) eliminates routing table updates for unused routes, balancing slow-path and fast-path processing especially in VoIPv6 environment.
- ✓ IPv6 Management Service (IMS) provides address automatic inventory, service provisioning, and service assurance services.

- ✓ IPv6 Operation Service (IOS) supplies on demand configuration, logging, diagnosis, and control services.
- ✓ IPv6 Testing Service (ITS) provides capabilities in functional conformance and performance testing for implementations of IETF IPv6 standards or RFCs. Interoperability testing is also a key ITS service.

New research and development platforms

In addition to new opportunities for users and network service vendors, there are IPv6 research opportunities for educational and research and development institutions as well. For example:

- ✓ Historically, one of the IETF IP next generation (IPng) project was the development of the 6Bone, which is an Internet-wide virtual network, layered on top of the physical IPv4 Internet. The 6Bone consists of many islands supporting IPv6 packets, linked by tunnels across the existing IPv4 backbone.
  The 6Bone was widely used for testing of IPv6 protocols and products.
  By June 6th, 2006 the 6Bone was phased out per agreements with the IETF IPv6 community [12].

- ✓ The 6NET project demonstrated that growth of the Internet can be met using new IPv6 technology. 6NET built a native IPv6-based network connecting 16 European countries. The network allows IPv6 service testing and interoperability with enterprise applications [13].

- ✓ Internet2 built an experimental IPv6 infrastructure. The Internet2 consortium (not a network) established IPv6 working group to perform research and education in the following areas:
  - Infrastructure engineering, operations, and deployment
  - Education for campus network engineers
  - Exploring the motivation for use of IPv6 [10].

- ✓ Another regional IPv6 example is the MOONv6 project. Moonv6 is just one of the world's largest native IPv6 networks in existence [11].

New open research problems in IPv6 include:

- ✓ IPv6 and next generation network architecture design: While IPv6 and associated protocols have solved problems of message specification and control management, the architecture of the next generation IPv6 network itself is still under experiment.
- ✓ Network infrastructure and service management: Peer-to-peer (P2P) network applications are available to flood the Internet. However, there is a lack of network and service management and control capability. While we should maintain the access and openness of the Internet, the business and commercial reality in the IP space require fundamental rethinking about network and service management infrastructure support.
- ✓ Security: In addition to the native security functions supplied in IPv6 protocols, IPv6 network security architecture needs to define how to extend security across upper layers of IP networks:
  - An integrated security infrastructure combines application security policies to underlying network security capabilities.
  - An integrated security infrastructure also combines content protection into a distribution and transport security layer.
- ✓ Real-time control capability: IPv6 quality of service features provide real-time support of voice and multimedia applications. Additional research topics include signaling and integration with IP multimedia subsystems.
- ✓ IPv6 network virtualization: Automatic configuration inventory and provisioning capabilities have to be studied in order to allocate networking resources and transport on demand.

CONCLUSION

IPv6 is deployable in a production environment. Not only does it solve the shortage of addresses, but it also promises a number of enhanced features which are not an integral part of IPv4.

There has been a rapid growth of internet users in the recent past, this increase created challenges for internet management groups, stake holders and service providers.
The transition between today's IPv4 Internet and a future IPv6-based one will be a long process during which both protocol versions will coexist.

Though the benefits of IPv6 are well understood, the cost of overhauling the existing IPv4 infrastructure is prohibitive for many network operators and service providers. The path to complete global IPv6 connectivity will be lengthy and full of challenges. Many transitional schemes and strategies will be used to ease the pains and minimize investment into IPv6 deployment.
The need for better test tools and methodology is essential for the success of IPv6.

REFERENCES

[1] Cisco roadmap: *http://www.cisco.com/ipv6* www.isoc.org.

[2] Rashid, Fahmida Y. (February 3, 2011). *"IPv4 Address Depletion Adds Momentum to IPv6 Transition"*.*eWeek.com*.*http://www.eweek.com/c/a/IT-Infrastructure/IPv4-Address-Depletion-Adds-Momentum-to-IPv6-Transition-875751/*..

[3] http://www.ietf.org/rfc/rfc1933.txt.

[4] SIPv6 Analyzer. *http://pcs.csie.nctu.edu.tw/~yhsung/sipv6_analyzer/*.

[5] Nordmark E., Gilligan R., "*Basic Transition Mechanisms for IPv6 Hosts and Routers*", Internet Draft, draft-ietf-v6ops-mech-v2-07.txt (work in progress), March 2005.

[6] Silvia Hagen, (2006), *IPv6 Essentials, Second Edition* O'Reilly Media, Inc.

[7] Thaler D., Handley M., Estrin D., (September 2000), *The Internet Multicast Address Allocation Architecture*.
[8] Whai-En Chen, Yi-Bing Lin and Ai-Chung Pang. *"An IPv4-IPv6 Translation Mechanism for SIP Overlay Network in UMTS All-IP Environment"*. IEEE Journal in Selected Areas on Communications (J-SAC). Volume 23, Issue 11, Nov. 2005 Page(s):2152 –2160.
[9] Lydia Parziale, David T. Britt, Chuck Davis, Jason Forrester, Wei Liu, Carolyn Matthews and Nicolas Rosselot; TCP/IP Tutorial and Technical Overview; (2006), pp.327-388.
[10] http://ipv6.internet2.edu
[11] http://www.moonv6.org/
[12] http://www.6Bone.net
[13] http://www.6net.org