Issues Surrounding the Migration to IPv6

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Introduction

Despite many successful years serving as the foundation for powerful and flexible internet communication, the venerable Version 4 of the Internet Protocol (IPv4) will soon have to be replaced. Explosive growth over the course of the last fifteen years has seen IPv4 employed to an extent that would have been inconceivable to its designers. Extensive additions have been built on top of IPv4 as a means of keeping pace with the global Internets evolving technological demands however these additions serve as only a temporary solution. A new protocol - Internet Protocol Version 6 (IPv6) - has been proposed to facilitate the Internets continuing evolution well into the 21st century. Unfortunately, integration and adoption of this new internet standard is no trivial task. A simple conversion from one protocol to the other cannot occur overnight as the software applications used globally to handle communication with IPv4 will have to be replaced in order support IPv6. A gradual migration is no easy task either in that direct interoperability of the two protocols is impossible. To allow for migration, new technology must be adopted that allows for both protocols to indirectly operate together while still maintaining the same level of service present with just IPv4.

Constraints placed on the length of this document do not permit a description of the technical specifications of the proposed IPv6 packet and protocol. Knowledge of the technical details is not a requisite to understanding the material presented here, however should the reader desire a more in depth discussion, they are encouraged to refer to [1] and [3].

To be discussed first are some of the motivating factors behind the need/desire to migrate to IPv6. This will be followed by an introduction to some of the engineering challenges that are presented during the migration. Proposed transition mechanisms designed to facilitate a smooth evolution from IPv4 to IPv6 are presented in the next section before some overall conclusions are drawn based on all information presented.

The Need for Change

The most obvious and inevitable deficiency with IPv4 is the simple lack of an address space large enough to support expansion of the global Internet into the distant future. The developed world alone has an exponentially growing demand for more IP addresses as more and more technologies support network connectivity. Add to this the demands placed by the developing world as large populations become more technologically aware and it is clear that the already burdened IPv4 address space will soon reach its limits. Temporary changes and rationing of IP address spaces has carried the current technology thus far but the cost of continually bandaging the problem will soon begin to cost more than changing the protocol entirely.1

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With IPv6, the 32-bit address space of its predecessor has been expanded to 128 bits. With this change, the IPv4 capacity of approximately 200 million addresses has been expanded to about 3.4x10^{38} addresses. To put this in perspective, this allows for “an IP address for every square inch of the earth's surface.”

Aside from just an increase in address space, other features of IPv6 provide an impetus to switch.

Wide adoption of global internet communication by governments, corporations and individuals has only been possible because of the guarantee of a level security with regard to the privacy of information communicated. In recent years, this guarantee has had less to do with features provided by the IPv4 protocol and more by extensions made on top of the protocol. Even despite these extensions, internet attacks made via exploitation of the weaknesses in IPv4 remain commonplace due to the ease at which the sources for these attacks can be masked. IPv6 improves end to end security at the protocol level making these types of attacks much more difficult. Furthermore, IPv6 mandates, and provides facilities for, the use of IPSec as a means of encrypting IP packet headers and data fields.

Routing schemes present in the current IP protocol are inherently complicated because the shear scale on which network routing is now required was never envisioned by the designers of IPv4. Heavily trafficked Internet routers today can contain “routing tables [with] anywhere from 70 000 to 80 000 entries” The schemes for handling such tables are often complex and require increased overhead during packet switching. IPv6 has been designed with a modern perspective on the scale and complexity of global networks so the routing algorithms have been improved accordingly and provide better efficiency with a simpler scheme.

The Problem Arising from Migration

Clearly, the phasing in of IPv6 will be a gradual process that will occur over the course of many years. Even long after IPv6 has successfully replaced IPv4 for the majority of the Internet, legacy support for IPv4 will still have to be maintained in select instances. Changing either a host or a router on a network that supports IPv4 to IPv6 involves replacing the entire TCP/IP software layer. This replacement cannot occur overnight as all the Internets nodes are individually owned and maintained. The rate of migration to the new protocol will depend upon the individuals (ISPs, corporations, institutions, etc.) desire to make the change. This means that networks will have to

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2 Ibid.
4 Ibid.
5 IPSec stands for IP security protocol.
7 Ibid.
support both technologies simultaneously and this must be done despite the fact that the two do not work together directly because of inherent differences in design.

The simplest example of this difference is the IP addresses themselves. How are 32-bit addresses to be interpreted in a 128-bit address space and, even worse, vice versa? How are DNS lookups to occur when IPv4 hosts attempt to communicate with IPv6 servers?

Transition technologies must be employed to allow for both protocols to exist at the same time.

**Transition Mechanisms**

There are two primary mechanisms currently proposed that allow for the coexistence of IPv4 and IPv6. The first involves maintaining the software layer for both protocols on each host and router and the second involves the encapsulation of the IP packets of one protocol into the packets of the other for transport across the latter’s network.

A dual stack network device is the name given to a network node that has complete software implementations for both the IPv4 and the IPv6 protocols. In this case, when packets arrive to this node, software first interprets the packet type and then employs the appropriate protocol software to process the packet accordingly. Networks nodes of this design can be easily employed on the boundary between networks of only IPv4 or IPv6. This way, the node can act as a translator between the two networks.\(^\text{10}\) \(^\text{11}\)

Aside from the obvious disadvantage of a bloated software protocol layer and increased communication overhead, there is one major disadvantage to this scheme. IPv4 and IPv6 addresses must be maintained for a single node. This means that as the global internet continues to expand with the support of both protocols, the IPv4 address space will continue to dwindle.\(^\text{12}\)

Tunneling is process of encapsulating IPv6 packets into IPv4 packets for transmission over an IPv4 network. This method is advantageous when two IPv6 networks are separated by an IPv4 network and the two wish to communicate with one another. At the interfaces between the two types of networks, the encapsulation process occurs allowing all the networks to treat packets as if they are their own. However, this also means the interface nodes must maintain the additional software protocols for performing the encapsulation.\(^\text{13}\)

Like dual stacking, tunneling does not completely remove the use of IPv4 addressing. Communication between two IPv6 networks involves 128-bit addressing but 32-bit addresses must be used in the intermediate transmission network. This means some mapping between 128-bit to 32-bit addresses must occur and clearly this mapping cannot be one-to-one. Furthermore, the tunneling process has thus far not proven very

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\(^\text{12}\) Ibid.

scalable and its implementation has been dependent on custom algorithms and protocols specific to the underlying hardware technology.\textsuperscript{14}

**Conclusion**

The framework for Version 6 of the Internet Protocol has come to fruition and only minor modifications to its design are expected in the future. In order to complete the migration, research and developmental efforts will no longer be focused on the protocol itself but rather the technology needed to support its integration. It is expected that the migration efforts will continue for at least the next 10 to 15 years\textsuperscript{15} so a concerted effort must be made towards maturing the technologies facilitating the coexistence of these two distinct but very necessary Internet protocols.

References


