# Internet Adoption and Integration of *IPv6*

## *SFWR ENG 4C03 Research Project Paper*

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### 1. Introduction

The current version of the Internet Protocol, IPv4, is rapidly becoming unable to meet the changing demands of today's Internet community. In recognition of this situation, the IETF has defined the next generation of the Internet Protocol, *IPv6*. The difficult challenge now faced is that of integrating this technology within the context of the existing IPv4. It is the purpose of this paper to (1) present to motivation behind IPv6, to (2) explore the salient features of IPv6, to (3) investigate the implications of design decisions on the integratability and acceptance of this new technology, and to (4) examine proposed strategies for IPv6 deployment. Having discussed these issues, the reader will gain an increased awareness of forthcoming internet technology, and insight into the general problem of migrating from one set of standards to another, while maintaining backwards compatibility.

### 2. Motivation Behind IPv6

As the Information Age continues to progress and businesses continue to grow, the stress imposed on the Internet and its underlying technology, IPv4, is becoming a serious problem. The most immediate problem concerns the availability of IP addresses. It is projected that by the year 2020 the current 32-bit IP address space will be unable to accommodate the growth of the global Internet [1]. Secondly, there are several aspects of the basic design of IP that deserve improvement. For example, the current design of IPv4 is not well suited to fulfill the timing requirements of certain applications, such as soft real-time applications. IPv4 also does not provide desired security features such and authentication and confidentiality that are crucial to such applications as electronic commerce. These shortcomings of IPv4 provide the main motivation for IPv6. To fully appreciate the need for IPv6, one must also consider the alternative. Most likely, in the absence of a new version of IP, markets will each develop their own protocols, perhaps proprietary [2]. These new protocols would probably not inter-operate well with each other. The opportunity for the IETF is to develop an IP that has a reasonable chance to be used in these emerging markets. As a direct consequence, this would have the very desirable effect of creating an immense, interoperable, worldwide information infrastructure created with open protocols. Thus, when one considers the alternative to IPv6, it becomes clear that a new version of IP is absolutely essential.

### 3. Salient Features of IPv6

IPv6 preserves most of the features offered by its predecessor IPv4. In fact, IPv6 differs mostly in details, while retaining the fundamental services of IPv4. Common to IPv4 is the use of connectionless datagram delivery, source determination of datagram size, and the source defined maximum number of router hops. Additionally, IPv6 maintains the majority of functionality offered by IPv4 options, such as fragmentation and source routing.

There are seven identifiable classes of changes brought about by IPv6. These are: (1) larger addresses, (2) extended address hierarchy, (3) header format simplification, (4) provision for protocol extensions, (5) improved support for options, (6) support for auto-configuration and renumbering, and (7) support for resource allocation [1,3]. What follows is a discussion of these changes.

The increase in address size is the most prominent change in the Internet Protocol. The address scheme of IPv6 uses 128 bits addressing, which is four times the length of that used by IPv4. This effectively provides 340,282,366,920,938,463,463,374,607,431,768,211,456 IP addresses. Consequently, the address space is large enough to support growth for an immeasurably long period of time into the future. Given the larger address space of IPv6, it becomes possible to extend the hierarchy of IP addresses. In particular, IPv6 can define a hierarchy of ISPs as well as a hierarchical structure within a given site. The main advantage of this scheme is that yields conceptual simplicity, while allowing organizations to have complex internal network structures. The change in header format is also significant. Unlike the fixed format header of IPv4, IPv6 provides for a collection of optional headers. This increases the efficiency of sending information, since now only the relevant portions of a header are transmitted. Protocol extensions directly follow from the optional headers of the new IP header scheme. These headers provide support for functions such as fragmentation, source routing, and authentication. At the internet level, the sender reserves the liberty to choose the appropriate extension headers, permitting maximum flexibility. Improved support for options is related to the extension headers. Two additional headers are defined to accommodate miscellaneous information that does relate to any of the already predefined extension headers. These are the *Hop By Hop Extension Header*, and the *End To End Extension header* [1]. As is suggested by their names, these headers provide two distinct processing directives, which depend on the needs of the sender. The Auto-configuration and renumbering capabilities of IPv6 allows computers to communicate without requiring a manager to specify an address and to control the allocation and de-allocation of network prefixes respectively. This greatly relieves a large burden of network administrators. Lastly, IPv6 provides support for resource allocation: this includes a flow abstraction and a differentiated service specification. The latter is akin to that of IPv4. The flow abstraction provides the mechanism for guaranteeing delay limitations and bandwidth requirements. As a result, soft real-time applications can operate using this aspect of IPv6.

## 4. Backwards Compatibility of IPv6

To allow for backwards compatibility with IPv4, several compatibility features have been incorporated into IPv6. The main feature is embedded, or encapsulated IPv4 addresses. A small portion of the IPv6 address space has been dedicated for the purposes of IPv4 address encoding. Specifically, an address which begins with eighty zero bits, followed by 16 bits of all ones or all zeros contains an IPv4 address in the remaining 32 bits. The 16-bit field present in the address provides information as to whether or not the interface has a conventional IPv6 unicast address[1]. This encoding will be required while transiting to IPv6, from IPv4 for two chief reasons. The first reason arises from the fact that a host may decide to upgrade to IPv6 protocol software before is has been given a valid IPv6 address. Secondly, a host running IPv6 software may need to communicate with another host that relies only on IPv4 technology [1]. However, the encoding method described above is not sufficient to allow two hosts running the two versions of IP to communicate. It is necessary to introduce an additional translation mechanism. In particular, what is needed is an intermediate translator so that an IPv6 host may send a datagram that contains the IPv6 encoding of the IPv4 destination address. The IPv6 computer passes the datagram to the translator, which uses IPv4 to communicate with the destination. When the translator receives a reply from the destination, it translates the IPv4 datagram to IPv6 and sends it back to the IPv6 source [1]. Such a translator that uses both IPv4 and IPv6 technology implements what is termed a *dual IP stack*. Another problem that arises surrounds the ability for two hosts using IPv6 to communicate over an IPv4 only network. The

[1] *Unicast addressing* is one of the three forms of addressing provided by IPv6, which allows one to specify an individual network interface.

solution to this problem uses a technique called *IPv6 over IPv4 tunneling*. Essentially, this is the process of encapsulating IPv6 packets within IPv4 packets to carry them over IPv4 routing infrastructures. IPv6 hosts that are only connected through IPv4 networks can build a virtual link by configuring a tunnel. IPv6 packets travelling towards another IPv6 domain will then be encapsulated within IPv4 packets. The tunnel end-points are two IPv4 addresses. There exist two types of tunneling: configured and automatic. Configured tunnels are created by manual configuration, whereas automatic tunnels do not need manual configuration: the tunnel end-points are automatically determined [3].

## 5. Adoption and Integration Strategies

Now that the technology has been introduced, and the compatibility features explored, it is possible to discuss the logistics of deploying IPv6. IPv6 is expected to gradually replace IPv4, with the two coexisting for a number of years during a transition period. The key transition objectives are to "allow IPv6 and IPv4 hosts to inter-operate"[3], "allow IPv6 hosts and routers to be deployed in the Internet in a highly diffuse and incremental fashion, with few interdependencies"[3] and to "[allow] the transition [to] be as easy as possible for end- users, system administrators, and network operators to understand and carry out"[3]. The first objective was discussed in section 4. The second and third objectives are currently being explored through the development of *6bone*, an experimental network that operates on the IPv6 technology. One of the goals of the 6bone network is to introduce IPv6 to the Internet community, and to demonstrate its usefulness. The results of the 6bone monitoring effort carried out by CSELT since September 1998 confirm that routing within the 6bone backbone has become highly reliable both with respect to stability and route availability. This in turn highlights the good level of maturity reached by the currently available IPv6 technology and confirms that it could be successfully employed even in a production environment [3]. Alongside the development of 6bone is the development of several migration tools to be used during the transition period. A representative of these tools is *6to4* [3]. The 6to4 tool is applicable for the interconnection of isolated IPv6 domains in an IPv4 world (i.e. it establishes a tunnel between two IPv6 domains). To date, several organizations have already adopted and are employing IPv6 and such tools as 6to4. Organizations, such as `http://www.ipv6.org/`, have contributed to the acceptance of IPv6 by providing implementations of the IPv6 software for most available operating systems.

## 6. Conclusion

As the Internet gains more and more popularity, and the demands made by its users continue to increase, so does the need for a new Internet Protocol that can meet these demands. The proposed IPv6 has been designed specifically to address these concerns. However, a good design unrealized is of little use to anyone, including those of the Internet community. Thus adoption strategies for IPv6 have been developed from its earliest formulation. Today these strategies are being employed in pilot projects, such as the 6bone network with good success. As efforts continue to prove the usefulness of IPv6, it is expected that more and more people will make the switch from IPv4 to IPv6. ■

## References


[1] Comer, Douglas E., "Internetworking with TCP/IP Vol I: Principles, Protocols, and Architecture Fourth Edition", Prentice Hall, New Jersey, 2000.

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[3] http://www.ietf.org/proceedings/99jul/I-D/draft-ietf-ngtrans-introduction-to-ipv6-transition-01.txt