A Model of Internet Standards Adoption: The Case of IPv6

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INTRODUCTION

Diffusion theory has made a significant contribution to our understanding of how innovations spread within and across populations. The traditional approach put forth by Rogers (1983) considers diffusion of an innovation (be it a new idea, technology, product or an administrative process) a process of communication among members of a social system. Over time, potential adopting firms become aware of the innovation, evaluate it, and consider its adoption.

The approach has been used to study diffusion among individuals, groups, and organizations for several different kinds of innovation, and from a variety of theoretical perspectives. Fichman and Kemerer (1994) argue that the variety among potential scenarios is so great that "no single strongly predictive theory of innovation adoption and diffusion is likely to emerge" (p. 23). Rather than focusing on a single theory, Fichman and Kemerer suggest that research regarding the diffusion of innovations should focus on specific innovations and contexts. In this paper we pursue that strategy. The context on which we have chosen to focus is the adoption and diffusion of Internet-based standards.

The Internet, often described as a "network of networks," is a loosely organized system of autonomous yet interconnected networks that support host-to-host communication (Bradner 1996). Its success is due, in part, to the voluntary adherence to open protocols and procedures (these are periodically updated in the RFC[1] titled "Internet Official Protocol Standards," last published in May 2001 (Reynolds, Braden, and Ginoza 2001)). With the growth of the Internet and its research community, control structures

[1] RFC: Request for Comments, are the official publication channel for Internet standards documents and other topics of interest to the Internet community. In addition to publishing standards, RFCs cover a wide range of topics from early discussion of ideas to status memos about the Internet. These documents may be obtained from a variety of Internet sites including the web site of the Internet Engineering Task Force (IETF) at www.ietf.org.

were introduced. The first such structure was the Internet Configuration Control Board (Leiner et.al. 1997). As the Internet grew additional structures were introduced (such as the IAB and IETF). Additional entities such as the Internet Society and the World-Wide Web Consortium were created in the 1990's (Leiner et.al. 1997). Like the Internet, these organizations are loosely organized democratic bodies composed of both commercial and non-commercial stakeholders. However, despite the Internet's inherent distributed nature, its participants are also strongly interrelated (Brader 1996). This is because these participants share common resources (for example, Network Access Points to a central backbone), and use common protocols (such as TCP/IP and FTP). This dichotomy of autonomous entities that are also strongly interrelated provides an interesting and unique context against which to examine the diffusion of standards as the emphasis on interdependence requires near ubiquitous adoption by otherwise independent organizations.

In this paper, we develop a model that describes potential paths to adoption of Internet standards. The model draws on traditional diffusion literature to suggest that two major factors, the conduciveness of the environment to the adoption of the new standard and the usefulness of the features of the standard to adopting firms, influence the mode of adoption. The model addresses the unique characteristics of the Internet when looking at the issues surrounding the adoption of standards.

Our analysis suggests that for a new Internet standard to succeed within an environment it should have significant sponsorship. For an Internet standard to succeed across multiple environments, it has to be compatible with existing standards. In addition, a "transitional infrastructure" should be easy to implement with measurable

outcomes. Another contribution of the model is that it implies four potential cases of adoption. Two of these cases are the traditional dichotomous notion of adoption – either full adoption of the standard or non-adoption of the standard. In addition to these, the concept of partial adoption is introduced via the two paths to full adoption. One path is called "adoption through replacement," and the other path is called "adoption through co-existence."

The application of the model to IPv6 indicates that ISPs in the United States will most likely be reluctant to implement IPv6, while ISPs in India, Japan, and Europe will be leading the commercial implementation of the new protocol. Since ISPs in both Europe and Japan have an extensive IPv4 infrastructure, they are most likely to support both for a period of several years. India, on the other hand, has less of an investment in IPv4 and is more likely to move to a full implementation of the new standard first.

In the next section, we present the theoretical foundation for the model based on technology diffusion literature. In the third section, we introduce a model of Internet Standards Adoption (ISA). Fourth, we show that four distinct cases of standards adoption are implied by our model, and how those four cases suggest two distinct paths to full adoption – "adoption through co-existence" and "adoption through replacement." Next, we use the ISA model to explain potential adoption patterns of the Internet protocol IPv6. IPv6 is a particularly appropriate case for analysis using the ISA model because it has yet to be adopted widely by stakeholders, although it has been designated the successor to IPv4 for Internet-based communication since 1998. Finally, we present our conclusions and suggest future research directions.

THEORETICAL PERSPECTIVES ON DIFFUSION

The goal of research in the diffusion of innovations (DOI) is, in part, to understand and explain how innovations are spread across a population of potential adopting firms over time. Classical diffusion theory considers diffusion of an innovation as a social process of communication, where potential adopters become aware of the innovation and are influenced to adopt it (Rogers 1983). The eventual adoption by a community is considered to be a function of characteristics of both the innovation and its adopters. In addition to classical diffusion theory, which has generated a large body of literature (for example, Rogers 1983, Tornatzky and Klein 1982, Kwon and Zmud 1987, Van de Ven 1991), a parallel stream of research examines diffusion from an economic perspective (for example, Rosenburg 1982, Katz and Shapiro 1986, Arthur 1996). Fichman and Kemerer (1993) characterize the economic perspective as one that looks at the diffusion phenomena from a community perspective. Often labeled as "economics of standards," this line of research focuses on an innovation's inherent economic value for potential adopters. A basic premise of this approach is that the economic value to an adopter of an innovation will depend on the size of the existing and the potential network of adopters. Both perspectives are useful when looking at adoption in an Internet context. While the DOI perspective focuses on the characteristics of the innovation and the adopters (which takes into account the Internet's decentralized structure), the economic perspective examines community effects (taking into account the Internet's inherent interrelatedness). Together, they provide a rich set of factors to investigate the adoption of Internet standards.

Diffusion of Innovation Perspective

Rogers' (1983) work, a synthesis of hundreds of studies of innovations, examined diffusion largely in the context of voluntary adoption by individuals. Roger's work and subsequent research in DOI has been primarily concerned with how individual adopters learn about innovations, and their decisions whether or not to adopt. Specifically, this research addresses issues such as the factors that determine adoption, characteristics of adopters, and other relevant antecedents and consequences of adoption.

A primary focus of this approach has been to identify and examine attributes of the innovation and their influence on the decision to adopt. Rogers (1983) identified five generic innovation characteristics that are considered to influence the diffusion process: **relative advantage, compatibility**, **complexity, trialability,** and **observability**. Relative advantage refers to the notion that innovations are likely to be adopted if they offer a solution that has some clear advantages over existing product or service. Innovations are also more likely to be adopted if they are compatible with existing practices, values, and skills of potential adopters, and are relatively easy to understand and use (low complexity).

Fichman and Kemerer (1993) argue that trialability and observability of an innovation refer to inherent risk in adopting the innovation. If the benefits offered by the innovation are not apparent by visual demonstration or logical description, and if it is not amenable to trial without commitment, then adopters are likely to perceive uncertainty about the value of the innovation. Other researchers have proposed additional attributes that in most cases can easily be mapped to one of the five attributes (Fichman and Kemerer 1993). In fact, Tornatzky and Klein (1982), in a meta-analysis of diffusion

studies, found only relative advantage and complexity to be consistently related to adoption. However, most innovation studies either adopt or build upon the basic five attributes identified by Rogers (1983).

Research on diffusion by organizations has been mostly based on a direct application of the principles of traditional diffusion theory. Research has shown that, as in the case of individual adoption decisions, attributes of an innovation influence organizational adoption decisions (Van de Ven 1991; Eveland and Tornatzky 1990; Kwon and Zmud 1987). Fichman and Kemerer (1993) state that innovation attributes not only influence diffusion, but also establish the technologies' adoptability to organizations.

Economics Perspective

Economists approach the diffusion phenomena as one where the diffusion of an innovation will be based on increasing returns to adopters (Arthur 1996). The approach is predicated on the belief that the benefits of adopting an innovation will grow with the size (existing or potential) of the community of adopters. Referred to as **network externalities** (Katz and Shapiro 1986; Farrell and Saloner 1985), it argues that likelihood of adoption is a function of the number of current adopters in the network. There are several concepts related to the existence of network externalities that influence adoption by a community of potential adopters. For instance, economies of scale may emerge when costs decrease as volume increases (Arrow 1962). Rosenburg (1982) describes "learning by using" among adopters, where as the number of adopters increase, the accumulated experience of using the technology grows. Finally, the development of a

related technology infrastructure (Arthur 1988), where the increased demand and market size spurs competition, creates a large base of compatible products. All of these improve the attractiveness of an innovation for adoption.

Farrell and Saloner (1987) argue that even if an innovation is considered to be superior on the basis of objective criteria, a potential adopter may still not adopt the innovation. Adopters may be unwilling to bear the transient incompatibility cost that they may incur from the delay in the innovation attaining sufficient network externalities. Adopters may also be unwilling to bear the risk of being locked into the innovation before it reaches critical mass. Furthermore, the presence of a large **installed base** of existing technology introduces a **drag** (Farrell and Saloner 1986) on the adoption of a new innovation. Farrell and Saloner (1986, 1987) define this effect as **excess inertia**, referring to the reluctance of potential users to adopt a new technology even if it is superior because of the existence of a large installed base. Related to this, Keil et. al (1995) found that the existence of **sunk costs** through irreversible investments can also impede adoption.

Farrell and Saloner (1985) also argue that adoption inefficiencies can result from lack of communication among adopters. Similarly, Nilakanta and Scamell (1990) argue that **communication channels** help the process of diffusion of innovation. Arthur (1988) states that **general industry knowledge** of the new technology can encourage adoption. In addition, the environment in which the adopters exist is also a source of information (Kwon and Zmud 1987).

Also discussed in the literature is the existence of **sponsorship**, or financial incentives provided by public or private sources, that can positively influence the

adoption of one innovation over another (Katz and Shapiro 1986). The presence of sponsorship decreases the risk of adoption by promoting the technology, setting and mandating standards, and subsidizing early adopters. An additional factor influencing adoption patterns is the availability and allocation of relevant **resources** (Kwon and Zmud 1987). These resources might be abundant or scarce, might be evenly distributed throughout a community or disproportionately concentrated among a few.

The following section describes the characteristics of standards and the importance of investigating the diffusion of standards in the context of the Internet. This section also argues the applicability of the two innovation theories described above to the study of standards.

The Role of Standards

Farrell and Saloner (1986) define standardization as a process by which compatibility is attained. Because a base of compatible products will encourage adoption of an innovation, and because of the Internet's dependence on standards due to its interrelatedness, standards are particularly important in the Internet environment. Organizations such as the IETF and the W3C propose and advocate standards to be adopted by the general community for the purpose of maintaining compatibility. However, unlike in the area of telecommunications where interoperability is ensured by standards setting organizations, Internet standards organizations such as W3C and IETF can only recommend a standard, but cannot mandate its implementation or adoption.

Standards compete for adopters in a way similar to innovations and new technologies (Arthur 1988). Therefore, the same basic influences on the adoption of

innovations can also be applied to standards. This is the approach taken in the development of the model. Arthur's (1988) emphasis on network externalities and related technologies as key influences on the adoption of a standard is particularly applicable in the context of the Internet because of the high degree of cooperation these factors require among potential adopters.

Table 1: Summary of DOI and Economic Adoption Literature

Diffusion of Innovation (Feature-Oriented)		**Economic Perspective (Environment-Oriented)**	
Factor	***Source***	***Factor***	***Source***
Relative advantage	Tornatzky & Klein (1982), Rogers (1983)	Network Externalities	Farrell and Saloner (1985), Katz & Shapiro (1986)
Compatibility	Tornatzky & Klein (1982), Rogers (1983)	Related technologies	Arthur (1988)
Complexity	Rogers (1983)	Installed base/Drag	Farrell & Saloner (1986)
Triability	Rogers (1983) Fichman & Kemerer (1993),	Excess inertia	Farrell & Saloner (1986, 1987)
Observability	Rogers (1983), Fichman & Kemerer (1993),	Irreversible investments, sunk cost	Farrell & Saloner (1987), Keil et. al (1995)
		Communications channels and general industry knowledge	Rosenburg (1982), Farrell & Saloner (1985,1987), Kwon & Zmud (1987), Arthur (1988), Nilakanta & Scamell (1990)
		Sponsorship	Katz & Shapiro (1986)
		Resources (availability and allocation)	Kwon & Zmud (1987)

Table 1 summarizes the two perspectives of diffusion, DOI and economic. By combining these two perspectives, we provide a more comprehensive approach to the studying diffusion of standards. Using the two perspectives increases the breadth of analysis by covering factors that impact an adopting firm at the community level and at the level of the innovation. In the next section, we will develop a model of Internet Standards Adoption

3. A MODEL OF INTERNET STANDARDS ADOPTION (ISA)

One of the main criticisms of diffusion research is that adoption is primarily modeled as a dichotomous outcome – adoption versus non-adoption (Bayer and Malone 1989). This approach does not fully address two potential scenarios for the adoption of standards across the Internet. First, due to the autonomy of participating firms, only some firms may elect to adopt the standard. Second, many Internet standards are comprised of multiple features. An organization might adopt a standard, but elect to use only some of the features based on their needs.

These differences occur with Internet standards because of the existence of two contradictory forces: the decentralized nature of the Internet on one hand and the need for high interoperability on the other. The Internet browser is one example, where different browser "brands" (Netscape's Navigator, Microsoft's Internet Explorer, Opera Software's Opera) can coexist in the same organization. These products compete for market share, and therefore could have developed proprietary standards for markup languages. However, the pressure for interoperability forces them to maintain a baseline level of compatibility (support for the latest version of HTML). Over the long-term, organizations that require extremely high levels of interoperability often adopt a "preferred" browser, ensuring a consistent client-side experience. In contrast, a selection of Local Area Network (LAN) architecture, from a technological standpoint, is internal to the organization. An organization may choose Ethernet or Token Ring. That decision can be made individually by each organization and is independent of architecture decisions in other organizations.

Most environments that require high levels of interoperability have some central governance that dictates baseline standards (e.g., the International Telecommunications Union (ITU) establishes telephone standards). The combination of autonomous adoption due to the lack of central governance combined with the demand for interoperability is unique to the Internet. Leiner et al (1997) assert that for the Internet's continued success, a social structure that recognizes the diversity of its stakeholders must continue to exist. They state the importance of not only the emergence of new technology, but also the ability "to set a direction and march collectively into the future." (p. 108)

The proposed model of Internet Standards Adoption (ISA) represents a perspective that integrates the two aspects mentioned above, building on the traditional notions of adoption while taking into account the unique characteristics of the Internet. The natural grouping of the factors influencing adoption into feature-oriented (technological) and environmental-oriented (community) are reflected in our proposed model (see Figure 1). The individual innovation characteristics of these two perspectives are identified as the components of one of the two factors that comprise the model – **Environmental Conduciveness to the Adoption of a New Standard (EC)** and **Usefulness of the Features of the New Standard (UF).**

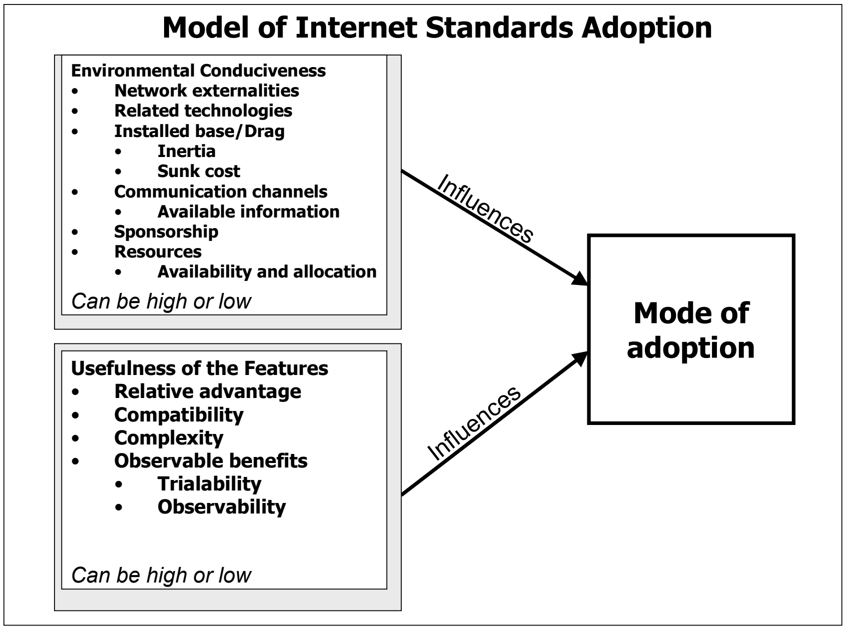

Figure 1: Model of Internet Standards Adoption

In the next section, we develop the two dimensions of the ISA model, based on factors that characterize the environment of the potential adopter and the features of the new standard.

The Application of the Factors to Internet Standards Adoption

Environmental Conduciveness (EC) is characterized by a set of components that favor an organization's adoption of a standard by creating an environment that is amenable to the adoption of that standard. Those components are:

- **Network externalities** refer to the benefits created through the adoption of the new standard by the other organizations in the community. Their existence can aid in the expectations of widespread adoption of a standard. Typical results of network externalities are a reduction in the cost of support (due to economies of scale) and an increase in potential synergies through the facilitation of interactions

among adopters. As a result, it is often the case that as more organizations adopt the standard, the barriers to adoption by others are lowered. Conversely, the inability to create network externalities can impede the adoption of a standard even when it is superior to rival standards (Cusumano et. al 1997). Network externalities are important to consider when examining the adoption of Internet standards because of the required interoperability, it is essential that a substantial number of organizations adopt the new standard. In addition, the lack of central governance increases the risk of adoption. Network externalities can reduce that risk.

- The existence of **related technologies** (Arthur 1988) in the environment creates a large base of products compatible with the new standard. The existence of complimentary or related technologies (Cusumano et. al 1997) increases the inherent value of the new standard, thereby encouraging its adoption. These "complementary technologies" would be applications that use the standard. The development of related technologies can also increase network externalities since more vendors have a stake in the new standard.
- **Current Infrastructure, which includes elements such as installed base, inertia, and sunk cost. Installed base** characterizes the prevalence of the existing standard in an environment. A well-established existing standard can create a high degree of **drag**, and deters an organization from adopting a new standard. This can be due to high levels of familiarity with the existing standard or the existence of well-developed skill sets. High installed base can have a negative impact on the adoption of new standards even when the existing standard

is inferior (for example see Gould 1997). High drag can also result in higher costs to convert, which is likely to limit the attractiveness of the new standard to potential adopters.

Similarly, in environments where the current standard is well-established and development of most new technologies are based on that standard, the **inertia** of that standard is said to be high. Like high levels of installed base, high inertia hinders the adoption of new standards even if they are superior to the existing standard (Gould 1997). Adopters are less likely to switch when a legacy standard is relatively inexpensive to maintain or when the risk in keeping the legacy standard is lower than the risk of implementing a new standard. **Sunk cost** refers to the amount of capital and equipment already invested in the existing infrastructure that will have to be discarded as a result of adopting the new standard. Although sunk cost traditionally are not part of future investment decisions, perceptions of high sunk cost can lead to lower proliferation of the new standard because the idea of "throwing out" the existing investment creates a reluctance to abandon the current standard. Environments where the new standard can build upon existing components of the current standard, and where these components can be replaced by natural attrition, are more conducive to adoption.

These factors are particularly interesting within the context of the adoption of Internet standards. The effects of installed base and inertia (and thus cost to convert and perceptions of sunk cost) are accentuated by the interoperability requirements imposed by this environment. An organization's decision to

upgrade its standard depends not only on their own installed base but also on the existing infrastructure of other related companies (thus the importance of an installed base within the environment). The lack of central governance also contributes to the effect of these factors since a number of competing standards can coexist despite the potential negative effect this may have on interoperability. Also, the geographic location of a firm has a influence on its installed base, inertia, and drag. Unlike other standards, which have been developed concurrently in different regions in the world and co-exist (such as TV broadcasting standards), or standards that were commercial products available to an entire market from their inception (such as the personal computer or the DOS operating system), the Internet was started by researchers within the United States. These researchers were primarily in the government and in universities (such as Stanford, MIT, USC and UCLA), and were funded by a United States-based government agency (DARPA). Only at a later stage TCP/IP and the Internet had spread to other regions and became ubiquitous.

- **Communication channels & information** refers to the amount of information available to organizations regarding the features of a new standard (including its benefits and limitations) and the accessibility of that information. Due to the lack of central authority that can disseminate information regarding new Internet standards in an efficient manner, the voluntary flow of information between existing adopters and a potential adopter is essential. This flow can lead to varied levels of available information among environments (Kwon and Zmud 1987).

The availability of information to an organization has a positive impact on the diffusion of an innovation (Nilakanta and Scamell 1990).

- **Sponsorship** refers to the level of governmental or private support of the new standard. Morison (1997) concluded that it is difficult for a society to adopt a new standard without the intervention of an external agent in a position of power. In environments with strong government or private support, the ability for a new standard to proliferate is increased because the sponsors can take the role of the central authority the Internet currently lacks. Government sponsorship, for example, can (1) mandate the implementation of the new standard in a certain regions, (2) defray some of the cost to upgrade via tax credits or training programs, or (3) increase network externalities via awareness programs, collaboration and consortiums which increase implementation synchronization. Private support can (1) increase network externalities via the creation of consortiums, (2) introduce an artificial crisis by stopping the support of technologies based on the old standard (by mandating a "cutover" date), (3) provide monetary incentives to early adopters, and (4) develop transitional technologies.
- **Resource** related influences refer to the availability and allocation of relevant resources (Kwon and Zmud 1987). Scarcity of resources in an environment will contribute to the adoption of innovations. In the context of the Internet, these resources can vary from physical technology (such as processor speed and bandwidth) to human capability (such as availability of certain programming skills). For example, the viability of video streaming depends on bandwidth

available to the mass market. Environments where broadband is readily available will be more likely to adopt streaming video compared to environments that still rely on dial-up connectivity.

Usefulness of the Features of the New Standard (UF) is characterized by a set of components that describe the attractiveness of the features of the new standard to potential adopters. The assumption is that a given standard can have multiple uses, or be used in multiple innovations. Different organizations may choose to implement different features of the standard. The components of this factor are:

- **Relative advantage** refers to the advantages offered by the features of a new standard over existing standards. These new features could generate new markets, products, and services creating a competitive advantage opportunities for early adopters. This factor is applicable even in an interrelated environment such as the Internet. When there is backwards compatibility, and the new standard can be implemented while the old standards is being phased out, a relative advantage is still available to first movers who can identify potential niche markets that can be exploited by upgrading to the new standard.
- **Compatibility** refers to the ability of the new standard to work with existing technologies or technologies that conform to other existing standards. Since interoperability is important in the Internet environment and since not all players will upgrade at the same time, compatibility is an essential component in understanding the adoption of standards in this context. Features that are compatible with technologies based on existing standards are more likely to be adopted. For example, XML is compatible with EDI's existing set of X12

standards (www.x12.org). The implementation of an XML-based business-to-business infrastructure can easily be built upon an existing EDI infrastructure, increasing the viability of XML adoption.

- Increased **complexity** of the features of the standard increases the effort required to implement, and therefore can reduce the level of their adoption. Such features are less likely to proliferate, especially if their benefits over the existing standard are not clear. This factor is interesting in the Internet environment because interoperability considerations may compel an organization to adopt a standard, but a high level of complexity may result in a minimal number of the standard's features actually being used, leading to partial adoption.
- **Observable benefits** that include trialability and observability, **Trialability** refers to the ability to verify and quantify the benefits of the new standard. Features that can be assessed without commitment and are easy to quantify will have an increased perceived value, reducing the perceived risk of adoption. **Observability** refers to the companies' ability to observe benefits from the adoption of a given feature or a set of features. These features are more likely to be adopted. Observable benefits are interesting in the Internet environment because they can reduce the perceived risk associated with adopting a new standard. Since there is no central governance (and in the absence of sponsorship, no mandate) for organizations to adopt, it is important to be able to observe the benefits from the adoption of a new standard and have a quantifiable advantage to implementing the new standard. These advantages can come through the implementation of related

technologies or via other competitive advantage that the standard features can provide.

Based on the two factors presented above, we derive a two-by-two framework that describes distinct "states" of Internet standards adoption (see Figure 2). Each factor is separated into two levels, low and high. Each of the four resulting quadrants describes a mode of Internet Standard Adoption (ISA). The first is called "status quo," where both environmental conduciveness and usefulness of the features is low. An organization operating in low EC and has low UF for the new standard's features is unlikely to adopt the new standard.

		Conduciveness of environment to adoption of a/the new standard (EC)	
		Low	**High**
Usefulness/ Need of Features of new Standard (UF)	**Low**	I. **Status quo** *Stay where you are*	III. **Replacement** *Implement but with no new features – use like the old technology*
	High	II. **Co-existence for best use (*niche*)** *Implement with some but not all features, and support both in the transition*	IV. **Full implementation** *Implement new standard with all of the features*

Figure 2: Modes of Adoption based on ISA Model

The second quadrant is called "Co-existence for best use," and describes a situation where environmental conduciveness is low but usefulness of some features is

high. In this case, an organization might implement the features of the new standards for a particular group while maintaining the existing standard for other markets and to maintain interoperability with other related organizations in its own environment. In the third quadrant, the environmental conduciveness is high but the usefulness of the features is low. In this case, called "replacement," the new standard is implemented, but there is minimal use of all its new features and capabilities, instead it is being used in much the same way as its predecessor. One instance in which replacement may occur is a forced upgrade. When a vendor stops supporting a technology or a new standard becomes the "de facto" standard, companies will be forced to adopt the new standard whether or not they intend to use its features. A complete adoption of the new standard and its capabilities (called "full implementation") occurs in the fourth case, where both environmental conduciveness and feature usefulness are high.

In summary, an organization may operate in an environment whose conduciveness to the adoption of the new standard is either high or low, and the standard's features for that organization may have high or low utility. Thus the decision to adopt, and the mode of adoption, depends both on the external environment and the internal organizational strategic needs regarding the usefulness of the standard.

We propose that diffusion of standards over the Internet can be classified into one of these four quadrants. Each describes a full or a partial adoption of a standard. The partial adoption is either driven by the features of the standard (i.e., only selected features of the standards are adopted) or by the environment the organization operates in (i.e., only certain organizations adopt the standard). Early stages of adoption of a new standard where a legacy standard exists would necessarily begin in "status quo" (quadrant

1). Firms choosing not to adopt would remain in this quadrant. For those who choose to adopt, there is a movement towards eventual full implementation (quadrant 4). The path from quadrant 1 to quadrant 4, whether it is via “replacement” or “co-existence,” depends on the characteristics of the environment in which the organization operates and on the value placed on the features by each organization.

Paths to Standards Adoption Implied by the ISA Model

Implied by the ISA model are two “paths” to adoption “maturity.” One path can be characterized as “adoption through replacement,” (see Figure 3) where organizations replace the old standard with the new one while not taking advantage of its new features. This is done to maintain interoperability with other Internet companies and because there is some incentive which makes the environment conducive to the replacement of the older standard. For example, RealNetworks’ RealOne media player will play media files created using older versions of their proprietary format. In addition, they distribute decoding software (codecs) which allows their media player to play many older digital audio and video formats from other vendors. This enables potential adopters to move to RealNetwork’s newest media player without necessarily using their newest media format (features). This is possible because their player’s compatibility with existing standards is maintained. Over time, the organization will implement additional aspects of the new standard based on need.

		Conduciveness of environment to adoption of a/the new standard (EC)	
		Low	**High**
Usefulness/ Need of Features of new Standard (UF)	**Low**	I. **Status quo** *Stay where you are*	III. **Replacement** *Implement but with no new features – use like the old technology*
	High	II. **Co-existence for best use** *Implement with some but not all features, and support both in the transition*	IV. **Full implementation** *Implement new standard with all of the features*

Figure 3: Adoption through replacement

A second path can be called "adoption through co-existence," (see Figure 4) where organizations phase-in features in the new standard that are needed to maintain a competitive advantage via new services or products while actively maintaining support for the old standard. These organizations usually operate in an environment that while extensive legacy support for existing players is required, certain features of the new standard provide some competitive value for the adopting organization. For example, an organization with a large Electronic Data Interchange (EDI) base in a financial industry where EDI is dominant might choose to also adopt XML to support a niche market (such as the delivery of financial information to wireless devices). However, the organization will continue to maintain support for EDI as their main method of intra-organizational data exchange as long as the environment requires it. A third scenario is possible. Companies may move directly to a full implementation. This may occur in a situation

where the standard is novel and no comparable legacy standard exists. Therefore, there is no standard with which to "co-exist" and no standard to replace.

		Conduciveness of environment to adoption of a/the new standard (EC)	
		Low	**High**
Usefulness/ Need of Features of new Standard (UF)	**Low**	I. **Status quo** *Stay where you are*	III. **Replacement** *Implement but with no new features – use like the old technology*
	High	II. **Co-existence for best use** *Implement with some but not all features, and support both in the transition*	IV. **Full implementation** *Implement new standard with all of the features*

Figure 4: Adoption through co-existence

THE CASE OF IPv6: AN UNADOPTED STANDARD

Internet Protocol Version 6 (IPv6) also known as Internet Protocol Next generation (IPng) is an interesting and appropriate case with which to apply the framework described in the previous section. IPv6 is the first major standard introduced by the Internet Engineering Task Force[2] and the Internet Society since the privatization of the Internet in 1992. Although many believe that IPv6 is superior to IPv4 and despite the fact that it has been announced as a proposed standard in 1998, it has not been adopted. An ISP's decision to implement IPv6 exemplifies the interaction between the decentralized nature of the Internet and the need for a communal decision. Each ISP can

[2] The IETF (www.ietf.org) can propose standards but it has no authority to enforce them, nor does it have the funding to financially support their implementation

decide for itself if it is to offer IPv6 services. The decision, based on its business plan, must also take into account interoperability because IP is a network layer protocol. Thus, the adoption decision is constrained by the decisions made by other Internet "players" (such as Network Access Points, other ISPs, and equipment providers). In this section, we will present a basic technical overview of IP. The next section will describe the application of the ISA model to IPv6.

The limitations of IP, the standard protocol used for Internet communication, illustrate some of the scalability problems faced by the Internet. These limitations are evident in the current version of IP, IPv4. Problems with IPv4 include (Microsoft 2000):

1. A limited number of available new addresses. The number of addresses that can be allocated using IPv4's addressing scheme is rapidly dwindling, exacerbated by increasing worldwide demand. In addition, the class structure and class-based address allocation limit the available addresses for newcomers to the Internet.
2. A consequence of the flat address structure of IPv4 dictates large, flat routing tables. As the number of allocated addresses increase, the search time through these flat tables also increases, slowing down the response time at the router.
3. There is no traffic prioritization (often referred to as "Quality of Service") for the smooth transmission of multimedia data. Current IP traffic is transmitted on a first-come, first-serve basis regardless of the type of data involved. Thus, e-mail messages or a file transfers (which are asynchronous transmissions that do not require consistent delivery) have the same priority as a video

conferencing stream (which is a synchronous interaction and does require delivery consistency).

4. IPv4's basic security is poor, relying on "ad hoc" solutions. IPv4 does not mandate the use of IPSec, the current standard for security for IP-based communications

In addition:

1. Implementing Internet-based mobile computing over IPv4 is complex.[3]
2. Multicasting capabilities in IPv4 are limited.

Separate solutions have been developed to address each of these issues, each introduced through a standards process. For example, network address translation (NAT) was developed to alleviate the addressing shortage issue, broadband solutions such as DSL and cable modem are introduced to accommodate multimedia applications, and Secure Socket Layer (SSL) technology have been developed to compensate for IPv4's security shortcomings. However, a comprehensive solution, IPv6, has been proposed by the IETF. The first call for comments on the Next Generation Internet Protocol (IPng) was published in 1993 (RFC 1550). Subsequent RFCs refined the requirements of IPng in areas such as multicasting (RFC 1667), cellular capabilities (RFC 1674), and security (RFC 1675) and its impact on various stakeholders such as large corporate networks (RFC 1678), ATM services (RFC 1680) and cable television (RFC 1686). IPv6 specifications were proposed as a standard by the Internet Society in December 1998 (RFC 2460).

[3] Current implementation of mobile IPv4 requires the use of a foreign agent (FA), a home agent (HA), and a care-of (CO) address. The FA has to communicate that address through a tunnel back to the HA on the user's home network. Now, the packets from the corresponding node to the mobile unit always have to go through the HA. Since IPv6 supports autoconfiguration capability, mobile IPv6 is simpler.

IPv6 currently serves as the proposed future standard for Internet-based communication. The new protocol offers a larger address space (Metcalfe 1998), simplified configuration, Quality of Service (QoS) capabilities, improved routing, built-in security, and mobile capabilities. Further details regarding some key features of IPv6 are provided in Appendix A.

Despite these innovations in the IPv6 protocol, as well as its existence as a standard since 1998, IPv6 has yet to achieve widespread adoption. In fact, a poll of 50 Internet Service Providers (ISPs), conducted in November 2000[4] in the United States found that not one of them had implemented the new protocol. To fully understand why a particular environment may be more conducive to the adoption of IPv6, the proposed ISA framework is applied. Table 2 summarizes the features of IPv6 and their potential impact on ISPs.

Table 2. IPv6 features and their impact on ISPs

Factor	Current Status	Evaluation
Relative advantage	See Table 1 for a list of technical advantages	Various ISPs will adopt the standard based on their business needs. For example, ISPs in developing countries might adopt IPv6 because they lack addresses. ISPs in Europe might be looking for the mobile services afforded by the new standard. The more advantage the features of IPv6 provide to an ISP the more likely they are to fully implement the new standard.
Compatibility (backwards)	In theory, IPv6 was designed to be compatible with IPv4. There are several mechanisms that support coexistence of the	In cases where the current infrastructure is more compatible with IPv6, IPv6 is more likely to be adopted. For

[4] An informal poll was conducted by the authors. The first 50 Internet Service Providers listed at: www.ispfinder.com in the 215 area code (metropolitan Philadelphia) were selected (out of 416 total). The web site lists the ISPs in alphabetical order. Each ISP was contacted and asked if they currently support IPv6.

	two protocols. Running both networks requires specialized hardware and software.	example. Young ISPs, use relatively new equipment, which is compatible with and can be easily upgraded to IPv6. Universities who have been on the original ARPANET might have old equipment that need to be completely replaced.
Complexity **Managing and upgrading**	IPv4's maintenance is complex (for example NATs do not work with all applications, manual maintenance of routing tables). The maintenance of IPV6 is promised to be less complex. In areas with relatively new infrastructure, the upgrade from IPv4 to IPv6 is relatively simple. However, Service providers with an extensive and older infrastructure will have difficulties upgrading. Thus the management of the transitional network in those cases may also be more complex	Similar to compatibility. In some cases the transition is more complex than in others. Where the transition is very complex, ISPs will be reluctant to upgrade.
Triability	Test beds exist in several environments. Europe and Japan are leading in that area. For example see 6BONE, BT-Japan, and 6NET	Environments where test-beds for IPv6 proliferate and there is an extensive sharing of trial information, are more conducive to adoption. ISPs that have access to trial data are more likely to adopt the new standard.
Technology interrelatedness	A limited number of technologies that take advantage of IPv6 exist. Several developments by Microsoft are forthcoming. In Europe the deployment of the 3G wireless phone standard is heavily related to the deployment of IPv6	ISPs that have related technologies available to them are more likely to adopt the new standard. For example, ISPs that intend to offer Internet services to 3G wireless devices are more likely to adopt IPv6 than a traditional ISP servicing mainly dial-up and DSL connections.

THE APPLICATION OF THE ISA MODEL TO IPv6

In this section, we will apply the ISA model to predict potential adoption patterns for IPv6. The unit of analysis is the Internet Service Provider (ISP) – that is, the model addresses the adoption decision of a particular ISP. The decision to adopt depends on an ISP's customers (companies that use the ISP for their Internet connectivity), vendors (companies such as Cisco that supply Internet and networking hardware and software), and other ISPs. We will describe each of the four ISA cases (status quo, adoption through replacement, adoption through co-existence, and full implementation) in the context of IPv6 adoption.

Status quo

In this case, ISPs stay with their current infrastructure, implementing a "wait and see" strategy regarding the adoption of IPv6. These ISPs operate in an environment with high installed base of IPv4 technologies and related products. IPv4 is the prevailing standard not only for the ISP itself but also for its vendors and customers thus producing high drag and inertia, and high conversion cost. There may be very limited network externalities since other ISPs in this environment are also adopting a "wait and see" strategy. Consequently, the amount of information available about IPv6 is limited. These ISPs operate in environments that have no sponsorship, which results in little or no incentive (monetary or legal) to adopt IPv6. In addition, the lack of IP addresses is not a problem for these ISPs because they already have significant control over that scarce resource.

In this situation, the environmental conduciveness to adoption is low.

ISPs, in this case, do not see much value in the features of IPv6. ISPs that have significant investment in legacy systems (such as the U.S. military which own parts of the original ARPANET) are likely to operate on an infrastructure that is not compatible with IPv6. This increases the complexity of the upgrade process. This increased complexity may make it difficult for an ISP to test, observe and quantify the benefits of IPv6[5]. ISPs in this case do not see a strategic advantage in adopting any of the features of IPv6 (mostly because their clients' infrastructure is also IPv4-based and there is little or no demand for new services that cannot be supported by the existing standard).

For example, in the general consumer market in the United States, there is an extensive investment in the current IPv4-based infrastructure. In addition, there is a wide range of substitute technologies that would require substantial de-investment (such as NAT for increased addressing and SSL for increased security). ISPs have little incentive to upgrade to IPv6 because the cost to convert is greater than the perceived benefits. Most of the currently available IP addresses (74%) are allocated within North America (Goodin 2001), reducing the need for additional address space (resource availability). Finally, the United States government offers minimal sponsorship for the "public" Internet, its efforts mostly directed towards regulating the telecommunications industry. The ISPs in the United States provide the central infrastructure for the Internet. This market is dominated by a few large ISPs (America Online and MSN alone constitute 23% of the consumer market (Fusco 2002)). These ISPs have significant investment in legacy technologies that are frequently incompatible with IPv6. Their user base is unlikely to demand new services that cannot be supported using IPv4-based infrastructure and that

[5] To accomplish triability, and observability ISPs should create a parallel system that uses IPv6 capabilities. This can be an expensive endeavor.

would generate demand for IPv6. Thus, there is little relative advantage to these new features. In addition, large internal service providers such as the U.S. military and government agencies have an infrastructure dating back to the 1970's. This infrastructure is incompatible with IPv6 and is even more complex to upgrade.

IPv6 is used with IPv4, depending on best use (adoption through co-existence)

In this case, firms will reach full adoption of IPv6 by first using both IPv4 and IPv6 in parallel, based on the specific demands of individual consumer groups. These ISPs operate in an environment with high installed base of IPv4 technologies and related products. IPv4 is the prevailing standard mostly for the ISP itself and for its vendors (however not necessarily for all of its customers) thus producing high drag and inertia and high conversion cost. Since ISPs in this environment are installing IPv6 infrastructure for niche markets, network externalities evolve around these markets and so is the flow of information. ISPs in the "best use" case may create application specific consortiums (such as the Internet 2 consortium) thus creating limited sponsorship, which results mostly in the promotion of the particular niche involved. The availability of IP addresses will only interest these ISPs if a large number of addresses is required for their specific application (meaning as a feature not as a resource). Thus the control over a scarce resource may be immaterial. Therefore, the environmental conduciveness to adoption is low.

The "adoption through co-existence" path is also characterized by the existence of niche applications that create new markets that demand the implementation of features available in IPv6. This will increase the value of IPv6 to ISPs that offer these services. Examples of this include embedded technologies and wireless Internet devices. It has

been predicted that 40% of homes will be smart homes to some extent, within 10 years (themovechannel.com). Smart appliances will each have their own IP address, significantly increasing the demand for the additional address space that IPv6 can provide. Smart appliances also rely on technologies such as Jini, which require multicasting capabilities. Similarly, mobile Internet connectivity utilize dynamic host configuration and interactive multimedia applications (such as virtual reality) utilize Quality of Service capabilities. Therefore, there is a relative advantage of adopting IPv6 in addition to IPv4 for ISPs servicing these niche markets. ISPs find it valuable to create test environments in order to perform an assessment of the viability of the technology. In summary, ISPs in this case see competitive advantage in adopting certain features offered by IPv6 to service niche markets, but due to significant existing investments in IPv4 may run the two concurrently.

For example, NTT, a Japanese ISP is one of the leaders in the introduction of IPv6 services. Japan has an extensive Internet infrastructure similar to that of the US. In their white paper Ezaka and Shibata (2002) state that NTT's motivation to install IPv6 was not lack of addresses but the potential new services they can provide based on the standards new features. NTT conducted numerous tests and trials before implementing the first commercial IPv6 based service in the Spring of 2001.

Another example are universities in the United States that do specialized research, are connecting to Internet 2, and use some of the features of IPv6. The Internet 2 consortium, supported by private companies, provides limited sponsorship and is deploying high-speed connection points called "gigaPOPs" that now support IPv6 (Thompson 2002). Abilene, as part of Internet 2, is an example of an IPv6-based network

that connects approximately 200 universities. One of the applications being tested using Abilene is voice over IPv6 using theVOICE6 protocol.

IPv6 works like IPv4 (adoption through replacement)

ISPs in emerging environments are likely to adopt IPv6 by default because it is the latest standard for TCP/IP-based communications and it is bundled with current technology such as routers and network operating systems (this trend can also be seen with the leading desktop operating systems such as Windows 2000, Windows XP, and Linux). Since these ISPs operate in an environment with low previously installed base of Internet technologies, IPv4 is less likely to be a prevailing standard. The result is low drag and low inertia, and little or no conversion cost. Since less developed environments are likely to have fewer ISPs, it is possible that network externalities are limited (and so is the information that is available about IPv6). These environments are also more likely to experience the lack of IP addresses (a scarce resource) because the majority of the IP address blocks have already been allocated. Local sponsorship may be negligible because the governments of these countries do not provide the financial resources to support major Internet initiatives. However, there are international initiatives, such as the United Nations initiatives to help developing nations with the implementation of technology, and a joint initiative of the World Bank and a Japanese investment firm to support Internet-based startups in developing countries (Gruenwald 2001). Therefore, environmental conduciveness is high.

At the same time, the value of the features of IPv6 is low since there are limited markets for the capabilities offered by these new features. The complexity of upgrading is low since there are no legacy systems, and therefore compatibility issues are minimal.

The value of observability and triability are low because the ISPs are not using the new features of the new standard.

For example, countries such as China have a relatively small allocation of IP addresses, despite their large populations. In fact, the entire Asia-Pacific region only accounts for 9% of the total IPv4 addresses available globally (Goodin 2001). ISPs operating in those countries are likely to adopt IPv6 primarily for its ability to provide additional IP addresses alone. China can start with IPv6 thus avoiding conversion costs in the future (Durham-Vichr 2001). Another example can be seen in less-developed countries, such as African nations like Kenya and Ghana, where there is little investment in the current IPv4-based infrastructure. There is also little investment in substitute technologies, requiring virtually no de-investment. Telecommunications companies and ISPs have an incentive to leapfrog over current standards and install "state of the art" technologies. Finally, government intervention in these countries often provide disincentives to adoption, by maintaining control over the existing telephone infrastructure and taxing imports of the necessary equipment to upgrade the infrastructure (Tomlinson 2001). While IPv6 will be installed by default, there may be little incentive to take advantage of its features.

IPv6 Full implementation

Full implementation of IPv6 is the logical endpoint in the diffusion of the standard. However, ISPs may move to full implementation without partially implementing IPv6 first, either through the co-existence or replacement scenarios. ISPs that adopt a full implementation strategy operate in an environment with a low installed base of existing Internet infrastructure. Therefore, IPv4 is not a prevailing standard

resulting in low drag and inertia and little or no conversion costs. Since in this environment there are relatively few ISPs it is possible that the network externalities will be limited. However, the information that is available about IPv6 will be communicated among the ISPs partially because in this environment there is some government sponsorship. In addition these ISPs have access to a limited number of available IP addresses. Thus their potential growth and continued operation depends on a resource that is scarce and controlled by others. Consequently, the environmental conduciveness to the adoption is high.

ISPs that choose to fully implement IPv6 are likely to have seen value in the features of the new standard. The lack of a significant legacy infrastructure mitigates most compatibility issues. This reduces the complexity of the upgrade. For example, ISPs that operate on newer Cisco routers, which are IPv6 compatible, require minimal effort to upgrade. Due to the low complexity, the ability of the organization to test, observe and quantify the benefits of IPv6 is relatively high. ISPs in this case see a strategic advantage in adopting all or most of the features of IPv6 and therefore will benefit significantly from the trialability and observability of IPv6. It is likely that these ISPs are given financial incentives from their governments to test and adopt IPv6.

An example is the ISPs in India (Schwankert 2001), where there is relatively little investment in the current IPv4-based infrastructure. Therefore, there is a low installed base, low inertia, making the cost to convert also low. The Indian government is funding the development of an Internet infrastructure (sponsorship) that will support the deployment of IPv6. As an emergent high technology market, Indian ISPs can exploit this consumer base using the new features in IPv6 to create new products and services. In

addition, India requires large blocks of IP address that it currently cannot get. The Indian IPv6 consortium plans to connect to similar IPv6 networks in Japan and Europe creating a transcontinental IPv6 backbone (thus creating network externalities) (Schwankert 2001). Figure 5 illustrates the application of the ISA model to IPv6.

		Conduciveness of environment to adoption of a/the new standard (EC)	
		Low	**High**
Usefulness/ Need of Features of new Standard (UF)	**Low**	I. **Status quo** *Mainstream ISPs in the United States and Canada*	III. **Replacement** *Emerging ISPs in developing countries*
	High	II. **Co-existence for best use (*niche*)** *ISPs serving niche markets in Japan and Europe*	IV. **Full implementation** *Emerging ISPs in technically oriented markets like India*

Figure 5: The application of the ISA model to IPv6

DISCUSSION AND FUTURE DIRECTIONS

The Internet presents new challenges in understanding the diffusion of new standards. The lack of central control and the coalition of independently operating entities provide a unique backdrop for introduction of new innovations. In this paper, we have developed a model for the adoption of Internet technology standards. The model draws on traditional diffusion literature to suggest that two major factors, the

conduciveness of the environment to the adoption of the new standard and the usefulness of the features of the standard to adopting firms, influence the mode of adoption.

The ISA model addresses the unique characteristics of the Internet when looking at the issues surrounding the adoption of standards. Specifically, the inherent tension between the autonomy and the interrelatedness of its participants is reflected in the model. Consequently, the model illustrates the significant role "environmental conduciveness" play in influencing the adoption process in the case of Internet standards. For example, the decentralized nature of the Internet makes sponsorship extremely important. This is because the infrastructure must be created to generate network effects so that firms will begin to use the standard. This sponsorship can come in either the form of government assistance or private consortiums and can provide needed uniformity by creating the necessary infrastructure.

The interrelated nature of the Internet also makes the environment an important influence on the adoption of standards. For example, this interrelatedness can create excess inertia. In addition to the disincentive to implement a standard in the absence of an adopter network, firms may also not adopt because it may make them incompatible with other participants. This incompatibility can result in the inability to exchange messages over the network, which is core to a communications-based environment such as the Internet. The above analysis suggests that for a new Internet standard to succeed across multiple environments, it has to be compatible with existing standards. In addition, a "transitional infrastructure" should be easy to implement with measurable outcomes. Another contribution of the ISA model is that it implies four potential cases of adoption. Two of these cases are the traditional dichotomous notion of full adoption of

the standard and non-adoption. In addition, the concept of partial adoption is introduced via the two paths to full adoption. One path, called "adoption through replacement," describes the situation where the old standard is replaced with the new one by default, but its functionality is not taken advantage of. The other path, called "adoption through co-existence," describes the situation where the new standard is introduced in order to take advantage of its functionality for a niche group, while support for the old standard is maintained for the remainder of the market.

The ISA model can potentially be applied to a number of emerging Internet standards. Our analysis of the IPv6 case (as illustrated in Figure 5) indicate that ISPs in the United States will most likely be reluctant to implement IPv6, while ISPs in India, Japan and Europe will be leading the commercial implementation of the new protocol. Since ISPs in both Europe and Japan have an extensive IPv4 infrastructure, they are most likely to support both for a period of several years. India, on the other hand, has less of an investment in IPv4 and is more likely to move to a full implementation of the new standard first.

Future research can verify the model through empirical studies. This verification can either be done via the development of a typology of international ISPs or through collection of quantifiable data. Although the model aims at explaining diffusion of an Internet standard, it can also be used to profile different market segments and help players in the market (such as ISPs) position themselves depending on their strategic orientation. The model and the framework also need to be assessed for their applicability to other Internet-based standards, such as XML. Finally, the factors identified in the

model can be used to develop a diagnostic tool for managers to assess where they would like to place their organizations in the market.

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Appendix A: Comparison of IPv6 to IPv4

Category	Advantage of IPv6	Why it is Important
Addressing	The address space in IPv6 is much larger than IPv4 (16 bytes instead of 4 bytes). This means that IPv6 allows for 3.4×10^{38} addresses, compared with 4.2×10^{9} possible addresses.	The number of unique IPv4 addresses is dwindling rapidly. This is mostly a problem in undeveloped countries[6]. It is also anticipated to become a problem if #g wireless standard replaces the current 2.5G and if smart homes proliferate[7].
Configuration	A node running the IPv6 protocol can automatically configure itself with a unique address, eliminating the need for static addresses or previous methods of autoconfiguration such as DHCP (Dynamic Host Configuration Protocol).	The management of multiple IPv4 clients within an organization involves tracking the assignment of addresses at either a client-level, or a "pool" level.
Data Delivery	There are new header fields in IPv6, which indicated the type of information being sent within each packet. This information can be used to prioritize traffic and guarantee Quality of Service (QoS)[8]. However, it is important to note that the actual implementation of QoS is still in the research and development stage as IPv6 alone is not sufficient for implementing end-to-end QoS.	For the transmission of multimedia data over the Internet, the fast and reliable delivery of IP packets is critical. Prioritization is one method of increasing speed and interactivity within the existing network topologies.
Routing	IPv6 packets are moved from segment to segment using a simplified, hierarchical routing structure.	Routing under IPv4 is only partially hierarchical, relying also on large flat routing tables that can exceed 70,000 entries. Routing under IPv6, with its significantly smaller routing tables, requires less overhead at the router and is therefore more efficient and faster
Security	IP security standards (IPSec) previously optional under IPv4 are now required under IPv6. However, the advantages of IPv6's security features are still under study.	Standardized, layer 2 security reduces hacking activities.

[6] In Pakistan, a class C in 2000 cost $1050 to $1275 a year. Due to lack of addresses, the price of a class c almost doubled. In 2002, a class C cost $1900 to $2300 a year.
[7] 'Smart' Homes for Smart People by Reuters. 9:10 a.m. Feb. 2, 1999 PST

[8] Blazing trails: By paving paths for packets, MPLS could clear the way for IP convergence. Margot Suydam, Technology Editor -- *CommVerge*, 5/1/2002.

Mobile	Current implementation of mobile IPv4 requires the use of a foreign agent (FA) an home agent (HA) and a care-of (CO) address. The FA has to communicate that address through a tunnel back to the HA on the user's home network. Now, the packets from the corresponding node to the mobile unit always have to go through the HA. Since IPv6 supports auto-configuration capability, mobile IPv6 is simpler	ISP support of Wireless devices such as PDA, smart cars and Pocket PC
Multicasting	The built in multicasting in IPv6 should allow a server to send a single packet with multiple addresses. The ISP will do the final routing.	Allows several levels of multicasting and the creation of routing trees. This is a more efficient routing mechanism for applications such as Jini, which depend upon the ability to "discover" compatible devices on the network.

(Adapted from Microsoft, 2000)