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INTERNET TECHNOLOGY DIFFUSION: ADOPTION OF IPV6 [RESEARCH IN PROGRESS]

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ABSTRACT

With the explosive growth of the Internet in the 1990s, the scalability of current technologies has become a significant issue. The current version of Internet Protocol version 4 (IPv4) apart from some other drawbacks limits the number of available IP addresses. The next version of IP, version 6 (IPv6), provides a comprehensive solution to several limitations of current Internet technology. However, to date Ipv6 has not been widely adopted. Traditional diffusion theory suggests five factors that effect adoption of new technologies. Economists who suggest network externalities and economic returns as additional factors *provide an alternative perspective. This paper discusses these factors and how they are likely to influence the uptake of IPv6 by Internet Service Providers.*

1. INTRODUCTION

The Internet has grown exponentially in the 1990s raising concerns about the scalability of current technologies. The standard protocol used for Internet communication, TCP/IP, has presented some scalability problems. These limitations are evident in the current version of IP, called IPv4, and include the availability new addresses, traffic prioritization for smooth transmission of multimedia data, and security (NetworkWorld Fusion 2000). Separate solutions have been developed to address each of these issues. For example, address translation, increasingly affordable high-bandwidth capabilities, and Secure Socket Layer (SSL) technology have been developed to compensate for IPv4's shortcomings.

A single, comprehensive solution has been proposed that will serve as the future standard for Internet-based communication. The next version of IP, called IPv6, provides this comprehensive solution. The new protocol has a 128-bit address space (Metcalfe, 1998), Quality of Service (QoS) capabilities and increased security features. Further detail regarding some key advantages of IPv6 is provided in Table 1.

Despite these innovations in the IPv6 protocol, and its existence as a standard since 1993, IPv6 has yet to achieve widespread adoption. In fact a quick poll of 50 Internet Service Providers (ISPs) in the United States found that not even one of them had implemented the new protocol. In this paper we explore the factors that are likely to influence the adoption of IPv6 by ISPs to set the stage for an empirical study. In the next section, we will present the underlying theoretical basis for technology diffusion. We will discuss how factors suggested by alternative theoretical perspectives inform the issue of IPv6 adoption. Finally, we will conclude by introducing the next steps in our research.

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 x 10^{38} addresses, compared with 4.2 x 10^{9} possible addresses.	The number of unique IPv4 addresses is dwindling rapidly, leading to the use of complex and inefficient "address translation" to manufacture additional IP addresses locally.
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).	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 reliability 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.
Security	IP security standards (IPSec) previously optional under IPv4 are now required under IPv6.	The requirement of adherence to a single standard for security promotes interoperability across the Internet.

***Table 1:** Advantages of IPv6 over IPv4*
(source: Microsoft, 2000)

2. THEORETICAL PERSPECTIVES ON DIFFUSION

An innovation is regarded as the process of developing and implementing a new idea (Rogers 1983; Van de Ven 1986). Traditional diffusion studies consider diffusion of an innovation a social process of communication whereby potential adopters become aware of the innovation and are influenced to adopt the innovation over time (Rogers 1983). An alternative perspective to diffusion of innovations has been developed in the economics literature. Based on the concept of economics of standards, it is proposed that there are increasing returns to adoption for a potential adopter to the extent that others in the community of potential adopters also adopt the innovation. The two perspectives provide a set of factors to investigate the adoption of a new innovation.

2.1 Diffusion of Innovation Perspective

The depiction of diffusion phenomena as a communication process led to the study of influence of three groups of factors on adoption decisions: (i) innovation, (ii) adopter, (iii) communication characteristics. Rogers (1983) identified five generic innovation characteristics that influence adoption of innovations:

1. Relative advantage of the new technology with respect to existing technology
2. Compatibility with existing technology
3. The complexity of understanding the technology
4. The ease of trialability of the new technology

5. The observability of the benefits of the new technology

Similarly diffusion studies have tried to characterize potential adopters based on how and when they adopt an innovation (Rogers, 1983). Other studies have focused on the influence of communication channels and information sources on adoption decisions (see for example Nilakanta and Scamel, 1990; Rai, 1995).

2.2 Economics Perspective

Economists approach the diffusion phenomena as one where the diffusion of an innovation will be based on increasing returns to adoption (Arthur, 1996). The approach is predicated on the belief that the benefits of adopting an innovation will depend on the size (existing or potential) of the community of adopters. Economists have identified several sources for increasing returns from adoption of innovations. These are based on the incremental contribution of each additional adopter;

1. *Positive network externalities* among adopters (Katz and Shapiro, 1986), which suggest that benefits of adoption, are a direct function of the number of current adopters.
2. *Learning by using among adopters* (Rosenburg, 1982) that suggests that as the number of adopters increases, the accumulated experience of using the technology will keep increasing to provide increasing returns to adoption.
3. *Economies of scale* in production and learning-by-doing among producers, (Arrow 1962) a natural function of increasing volume where the cost of technology itself will decline increasing its attractiveness to adoption.
4. *General industry knowledge* about the innovation (Arthur, 1988), which is a natural consequence of learning by using among adopters.
5. *Rapid development of related technology infrastructure* (Arthur, 1988; Van de Ven 1993) as a large base of compatible products is introduced to support the innovation making it easier to adopt by potential adopters.

Farrel and Saloner (1987) suggest that potential adopters will base their adoption decisions on their expectation of an innovation's ability to achieve the critical mass. They argue that even if a standard is considered to be superior on the basis of objective criteria, a potential adopter may still fail to adopt the innovation, waiting for others to adopt first. Economists have identified the following factors that can determine if a particular innovation will achieve critical mass:

1. *Prior technology drag*, where the established base the existing installed base of prior technology provides negative network externalities to the adoption of the innovation.
2. Adoption of the innovation calls for investments that are *irreversible* with the risk of minimal or no returns if the technology fails to achieve critical mass.
3. Presence of *sponsorship*, that decreases the risk of adoption be promoting the technology, setting standards, subsidize early adopter, etc.
4. *Expectations* of widespread adoption can play a critical role in the adoption of an innovation. If a sufficient number of initial adopters do not expect widespread adoption, it is unlikely to achieve critical mass.

The two perspectives, diffusion and economic, can provide a more comprehensive approach to studying adoption. Using the two perspectives in a complementary fashion increases the breadth of analysis by covering factors at the community level to those at the level of the innovation.

3. THE CASE OF IPV6

Traditionally adopters have been characterized as leaders, initial adopters, late adopters and laggards, based on when they adopt an innovation. Based on the factors identified, we discuss how they are likely to influence different categories of adopters. Table 2 provides a snapshot of the analysis while we discuss the adoption by leaders and laggards as logical contrasts.

Characteristics of the adopting ISP	Leaders	Early adopters	Later adopters	Laggards
Barrier to adopt - Culture	Adaptive and creative company. Barriers to change are relatively low.	Barrier to adopt is high but the culture is of change and innovation	Barrier to adopt is low but the culture does not support quick adoptions and change	Barriers to adopt are high. Culture does not support change
Compatibility	No need for long term backwards support	Need for some backward support	Need for support of both Ipv4 and v6	Need to continue support of Ipv4
Complexity	Available skills and R&D capabilities	Available skill. Technology is acquired externally	Skills and technology can be obtained	No available skills increase the complexity of installation and management
Cost to convert	High	Medium	Medium	Low
Crisis	Major impact	Impact	Some impact	No impact
Drag	Low	Medium	Medium	High
Existing sunk cost	High	High	High	High
Inertia	Low	Medium	Medium	High
Maturation	Create early prototype	Trials with new technology	Wait until standard is establish	Will only adopt fully mature technology
Network Externalities	Partnerships with H/W and S/W suppliers and standard setting consortium	Cooperation with H/W and S/W suppliers	Minimal networking	None
Observability – the ability to observe the benefits	Significant factor	Important factor	Minor factor	Not a factor
Relative Advantage	Creating competitive advantage	Following industry leader	Survival	Niche market. Ipv6 does not provide an advantage
Sponsorship	Major governmental involvement	High	Medium	None
Technical features align with market trends	Market driver	Highly aligned	Some alignment	Market is not interested in the technical features provided
Technological interrelatedness	No interrelated tools are available. Need to develop them	Few interrelated tools are available.	Interrelated tools are available	Current tools are completely interrelated with Ipv6
The need for supply of new IP addresses	Supply << demand	Supply < demand	Supply = demand	No current demand for new IP addresses
Triability- the ability to pilot test	Significant factor	Important factor	Minor factor	Not a factor

Table 2: *Characteristics of Four Types of Adopting ISPs*

3.1 The "Leaders"

The culture of the Leaders is that of innovation, creativity and change. The leading adopters of IPv6 are likely to be companies that traditionally partner with networking hardware suppliers (e.g., Cisco) or software suppliers (e.g., Sun). These companies would be involved in standard setting activities and active in standard setting consortiums such as the Internet Engineering Task Force (IETF). Therefore, the level of inertia is low and so is the drag. Despite the high cost to convert and high existing sunk costs, the barriers to adopt would be relatively low as technology upgrades would be a part of the companies on-going budget.

These leaders would create early prototypes, invest heavily in R&D, and are likely to implement it at a very early stage. If the technology is not mature and related technologies are underdeveloped, the leaders and their partners develop these tools. The leaders may have a lower supply of new IP addresses than their clients demand, and might be involved with innovative Internet based applications, such as smart appliances that require an increasing numbers of IP addresses. They will look to gain competitive advantage by leading the implementation of IPv6 and driving the Internet market. Alternatively, the leaders might be companies in countries that have a limited supply of IP addresses and are facing major crisis in the growth of e-commerce providing an impetus for strong sponsorships and even major governmental involvement.

Triability, the ability to run pilot testing and observability, and the ability to observe the benefits from the product are significant factors. The leaders need to be able to prove that IPv6 will create the competitive advantage they anticipate and reap the predicted benefits.

3.2 The Laggards

The culture of the Laggards is of standard operating procedures and structure. The lagging companies in adopting IPv6 would be companies that serve stable or niche markets and are not involved in standard-setting activities or in the development of new products. Therefore, the levels of inertia and drag are high. Despite the low cost to convert, the barriers to adopt are high because upgrading skills is uncommon and costly. Resistance to change is high by customers and the company.

These laggards hardly invest in R&D and will only adopt a fully mature technology. They are likely to have no need for a supply of new IP addresses since their clients have low demands. These companies serve traditional and unsophisticated Internet user (e.g., AOL). Thus, the implementation of Ipv6 does not provide them with a major competitive advantage. Alternatively, the laggards might be companies in countries that have an ample supply of IP addresses and alternative technologies to resolve the addressing crisis. These ISP will not enjoy strong sponsorships.

The laggards will implement the new protocol at a very late stage and only when the level of maturation is very high. Since the laggards serve a traditional market they will have to continue to support IPv4 for a while. Despite the availability of interrelated technologies and maturation, the complexity of the installation will be high due to the laggards' lack of available skill and R&D capabilities. Other factors are not likely to be significant as they are likely to have more influence in early stages of diffusion.

4. NEXT STEPS

The diffusion of new standards in the Internet environment is a relatively new phenomenon, and there is little if any research on the overall implementation of new Internet technologies to date. The next step for this project is to complete the formulation of the scenarios for IPv6 adoption. This involves the grouping of the characteristics in Table 2 into broader categories that will allow for more general conclusions to be drawn, and supporting our scenario descriptions with anecdotal evidence.

After the completion of the scenario exercise, we plan to test the conclusions drawn from that analysis using case studies. Yin (1994) suggests that exploratory studies that address the question of why something is done should use case methodology. Eisenhardt (1989) suggests that case studies may be used to build theories when little is known about a phenomenon, or in the early stages of research on a topic. Hence, the exploratory nature of the study calls for the use of a multiple case study methodology to explore alternative perspectives and explanations. We will select ISPs that are likely to fit the profile of each category of adopter to fully explore the influence of different factors. Following the case studies, we plan to empirically validate the conclusions drawn from the cases using a large stratified survey of ISP in various countries.

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