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A COMPARISON OF ATTITUDES TO IPV6 IN THREE COUNTRIES

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Abstrak

Internet Protocol (IP), the underlying protocol upon which the Internet is based, has a number of serious flaws, including limited address space, security and performance limitations. Since the early 1990s a new version of IP (IPv6) has been developed in which these problems are addressed. Yet despite years of "hype", adoption of IPv6 has been minimal or non-existent. Many efforts have been made to encourage IPv6 adoption around the world but none have been widely successful.

The decision to adopt is influenced by the information available to the decision maker. This paper reports the results of studies of attitudes and perceptions to IPv6 in three countries and determines that the prevalent information about the standard in each country is often scarce and inaccurate. This contributes to reluctance to adopt IPv6 and further exacerbates the problem. The paper concludes with recommendations to improve available information so as to increase IPv6 acceptance and adoption.

Key words: IPv6, Jaringan, Difusi Teknologi

1. INTRODUCTION

IP (Internet Protocol) is the protocol that governs all communication on TCP/IP networks such as the Internet. Its development commenced in 1973 and was based on NCP (Network Control Protocol), the protocol in use on ARPANET at that time. TCP/IP became the official set of protocols for use on the Internet on 1983 and is today referred to as "IPv4": the fourth version of IP[1].

Today the TCP/IP protocol suite includes hundreds, if not thousands, of protocols for specific purposes such as the transmission of email, files and web pages, instant messages and multimedia. All of the higher protocols in the TCP/IP family rely on IPv4 for basic communication across the Internet, and thus every transmission on the Internet, regardless of what it is, depends on the smooth functioning of IPv4.

The researchers, scientists, and engineers responsible for the development of IPv4 could not have anticipated the extent to which the Internet would grow, and the applications for which it would eventually be used. Consequently, design decisions were made that, while appropriate and sensible for the time, are anachronistic and inappropriate today.

[1] This seemingly curious choice to start at version 4 was made due to three previous versions that had been called TCP rather than IP.

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Chief among these is the limited address space present and the inefficient way in which IP addresses are structured. IPv4 uses a 32-bit address space, which has the implication that there is a theoretical maximum of 2^{32} – approximately 4.3 billion – addresses. While this may seem a large number, it must be considered in conjunction with inefficiencies in address allocation methods, and with the exponential growth of the Internet that commenced in the 1990s. By the late 1990s measures had been introduced to improve the efficiency of address allocation and to slow the rate at which addresses were required to a linear rate. Nevertheless, even with these measures in place, current projections are that the IPv4 address space will be exhausted by approximately 2011-2012 (ARIN, 2007).

IPv4 also suffers from security problems, such as its inability to provide authentication or to provide standard encryption measures to packets transmitted across the Internet. Although many third-party solutions are available to provide these features, such measures are not universally adopted, suffer from incompatibility problems, and are typically only implemented to protect "important" transmissions, such as online banking or B2B transactions. Consequently, a huge volume of today's Internet traffic remains unencrypted and unauthenticated, and many of the problems such as Denial of Service (DoS) attacks that currently plague the Internet can be traced back to the insecure design of IPv4.

Further, IPv4 was not designed to scale to networks the size of today's Internet. Backbone routers on the Internet today manage routing tables of up to approximately 250,000 records; further, these tables are growing at an exponential rate (Nimpuno and Ross, 2007). As larger routing tables contribute to increased delays as packets traverse the Internet, it is clearly desirable to minimise the size of routing tables.

Fortunately, a new version of IP was developed in the early- to mid-1990s. This version, known as IPv6[2], addresses all of IPv4's weaknesses described above. Most important among its benefits is its increased address space, which at 128 bits provides 2^{128} – approximately 3.4×10^{38} – addresses. It has been said that this is enough to provide a unique address for every grain of sand on Earth (Wiljakka, 2002). Another way of looking at this figure is that it is enough to provide 6.7×10^{23} addresses for every square metre of the Earth's surface. Clearly, IPv6 should be able to provide adequate address space for the foreseeable future.

As IPv4 address space exhaustion is predicted to occur possibly within the next five years, and given the size of the migration task, it would be wise to begin the transition as soon as possible. It is noted that this migration involves not only upgrading netwok devices such as the routers and switches that carry Internet traffic, but end-user technologies such as PCs and applications. Further, the longer this situation remains, the bigger the migration task becomes as the Internet continues to grow.

[2] A fifth version of IP, IPv5, does exist, but was an experiment in multicasting and was not intended to be a replacement for IPv4.

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Nevertheless, IPv6 is available and ready and the transition frameworks are in place for the transition to occur. Attempts have been made to promote IPv6 adoption in the past but none have had widespread success. What is lacking is motivating and convincing current users of IPv4 to upgrade to IPv6. As with all technology adoption decisions, people will decide to adopt – or not to adopt – IPv6 based on their perceptions and beliefs about the technology. This will be so even in cases where those perceptions and beliefs are inaccurate.

In order to facilitate widespread adoption of IPv6, its promoters need to understand the information and beliefs that guide those that are the targets of IPv6 campaigns. Yet little is known of public knowledge and perceptions of IPv6. Consequently, and drawing on diffusion of innovation theory, we report the results of studies in three countries examining the attitudes to and perceptions of IPv6. The paper is structured as follows. The next section provides a brief discussion of the theory of diffusion of innovation. This is followed by discussion of the three studies from Indonesia, Mauritius and Western Australia. The paper concludes by drawing comparisons between the studies and makes some observations informing communities working to promote the diffusion of IPv6.

2. DIFFUSION OF INNOVATION

Although IPv6 is strictly speaking a standard rather than a technology, standards compete for adopters in the same was as new technologies and diffusion of innovation theories can be applied to standards (Hovav *et al*., 2004).

This paper is informed by Everett Rogers' (1995) classic model of the diffusion of innovation, one of the most – if not *the* most – widely used theories in this area. Hovav *et al*. (2004) assert that this approach has some deficiencies with respect to Internet standards, particularly its focus on the adoption decision of individual firms, and that it overlooks the influence of external factors such as community effects. The focus in the three studies reported here is on the perceptions and attitudes of relevant ICT practitioners, and is thus primarily concerned with the Knowledge and Persuasion stages of Rogers' model. Thus, the effects of the shortcomings identified by Hovav et al. have only minimal relevance to the current paper. Nevertheless, they are relevant in some respects and are drawn upon where useful.

Rogers' Model

The process in which the decision is made to adopt a technological innovation is made is composed of five stages: Knowledge, Persuasion, Decision, Implementation and Confirmation (Rogers, 1995).

In terms of Rogers' (1995) analysis of the diffusion of innovation, this study is primarily concerned with the Knowledge and Persuasion stages. Analysis of the subsequent three phases is currently inappropriate as there are almost no organisations in any of the three countries investigated that have decided to adopt IPv6.

ISSN Print : 2085-1588
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The knowledge stage refers to the ways in which people become aware of new technological innovations, and focuses socio-economic, personality and communication characteristics of the decision-maker. The persuasion stage refers to ways in which a favourable or unfavourable attitude toward the innovation is formed. Individuals become more involved with the innovation and actively seek more detailed information about the innovation in order to reduce uncertainty.

Persuasion to adopt an innovation is affected by five factors (Rogers, 1995):

1. Relative advantage – whether the innovation will give the adopted an advantage – can be measured in economic terms, social prestige factors, or convenience and satisfaction. Previous empirical studies suggest that relative advantage plays a particularly important role to determine the level of diffusion a new idea or technology (Teo *et al.*, 1999, Moon and Kim, 2001; Achjari, 2003).
2. Compatibility – whether the innovation is compatible with the adopter's organisation – includes compatibility with existing work practices, preferred work style, prior experience and values (Agarwal and Karahanna, 1998). Increased compatibility results in lower switching costs.
3. Complexity refers to the difficulty involved in implementing the innovation. Those who believe that a new system is too complex and beyond their ability to implement will be reluctant to adopt it (Igbaria and Iivari, 1995, cited in Achjari, 2003).
4. Trialability is the possibility of trialling an innovation before committing to it. When users consider adopting an innovation they face uncertainty as to whether it will yield a benefit or a detriment. The possibility to conduct an experiment or trial reduces risk (Rogers, 1995), and there is a significant link between early adopters and trialability (Hovav and Schuff, 2005). However, to provide this capability often requires significant investment, and often support from consortia or government. In the case of IPv6, countries such as Japan, China and South Korea have strong government support to deploy IPv6.
5. Observability refers to opportunities to first observe the innovation and learn from others' experiences. If individuals can see the result of the implementation of an innovation from others they are more likely to adopt. Users in the late majority and laggard categories tend to adopt a new technology only after it has been widely adopted, and the possibility to observe others' experiences is maximised (Hovav *et al.,* 2004).

3. THREE STUDIES

Studies of ICT community attitudes towards IPv6 in Indonesia (Syamsuar, 2005), Mauritius (François, 2006) and Australia (Choy, 2003) have been conducted at the School of Information Systems, Curtin University of Technology. This section summarises the results from each of these studies and compares them in a tabular format, leading to the conclusions and recommendations described in the next section.

ISSN Print : 2085-1588
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http://ejournal.unsri.ac.id/index.php/jsi/index

3.1. Indonesia

The survey of Indonesian ICT practitioners, conducted in 2005, received 90 responses. 26% of these were from the Internet and telecommunications industry, and 43% from the education industry – a major consumer of Internet services in Indonesia. The remaining respondents were from other industries. Indonesia is a developing country with low Internet penetration in general; a recent estimate is only 3.4% (www.InternetWorldStas.com, 2004). For this reason, although the sample used in the Indonesian study was not representative of society at large, it is considered representative of organisations relevant to the potential diffusion of IPv6.

The results indicated that participants had a high level of awareness of the looming difficulties facing the IPv4 address space. 88% of respondents had some knowledge of IPv6, and there was widespread belief that IPv6 exists to solve the address space difficulties facing IPv4.

These difficulties facing IPv4 were believed to be of an urgent nature, and 76% of respondents believed that IPv4 address space exhaustion would occur in the near future. Only 16% believed that NAT, CIDR or similar technologies would solve IPv4's problems. Although almost 75% believed that IPv6 was important for their organisation's future, only 39% believe that IPv6 should be implemented at the current time. The prevailing perspective was thus somewhat paradoxical: IPv6 is a highly important and pressing issue, but it is not yet time to adopt it.

This paradox is perhaps partly explained by perceptions of the cost of adopting IPv6. Almost half (47%) of the respondents in the Indonesian study believed that IPv6 would involve high costs, while only 25% believed it would not. It is noted here that past research has noted the importance of switching cost, even in developed countries (Bohlin and Lindmark, 2002; Hovav *et al.*, 2004; Pau, 2002), so its importance in a developing country such as Indonesia is not surprising.

The importance of cost is also highlighted in the finding that the majority (57%) reported that they would adopt IPv6 if a suitable financial incentive or subsidy was provided. The opportunity to trial or test IPv6 prior to implementation was also important: 79% of respondents indicated this would influence their decision to adopt IPv6, while 90% felt the provision of adequate training would also be important.

It is possible that reluctance is due in part to lack of information about IPv6 support from vendors. Although most major vendors support IPv6, only 58% of respondents understood their vendors' IPv6 capabilities, and there was a fairly high level of respondents who were unsure in this regard (33%).

Finally, these findings indicate that in terms of Rogers' model of diffusion of innovation, Indonesian organisations are still largely at the knowledge stage. Although they had basic knowledge of IPv6 and the problems it addresses, many respondents lacked detailed knowledge of key aspects such as vendor support. Further, the majority of respondents were yet to be persuaded to adopt IPv6 and were not actively seeking

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information about it. In terms of Rogers' terminology, the majority of respondents (61%) were either "late-majority" or "laggards", and will adopt IPv6 only after is already widely adopted.

3.2. Mauritius

The Mauritian study was carried out in 2006 and made use of qualitative interviews with relevant and knowledgeable ICT practitioners from both service providers and regulatory bodies (supply side) and potential consumers (demand side) of IPv6 technology. Three organisations were selected to take part in this study and a key person in each of these organisations was interviewed in regards to their perception towards new technologies in general and also more specifically to the reasons for IPv6's non-adoption.

There was general agreement among all the respondents that very little or no knowledge about IPv6 outside of ICT specialist roles. This corroborated François' (2006) conclusion, when a prior attempt to carry out a wider, quantitative survey in Mauritius was confronted with such a high lack of awareness of IPv6 that a practical sample could not be obtained.

Another key point to arise from the Mauritius study was the serious lack of information and guidance available to the organisations considering the adoption of IPv6. All participants from the demand side perceived that this was due not only to a lack of guidance from the ICT governing bodies, but also due to the fact that much remains to be done in terms of policy, legal and regulatory endeavours and infrastructure development.

The severe shortage of ICT labour in Mauritius also prevents experimentation with new technologies in that field because most resources are utilised to maintain current technologies. The Mauritian government has attempted to counter this by providing training though the National Computer Board (a government ICT training and regulatory organisation). However, this organisation does not provide any IPv6 training.

ICT professionals in Mauritius also have no awareness of the benefits of IPv6 beyond its expanded address space. This was particularly true of the security benefits, and it was noted by the participants that security issues have been only partially addressed by the authorities in Mauritius. The widespread use of NAT also contributes to widely held perception among the Mauritius ICT community that there is plenty of IPv4 address space still available. It is noted that this has actually been quite true since the rate of consumption of IPv4 addresses slowed considerably since the late 1990s; however, recent IANA predictions are that unallocated IPv4 address space will be exhausted at some time in late 2010[3] (IPv4 Address Report, 2007).

[3] This date is of course only a prediction, but it is unlikely to be out by orders of magnitude.

Perceived cost was also identified as a major barrier to adoption. Participants felt that widespread assumption of the need to upgrade a large proportion of custom applications and network hardware to support the new protocol. Further, even though Mauritius is suiting up to make IT development a major pillar of its economy, the scarcity of bandwidth for international traffic still leads to high prices for Internet connections, thus slowing down the Internet penetration in general.

Finally, the Mauritius study observed that the view that ISPs should be leading the way in terms of IPv6 adoption was widely held. In the words of one participant, Mauritians tend to "stick to technologies that have proven themselves"; another noted that the attitude that "if it's not broken, don't fix it" is commonplace. In this respect, the ICT community in Mauritius is similar to that in Indonesia, and can be characterised in "late-majority" or "laggards" in terms of Rogers' model.

3.3. Western Australia

A survey was conducted in Western Australian in 2003 and received 62 responses; although this is slightly earlier than the Indonesia and Mauritius studies, IPv6 has not been prominent in mainstream ICT press in the interim and opinions are unlikely to have changed much. The survey sample consisted of ICT practitioners in medium to large organisations.

Awareness of IPv6 was low – only 38% of respondents had heard of IPv6 – and the majority those who had heard of IPv6 had done so through training or education, rather than through industry experience. The authors believe that this figure would be somewhat greater if a similar study were conducted today, although the means by which people learn about IPv6 would not be any different.

While general awareness of IPv6 was low, 71% of those with IPv6 knowledge had at least moderate knowledge of the degree of IPv6 support in operating systems and applications in use. This suggests that those who were aware of IPv6 tended to have considerable knowledge about its potential application in their own organisations.

None of the organisations that responded to the Western Australian study had adopted IPv6, and the survey investigated influences behind non-adoption. Key among these (58% of respondents) was a belief that NAT was a sufficient and that IPv6 was thus unnecessary. Indeed, 42% of respondents with IPv6 knowledge had no plans for IPv6 in the foreseeable future.

As well as the belief that IPv6 was unnecessary, there were also substantial concerns that its implementation would be difficult. For example, 17% cited concerns that support would be difficult to obtain; similarly, 17% reported needing more knowledge before moving to IPv6, indicating that the Western Australian ICT community was still in the knowledge stage of Rogers' model. Indeed, 83% reported having no information about migration from IPv4 to IPv6.

Further, 21% of respondents were concerned about compatibility problems with their organisation, while 8% felt that IPv6 was not yet standard enough. Cost of transition was also a significant concern (17% of respondents), although this is a smaller proportion of respondents than that found in the Indonesian study.

Finally, as with Indonesia and Mauritius, Western Australians can often be categorised as "laggards" or "late majority". Concern about being an early adopter was prevalent; 29% expressed explicit concerns about this issue. 21% were waiting for customers to demand it, 21% were waiting for ISPs to provide it, and 12% were waiting for widespread use.

3.4. Comparison of the three studies

The three studies are compared in Tables 1 and 2. Table 1 compares factors that influence the knowledge stage, while Table 2 compares factors that influence the persuasion stage. Despite the obvious differences between the three countries, particularly economic differences, there are some similarities between the results of the three studies.

Table 1: Factors influencing the knowledge stage

Factor influencing knowledge stage	*Indonesia*	*Mauritius*	*Western Australia*
Level of awareness	Level of awareness was high among relevant ICT practitioners.	Level of awareness was low among relevant ICT practitioners. IPv6 information is very difficult to find in Mauritius, and very few guidelines are available for interested ICT practitioners.	Level of awareness was low among relevant ICT practitioners.
Need for IPv6	Majority believed IPv6 was necessary in the long run and relatively few believed that NAT/CIDR would solve problems. Perceived need for IPv6 attributed to IPv4 address space shortage rather than other factors (performance, security).	Lack of awareness of need for IPv6 beyond IPv4 address space issues. There is an assumption that NAT will solve problems and that IPv4 address space is available. In the words of one interview participant, “if it’s not broken don’t fix it”.	Majority did not perceive a need for IPv6 and believed that NAT is sufficient to solve address shortage problems.
Urgency of IPv6	Majority believed that IPv4 address-space exhaustion would occur in the near future.	Perception that there is a need for work to be done in policy, legal and regulatory, and infrastructure areas before IPv6 is viable.	Some waiting for customers to demand it and others waiting for ISPs to provide it. Many had no plans for the foreseeable future, and none had plans other than long-term.

Table 2: Factors influencing the persuasion stage

Factor influencing persuasion stage	*Indonesia*	*Mauritius*	*Western Australia*
Relative advantage	Majority believed IPv6 will be an important technology for their organisation. High dissatisfaction with IPv4, suggesting that retaining IPv4 might be disadvantageous. The advantage of IPv6 was perceived to come at a high initial cost, however.	High cost of transition to IPv6 perceived to be a barrier to adoption. High level of satisfaction with IPv4 suggests IPv6 is not perceived to provide a relative advantage.	Some worried about cost of transition. Majority believed IPv6 would not improve performance.
Compatibility	Majority believed that IPv6 will not pose compatibility problems with IPv4, although only 35% of respondents were confident of compatibility with applications.	Largely unknown due to low level of awareness. Some concerns about custom applications requiring modification, and some concerns about network devices requiring upgrades.	Majority who have at least heard of IPv6 also have some idea of compatibility with applications and network devices. Some concern about compatibility with applications and network devices. Some concerns that IPv6 standards are not mature.
Complexity	High degree of uncertainty regarding the complexity of IPv6, and up to one third or more respondents may have a knowledge barrier increasing the perceived complexity of IPv6.	Shortage of labour with relevant skills in Mauritius may exacerbate any perceived complexity of IPv6 adoption.	Minority expressed concerns about support. Minority expressed concerns that they do not have enough knowledge. Majority had no information about migration, increasing the perceived complexity of IPv6.

Trialability	Majority wanted training and the opportunity to experiment with IPv6 before adoption.	Without the opportunity to test IPv6 in advance, most Mauritian ICT practitioners will defer IPv6 adoption.	No data gathered.
Observability	Majority of respondents were "late-majority" or "laggards".	Quantitative data not gathered, although perception is that Mauritian ICT practitioners are typically "late-majority" or "laggards".	Some waiting for widespread use, some waiting for customers or ISPs to move first. "Late-majority" and "laggards" are common.

4. CONCLUSIONS

The context differs between the three countries, particularly in terms of different levels of knowledge and awareness of IPv6. There are also varying perceptions of need and urgency of IPv6 between the three studies, and whether IPv6 would provide any competitive advantage. Thus, it is concluded here that strategies to promote IPv6 adoption in each country should be customised to suit the local context.

Nevertheless, although there are differences from one country to another there were considerable similarities and availability of information is a problem in all three countries. Addressing this will be key to addressing IPv6 non-adoption as knowledge is the first stage of the adoption cycle.

One area in which information is lacking is in the technical case for IPv6. Symptomatic of this is that there was little awareness of issues other than address space, such as security and performance, and although perceptions of the advantages IPv6 may confer differed between countries, opinions were generally based on address space concerns, leading authors to the conclusion that although a wealth of technical information is already available is appears not to be fully appreciated by ICT professionals. Thus, efforts should be concentrated on ensuring such information effectively reaches a wider range of industry personnel.

Further highlighting the lack of IPv6 knowledge were concerns about compatibility, despite the fact that mechanisms to facilitate migration from IPv4 to IPv6 with no loss of connectivity have been available for many years. (Indeed, there are a number of advocacy websites which can be reached via both IPv4 and IPv6 to demonstrate the point.)

Another similarity is the impact risk aversion will have in each of the three countries. IPv6 is unlikely to gain acceptance beyond a curious novelty until trialability and observability are possible; thus, as well as improving access to technical information, efforts by parties concerned with broadening IPv6 adoption should consider programs which facilitate obtaining and exchanging first-hand experiences among industry practitioners.

Finally, it is noted here that although measures such as these may help to increase adoption in organisations that perceive a business benefit, there is a clear need to address the business case in general. Information in this respect is hard to find, and indeed, making a business case for first movers is difficult because of the demand for interoperability with legacy IPv4 networks (see Hovav *et al.*, 2004). This raises other issues beyond the scope of this paper, but is flagged here as a high priority issue for future research.

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