Australian IPv6 Readiness: Results of a National Survey

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IPv6 is the replacement for the Internet's incumbent protocol, IPv4. Although exhaustion of the IPv4 address space is now imminent there has been no meaningful uptake of IPv6 since its standardisation in 1998. Data from a national survey of the top 1,000 IT user organisations in Australia are analysed, revealing that they have made little or no preparation for IPv6. This creates the potential for considerable disadvantage for Australian organisations. The author recommends that governments and regulatory bodies should consider regulatory or policy action to encourage the diffusion of IPv6. The author also recommends that enterprise organisations develop a long-term IPv6 strategy, implement IPv6 training programs, update their policy frameworks, and assess their IT assets and applications portfolios.

Keywords: IPv6, readiness, Australia, survey

ACM Classification: C.2.2

INTRODUCTION

On 3 February 2011, ICANN held a press conference in Miami, Florida in which the last remaining IPv4 address blocks were allocated to the five Regional Internet Registries (RIRs). The significance of this announcement is clear: the IPv4 address space is now almost entirely consumed and the only address space available is that in the RIRs' working inventories.

The following month, Microsoft bid US$7.5 million to buy a block of 666,624 IPv4 addresses, or US$11.25 per address (BBC, 2011), in the first real indication of a market price of IPv4 address space as the era of virtually free allocations comes to an end. This was quickly followed by the launch of at least four websites that broker sales between IPv4 address buyers and sellers (Marsan, 2011).

The emergence of a market for IPv4 address space can be predicted by economic theory (Dell, Kwong and Liu, 2008). As it is impossible to connect to the Internet without an address, IP addresses can be considered as analogous to "Internet connection permits". Just as permit systems have often been used to limit the use of technologies with negative environmental consequences, the fixed number of IPv4 addresses limits growth of the IPv4 Internet. When the number of permits is constrained, permit trading is an obvious outcome where permitted by regulations – and the greater the demand for IPv4 connectivity the higher the permit price will be. It is only when the cost of IPv4 exceeds the cost of IPv6 that one would expect to see large scale adoption of the latter (Dell, 2010).

Given that the cost of deploying IPv6 includes not only the cost of IPv6 address space but the cost of training, upgrades to equipment and applications, and labour costs for a wide variety of other

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tasks, if left entirely to market forces it is possible that the market price for IPv4 could grow well beyond this initial indication before IPv6 experiences significant growth.

On the other hand, market forces are not the only means to encourage technology adoption. Regulatory and governmental organisations can have a powerful influence on the adoption of new technologies (Hall and Khan, 2003), and just as regulation has been used to regulate environmental technologies it could also be used to regulate IPv4 and IPv6.

Whether market forces will lead to IPv6 diffusion in the near future, whether some form of regulation might be necessary, or some combination of the two is unclear. For some time it has been accepted that organisations should start working towards IPv6. For example, the Gartner group recommended in 2008 that enterprises should start planning for IPv6, including training, inventory work, and ensuring that long-term investments were IPv6-ready (Rickard, 2008); however, despite the importance of early planning and the scale of the IPv6 migration task ahead, anecdotal reports suggest enterprises are not well-prepared.

This is a significant issue for two reasons. First, now that IPv4 is practically entirely exhausted, it is possible that IPv6 adoption will now see more rapid growth. Organisations that are not well-prepared for IPv6 may find themselves at a disadvantage; low levels of IPv6 readiness could thus constitute a significant problem for the Australian ICT industry.

Second, if the majority of organisations are not making any effort to prepare for IPv6, it is likely that widespread adoption of IPv6 is still some way off, and in all probability the market price of IPv4 address space could grow considerably. In this case, stronger action from regulatory authorities to encourage IPv6 adoption might be desirable. Further, the scenario in which IPv6 does not achieve a critical mass is not unthinkable if enterprises are not preparing for IPv6 at all. Indeed, potential IPv6 adopters may base their adoption decisions based on their expectation of IPv6's capability of reaching critical mass (Hovav, Patnayakuni and Schuff, 2001).

There have been no prior empirical investigations into the scale of this potential problem. If empirical research supports anecdotal reports of complacency, this may inform policy decisions that affect IPv6. This study provides such an empirical investigation into Australian enterprises' IPv6 readiness; related literature is reviewed in the following section.

AUSTRALIAN READINESS FOR IPV6

Practically nothing is known about Australian organisations' IPv6 readiness. The only study to date is a market research report commissioned by the Communications Alliance (Market Clarity, 2009), which assessed Australia's "market readiness". The Communications Alliance report was based on data collected from carriers and ISPs, and network equipment and software vendors and thus focused on the supply side of IPv6 (reflecting the alliance's membership of vendors, service providers, suppliers and consultants). It concluded that most carriers and service providers could move quickly to IPv6 when required to do so, that all carrier vendors and most enterprise vendors were able to support IPv6, but that there was very little demand from customers. Thus, the Communications Alliance report concludes that the greatest obstacle to IPv6 diffusion in most markets was not so much "readiness" but "willingness".

The Communications Alliance's finding must be interpreted with caution. The report was based on minimal data – 14 carriers and service providers, nine carrier equipment/software vendors, eight enterprise vendors (some of which were also included in the carrier/service provider data), and only five consumer vendors. However, the lack of demand for IPv6 has also been observed by other authors (e.g. Edelman, 2009; Huston, 2006) and it therefore seems likely that demand-side issues are a major challenge to Australian IPv6 adoption.

Nevertheless, there is no published research into demand-side aspects of IPv6 readiness in Australia, or indeed in any country. Without concrete knowledge of the IPv6 readiness of Australian organisations in general, it is difficult for practitioners and governments to achieve a well-managed transition, as opposed to a knee-jerk transition in response to complete exhaustion of IPv4 address space – or worse, no transition at all. This study fills this research gap by illustrating the "state of play" of IPv6 readiness among demand-side organisations in Australia. It was hypothesised that the government sector would have a higher level of readiness than others. This was due to the Australian Government's "whole-of-government" plan for the transition, which aims to have it completed by the end of 2012.

Although there has been no empirical research into Australian end-user organisations' actual readiness for IPv6, more is known about how organisations should prepare for it. Although adoption remains extremely low worldwide, a small but growing number of organisations that have made the transition and from such cases it has been possible to develop guidelines for the transition.

Prominent among these is Grossetete *et al* (2008), a text aimed at practitioners that describes a number of case studies of both service provider and enterprise organisations, and which provides detailed guidelines for planning the transition. This study assesses Australian end-user organisations readiness for IPv6 in terms of these guidelines; the method used is described in the following section.

METHOD

Based on recommendations in Grossetete *et al* (2008), a questionnaire was developed to investigate organisations' IPv6 readiness. Five facets of organisations' IPv6 preparedness were investigated, details of which are provided in Table 1.

Facet	*Specific aspects*
Training	• Has training in IPv6 technology been provided? • Has training in IPv6 deployment been provided? • Has training in IPv6 security been provided? • Has training in configuring IPv6 equipment been provided? • Has training in configuring IPv6 in operating systems and applications been provided? • Has training in developing IPv6 applications been provided?
High-level planning	• Has IPv6 planning commenced? • Has an IPv6 strategy been developed? • Has an IPv6 project been created?
Assessment of the current environment	• Have training requirements been assessed? • Have IT assets been assessed for IPv6 requirements? • Has the applications portfolio been assessed for IPv6 requirements?
Policy frameworks	• Have purchasing policies been updated to incorporate IPv6 requirements? • Have application development policies been updated to incorporate IPv6 requirements? • Have security policies been updated to incorporate IPv6 requirements?
IPv6 deployment	• Has the organisation done IPv6 address planning? • Has the organisation deployed IPv6?

Table 1: Facets of IPv6 readiness

Because the value of early planning was clear across all of the case studies examined by Grossetete *et al*, leading to a smoother and less expensive IPv6 deployment, the questionnaire also assessed respondents' perspectives of the importance and urgency of IPv6.

The questionnaire was distributed as a nation-wide, single-round postal survey to CIOs or similar individuals at the top 1,000 Australian IT users. This included corporations, state and federal government departments, and not-for-profit organisations, ranging in size from approximately 600 to over 230,000 screens.

Twenty nine surveys were undeliverable, resulting in a total sample size of 971. Of the surveys that were successfully delivered, 180 responses were returned, giving a response rate of 18.5%. This was considered acceptable, particularly as surveys delivered to CEOs, managing directors, HR directors and other senior executives typically have lower response rates than other surveys (Baruch, 1999). A summary of the responses is provided in the next section, followed by discussion and analysis.

Respondents were asked to report in which industries they were active using industry descriptors from the 1993 Australian and New Zealand Standard Industrial Classification (ANZSIC). A summary of respondents' industries is shown in Figure 1. No individual category constituted a majority of the responses; however, between them the Education, Manufacturing and Government Administration and Defence categories comprised 55% of responses. These are large sectors in Australia, and the results are considered to represent a good cross-section of large Australian organisations.

Respondents were also asked to report the size of their organisation. Results are illustrated in Figure 2. 75% of responses were from organisations of over 1,000 employees.

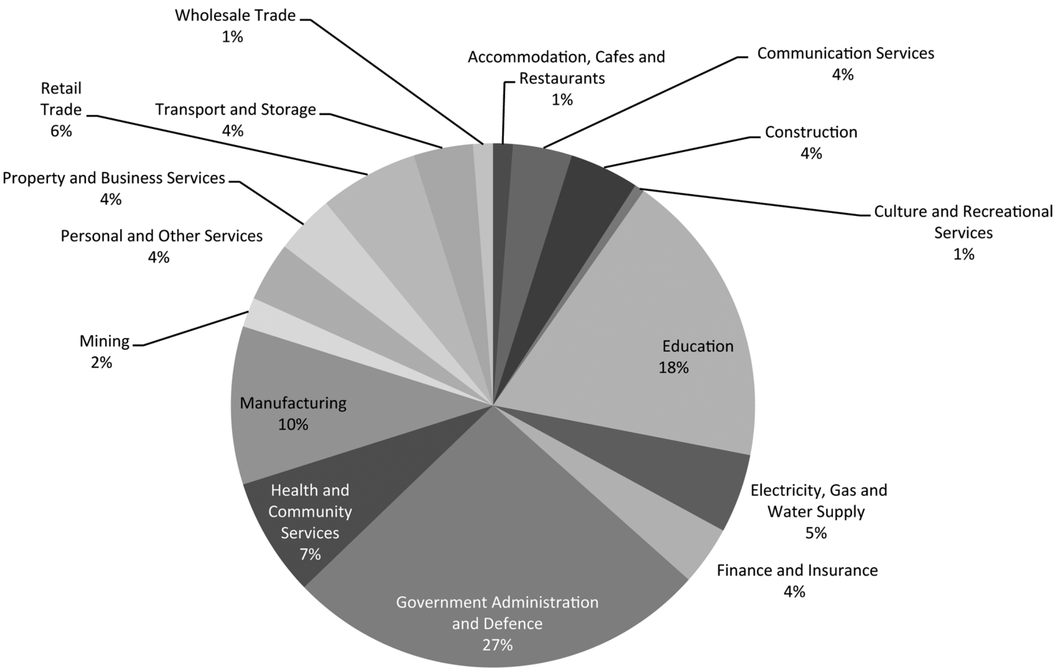

Figure 1: Respondents' industry categories

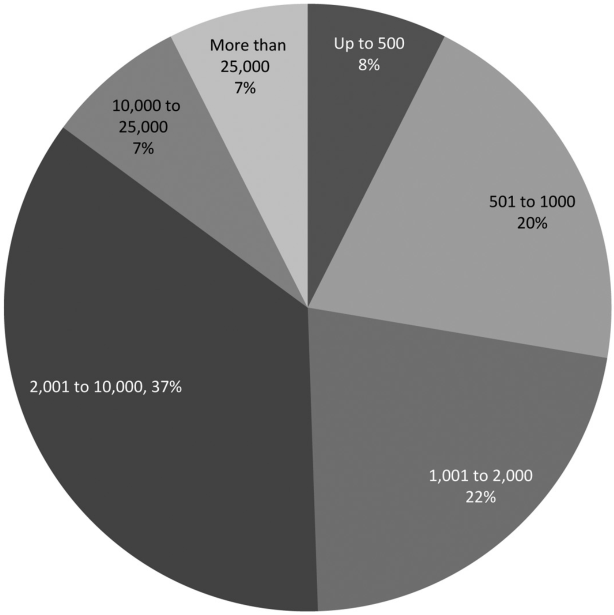

Figure 2: Size of respondents' organisations

This distribution of organisation sizes also indicates that the responses provide a good representation of Australian large organisations.

RESULTS AND DISCUSSION

Awareness of IPv6 was high. Most respondents (91%) had at least heard of the protocol before receiving the survey, and the majority (75%) of those who had also believed it to be necessary. Pearson's Chi-square and Fisher's exact tests were used to determine if there were statistically significant differences between individual industries in terms of a belief that IPv6 was necessary. No statistically significant differences were found.

However, while basic awareness was high, only 27% believed it to be urgent; 21% were not sure, and half (52%) asserted it was *not* urgent. Chi-square and Fisher's exact tests were used to determine if there were statistically significant differences between industries, and this revealed no support for the hypothesis that government organisations would be more sensitive to IPv6 than other organisations. In fact, the only industry category that was significantly different from the others was education, respondents from which were more likely to believe IPv6 was urgent than non-education organisations ($\chi^2 = 4.148$, $p = 0.042$). As well as being statistically significant, the difference was considerable: 43% of responses from education industry category believed IPv6 was urgent, compared to only 24% of other respondents.

An open-ended question asked respondents to provide the reasons behind the urgency or otherwise of IPv6, for which 74 respondents offered an answer. 25% of these believed that the transition to IPv6 was still too far into the future to be considered urgent. However, a Fisher's exact test revealed a statistically significant difference between responses from the education sector and those in other sectors; while only 20% of education sector responses reported this belief, 64% of non-education responses felt this way ($p = 0.006$).

Further, 21% of respondents believed that IPv6 was not urgent because Network Address Translation (NAT) would solve their problems. NAT was developed during the 1990s in response to the increasing shortage of IPv4 address space, and connects an entire network to the Internet using a single address, rather than using one address for each device on the network. The level of faith respondents had in NAT is regrettable as NAT has significant disadvantages, including imposing constraints on the services networks can offer to the Internet, disrupting a variety of common protocols, and driving up the total cost of ownership of a network (Dell *et al*, 2008).

Further, 17% of respondents reported already having sufficient IPv4 address space, and 23% believed that IPv6 was irrelevant to their circumstances. There were no significant differences between industry sectors for these beliefs.

The differences noted above between the education sector and other responses could be due in part to most Australian universities' connectivity being provided by AARNet (Australian Academic and Research Network), which provides native IPv6 support and has encouraged IPv6 adoption among universities through awareness campaigns, training delivery and other measures since at least 2002.

However, despite AARNet's efforts appearing to have influenced perceptions of urgency among education respondents, this does not seem to have had a significant impact on the Australian ICT industry more broadly: results from this study show minimal IPv6 readiness in all of the five facets listed in Table 1. First, few organisations have conducted IPv6 training of any sort, as illustrated in Figure 3.

This raises questions about the level of IPv6 skills in Australian organisations as the IPv4 exhaustion draws nearer. Technical knowledge is relatively immobile and does not flow easily from manufacturers and distributors to user organisations; consequently, users must often develop technical knowledge in-house, and the burden of doing so is often a barrier to technology diffusion (Attewell,

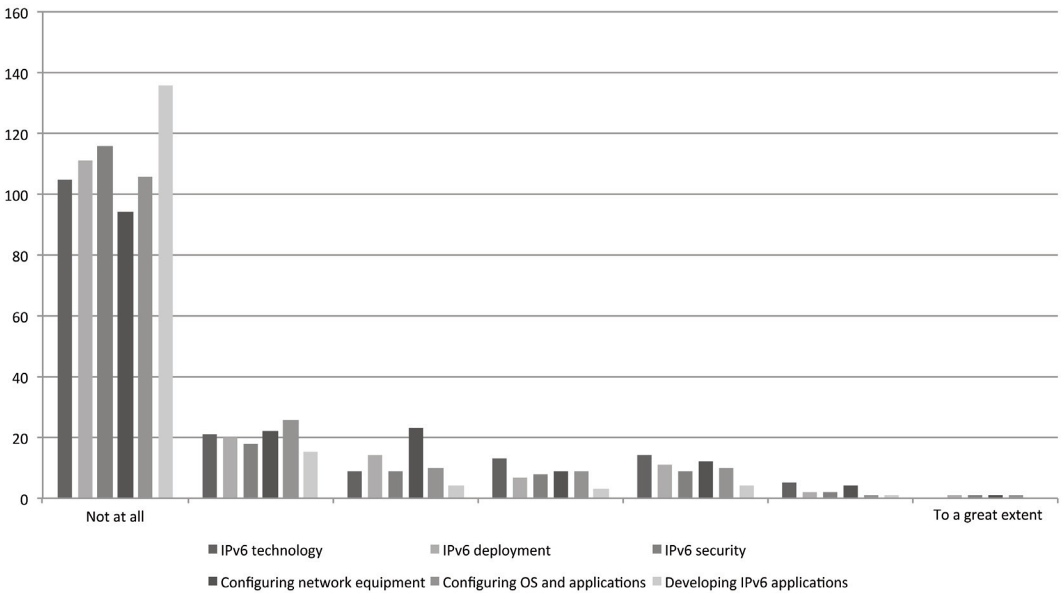

Figure 3: Levels of IPv6 training

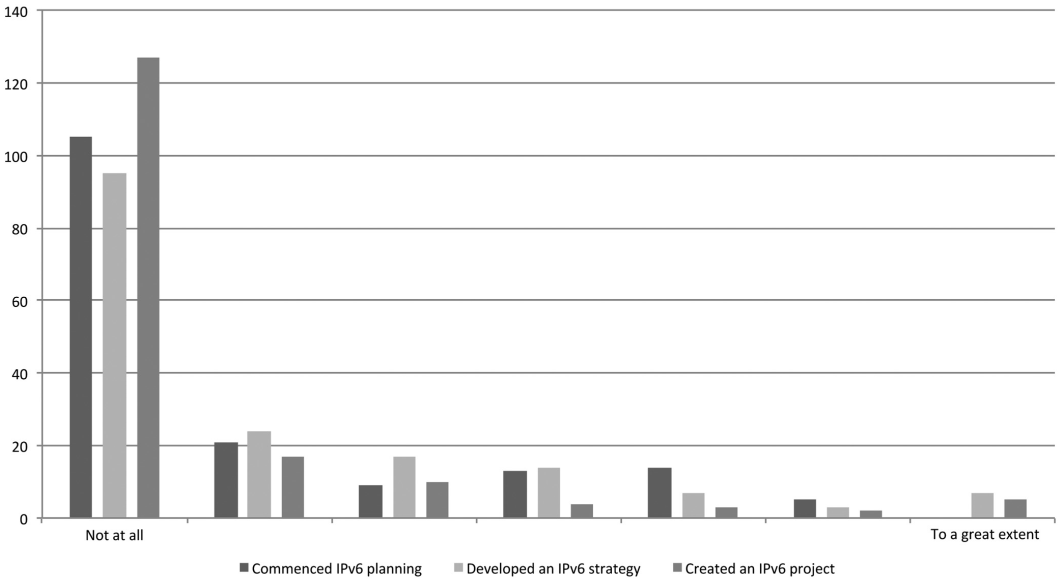

Figure 4: Levels of IPv6 planning

1992). If the low level of training and deployment are associated with low levels of IPv6 skills in general, this might not augur well for adoption of IPv6. A mitigating factor to this barrier to IPv6 diffusion might be the growth of organisations providing IPv6 expertise and consulting services; however, it remains to be seen as to whether a significant number of such organisations will emerge.

Similar to the situation with training, very few organisations have made significant progress towards high-level planning for IPv6, as illustrated in Figure 4.

A clear majority of respondents have not commenced planning for IPv6 at all, and only a tiny number have commenced planning to a significant extent. One interpretation of these results is that most organisations have little or no intention to adopt IPv6 in the near to medium term. This is consistent with the low levels of urgency perceived by respondents, and that many respondents did not believe IPv6 was relevant to their organisation. These results might also do not bode well for future IPv6 diffusion in Australia.

These results also raise the possibility that IPv6 might be deployed in an unplanned and hasty manner, should it become necessary to adopt it sooner than organisations expect. This could occur as a consequence of events in other parts of the world due to the global nature of the Internet.

The same pattern, in which the vast majority of respondents have not done anything at all, was reflected in organisations' assessments of their current IT environments, as illustrated in Figure 5.

Depending on when and if IPv6 adoption becomes necessary, organisations may be poorly placed for the adoption due to a lack of knowledge about their training, asset and applications needs. This lack of understanding may also result in a poor understanding of the scale of the IPv6 project. One possibility is that the low level of perceived urgency is a consequence of underestimating the scale of the IPv6 project.

Perhaps as a consequence of not having done any assessment of their IT environments, very few organisations have updated their policy frameworks to prepare for IPv6. This result is illustrated in Figure 6.

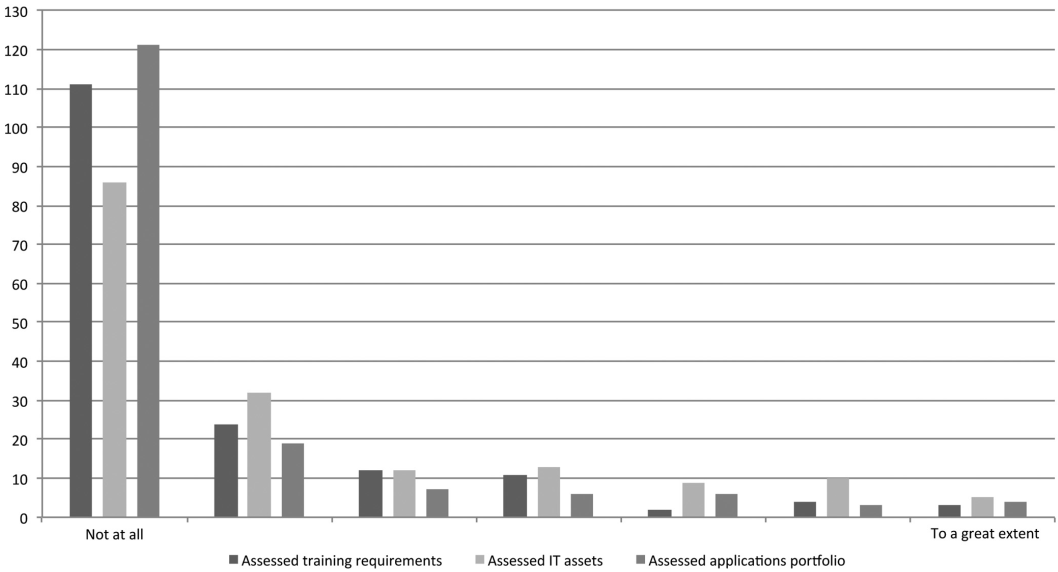

Figure 5: Levels of IT environment assessment for IPv6

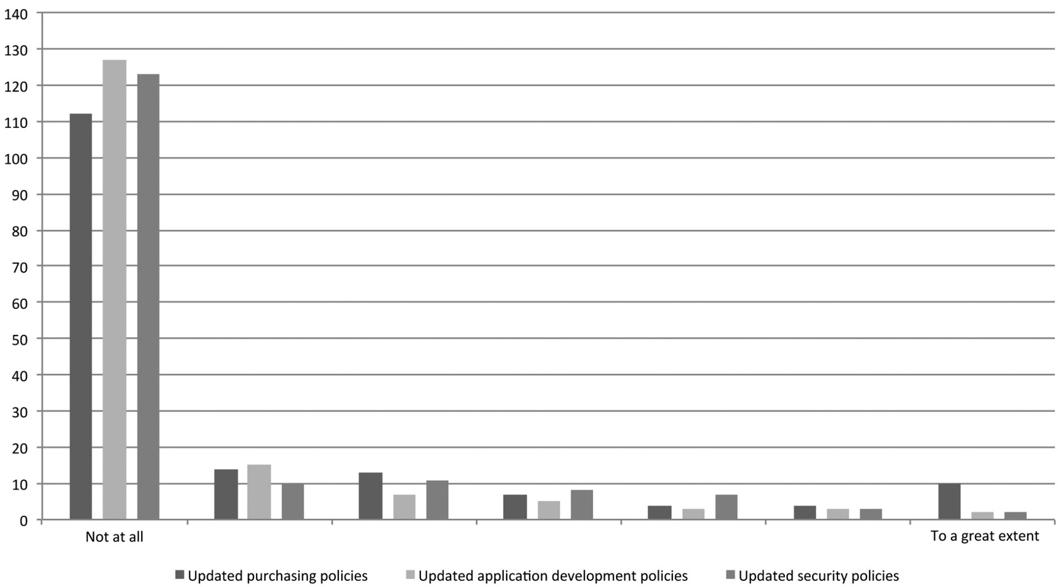

Figure 6: Levels of IPv6 readiness in policy frameworks

Particularly concerning is the very small proportion of organisations that have updated their purchasing policies. Network devices such as switches and routers may have a lifespan of between three and seven years (Nassoura, 2000); if IPv6 capability is not considered when making

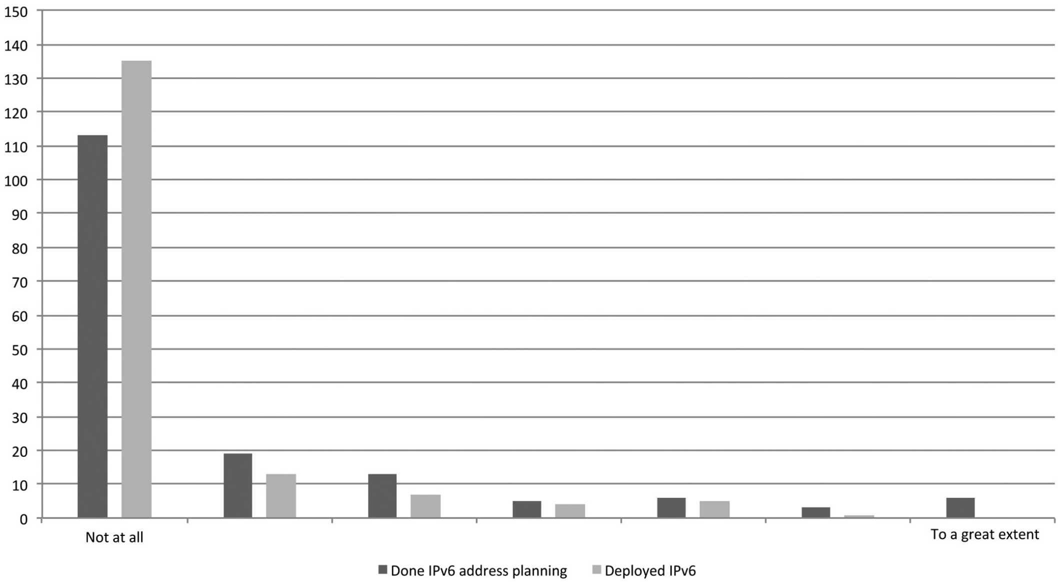

Figure 7: Levels of IPv6 deployment

purchasing decisions these devices may need to be replaced earlier than would otherwise be the case, resulting in a more expensive transition.

Similarly, that a very low proportion of organisations have updated application development policies to incorporate IPv6 requirements could lead to organisations needing to perform otherwise unnecessary remediation of applications in the future, or alternatively might create a barrier to IPv6 adoption in the future.

Finally, very few organisations have deployed IPv6, as illustrated in Figure 7. Given the results discussed above, this finding is hardly surprising, and corroborates other sources that show low levels of IPv6 adoption (Colitti, Gunderson, Kline and Refice, 2010).

DISCUSSION

Hovav *et al*'s (2004) model of Internet standards adoption suggests that adoption of IPv6 will be driven by the need for its new features and by the degree to which the environment is conducive to its adoption. In the event that usefulness remains low but conduciveness increases, a "replacement" adoption mode will be followed, in which IPv6 is implemented as a drop-in replacement to IPv4 but without using any of its new features. Alternatively, if the perceived usefulness of IPv6 increases but the environment remains unconducive, a "co-existence" mode of adoption will be followed in which IPv6 will co-exist with IPv4, initially in niche applications before possibly achieving more widespread success.

There is an alarming third possibility, however: that IPv6's perceived usefulness and environmental conduciveness both remain low, in which case the status quo will continue indefinitely. Hovav *et al* (2004) characterise the status quo as organisations' following a "wait and see" approach, and this is clearly the strategy adopted by the majority of Australian organisations who have made very little effort to ready themselves for IPv6. This raises the distinct possibility that IPv6 will never diffuse widely if the situation in Australia echoes that found elsewhere around the world.

The potential failure of a new Internet standard should not come as a surprise. Several changes to the Internet's network layer have been proposed over the years that have not seen widespread adoption; Internet Protocol (IP) multicasting, mobile IP, Quality of Service and Explicit Congestion Notification (ECN) have all failed to diffuse because none of them solved a problem that was immediately pressing (Handley, 2006). If IPv6 is similarly perceived as unrelated to any pressing problem, it too may fail to diffuse. A key question is thus whether IPv6 is seen as solving an immediate problem.

Unfortunately, this study has shown that although awareness of IPv6 is high, many organisations do not see any need to ready themselves for IPv6. A key component in this lack of perceived need is the view that an organisation does not presently need to prepare for IPv6 if it currently has adequate IPv4 connectivity. This indeed may turn out to be true for some organisations. However, given the likelihood that public IPv4 address space will become increasingly expensive, it behoves organisations to prepare for its successor.

Another key component in the lack of perceived need for IPv6 is the industry's apparent faith in NAT, of which there are two dimensions. One dimension is the assumption that service providers can use NAT to address a shortage of public IPv4 address space, thus providing reserved IP address space to customers. Such a belief is misguided; although thought to be a solution in the past, it is now known that NAT does not scale well (Domingues, Friaças and Veiga, 2007).

A second dimension is a faith in NAT from the perspective of the individual organisation, which contends that IPv6 is unnecessary as long as a small amount of public IPv4 address space – possibly even a single address – can be obtained. In this view, NAT is used within the organisation. This approach might minimise the impact of increasing IPv4 address costs but ignores potential problems such as the potential unavailability of public IPv4 connectivity due to issues within the service provider network, and possibly underestimates the Total Cost of Ownership (TCO) of NAT (Dell *et al*, 2008).

Reflecting the absence of a "killer app", the view that there is no business case for IPv6 is widespread and therefore a lack of investment in IPv6 is also widespread. If demand for IPv6 continues to lag behind the demand for IPv4 connectivity it will not diffuse successfully and given the difference between the levels of demand for each standard, the long-term failure of IPv6 appears plausible.

The failure of IPv6 would have significant implications. Most importantly it would lead to a reliance on NAT among end-users, enterprises and service providers for many, many years to come. This would have a damping effect on innovation because breaking the end-to-end idea inherent in the Internet's original design renders the implementation of a wide range of peer-to-peer applications difficult or impossible, and tends to force end-user networks into passive, client-only modes of operation limited to tasks such as web surfing or sending email. Further, NAT raises costs both in terms of money and technical skill required. Further, NAT has resulted in a multitude of ad hoc solutions in response to technical limitations, and this increased complexity can create security risks (Goth, 2005). This would be a missed opportunity of great proportions.

RECOMMENDATIONS AND CONCLUSIONS

This study is the first empirical assessment of end-user organisations' readiness for IPv6, and reveals that organisations have not made significant preparations for its adoption in the future. This is a grave problem for the Internet and for the ICT industry more broadly and should be addressed as a matter of priority. Continuing to expect this situation to change without altering the policy regime is reminiscent of Einstein's fabled definition of insanity: "doing the same thing over and over again and expecting different results".

Regulatory and governmental organisations can have a powerful influence on the adoption of new technology, particularly when sponsoring a technology with network effects. For example, environmental legislation often mandates or prohibits the use of certain technologies, and the provision of health insurance can directly affect the adoption of new medical techniques and methods (Hall and Khan, 2003). In the same way, regulatory or governmental action could have a powerful effect on the readiness and ultimate adoption of IPv6, thus minimising the risk of problems such as those described above.

Economies of scale are important in the earlier stages of technology diffusion. This is a form of network effect that results from the density of “consumers” (Hall and Khan, 2003). In the case of IPv6 this refers not to actual consumers but to entities that will consume the service enabled by IPv6 – in other words, network devices and applications. Thus, this factor favours IPv6 adoption by larger networks because the fixed cost of its implementation can be spread over a larger base. This suggests that any governmental or regulatory intervention should focus on organisations with larger networks such as those investigated in the current study.

Given the prevalence of the probably erroneous belief among such organisations that IPv6 is not relevant to them, dissemination of detailed information about the possible consequences of IPv4 address exhaustion for end-user organisations could be an effective strategy to help counter the widespread complacency currently exhibited by Australian organisations. It is therefore recommended that governmental, industry and regulatory organisations facilitate the development and dissemination of appropriate materials.

Also identified by Hall and Khan (2003) is the importance of the availability of complementary skills and inputs to the technology adoption decision. In the case of IPv6, the lack of training being undertaken by end-user organisations likely constitutes an industry- or even economy-wide barrier to adoption. Facilitating the development of appropriate skills at such a large scale may be an appropriate action for government.

Finally, governmental and regulatory bodies should consider sponsorship of IPv6 efforts. Such sponsorship could be in the form of government financial assistance, provision of appropriate infrastructure or support of relevant consortia.

As well as these recommendations for governments and regulatory bodies, the author makes a number of recommendations for end-user organisations:

- Commence IPv6 planning as soon as possible

  Although serious connectivity problems may result from a poorly-planned, knee-jerk IPv6 deployment, the current level of IPv6 readiness among Australian organisations is low. To avoid an unnecessarily high risk of a problematic deployment, Australian organisations should commence IPv6 planning as soon as practically possible.

- Develop a long-term IPv6 strategy

  A multidimensional, comprehensive approach is essential to the success of IPv6 implementation (Grossetete *et al*, 2008). There will be an extended period in which IPv4 and IPv6 will co-exist and planning must ensure this co-existence doesn’t create problems across the organisation. Thus, organisations should develop a long-term IPv6 strategy.

- Update the organisation’s policy framework to address IPv6

  A related issue is the organisation’s policy framework. Organisations should update policies including those regarding purchasing and procurement, application development (both in-house and outsourced) and information security.

- Ensure the availability of IPv6 skills

  Adoption of the new protocol raises issues across the organisation, including network administration, software development, security, information assurance and business functions (Grossetete *et al*, 2008). Organisations should ensure the availability of adequate IPv6 skills; given the scarcity of these skills across the industry and the likelihood of increasing competition for these skills, organisations should consider developing their own IPv6 capacity by providing training before commencing transition efforts. However, to ensure the appropriateness of training provisions, organisations should first assess their training requirement before implementing any IPv6 training.

- Assess the environment for IPv6 readiness

  As well as assessing their training needs, organisations should also assess their IT environments. Specifically, both IT assets the applications portfolio should be scrutinised to determine the level of IPv6 readiness.

Although awareness of IPv6 among Australian end-user organisations is high, readiness to make the transition remains extremely low. Although one might hope that the transition to IPv6 does not occur at the last-minute as was the case with Y2K or the "millennium bug", it increasingly looks as though this is going to be the case. This would result in either the chaos and increased costs that Domingues *et al* (2007) warned will result from a hurried transition to IPv6, or worse still, the failure of IPv6 to diffuse at all.

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BIOGRAPHICAL NOTES

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