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Why Isn't Digital Infrastructure Being Updated?: The Case of IPv6

Awinder Kaur Mohinder Singh
Auckland University of Technology, awkaur@aut.ac.nz

Harminder Singh
Auckland University of Technology (AUT), hsingh@aut.ac.nz

Felix Tan
Auckland University of Technology (AUT), ftan@aut.ac.nz

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Awinder Kaur
Harminder Singh
Felix Tan
Business Information Systems Department
Auckland University of Technology
Auckland, New Zealand
Email: awkaur@aut.ac.nz
hsingh@aut.ac.nz
ftan@aut.ac.nz

Abstract (Abstract heading)

While the transition from Internet Protocol version 4 (IPv4) to version 6 (IPv6) promises significant advantages and is critical given the exhaustion of IP addresses, surprisingly few studies have examined the reasons for its poor organizational adoption. Moreover, most existing studies have focused on the technical issues surrounding IPv6 adoption. This study seeks to address this gap by examining the determinants of and barriers to IPv6 adoption by organizations. More broadly, the study will identify the processes by which components of digital infrastructure, such as IPv6, are assimilated. Drawing upon institutional and process theories, an IPv6 technology adoption model is developed. A positivist case study research approach was used to provide a richer understanding of digital infrastructure adoption and assimilation. We are currently in the midst of our data collection and have collected data from four organisations on their IPv6 adoption experiences. These organisations are in the tertiary education industry in New Zealand, and are at different stages of their IPv6 adoption process. We present the preliminary findings and discuss their fit with our initial model.

Keywords (Minor Heading)

Digital Infrastructure, IPv6, Adoption, Process Theory, Institutional Forces

INTRODUCTION

While the current system that assigns unique addresses to each device connected to the Internet (Internet Protocol version 4 or IPv4) can cater for 4.3 billion addresses, most of these addresses have already been allocated, and Internet users run a clear risk of IP addresses being completely exhausted in the near future[1]. Without any new addresses, the growth of the Internet and its use to support innovations will be severely restricted. For example, the development of the "Internet of Things", in which physical objects, such as appliances and sensors, will be linked to the Internet, will be hampered (Minoli, 2013). To counter this shortage, a new standard, Internet Protocol version 6 (IPv6), was designed to replace IPv4. IPv6's larger address space enables an extraordinarily high number of IP addresses (up to 10^{38}) to be created.

While IPv6 has been around for more than a decade, its adoption by organisations has been limited. While IPv6 has some clear operational benefits, such as the ability to enjoy a higher quality of service and built-in security, organisations that do not adopt it also face some competitive risks. For example, they may lose out in the ability to deploy new applications, or be invisible to users in emerging economies that have "leap-frogged" technologies by moving directly to IPv6 networks. These may lead to customer retention issues: a bank's online banking application that is delivered through IPv4 will be with stuck in translation hurdles when someone in an IPv6 household tries to access it, leading to the risk that the bank may lose that family as its customers (Vaughan-Nichols 2012).

Despite the criticality of this issue, research on the organisational adoption of IPv6 has been surprisingly limited (Che and Lewis 2010), and the studies that do exist focus mainly on technical issues. This study seeks to address this gap by examining how the process of IPv6 adoption takes place, and the factors that influence this process. While most studies on digital adoption focus on firm-specific factors, this study argues that institutional forces may also be relevant here, since IPv6 is a component of an organisation's digital infrastructure, not an application. The embedded nature of an organisation's digital infrastructure means that changing it is more

[1] Each device connected to the internet has a unique address which differentiates it from one another (e.g. 192.101.1.1). IPv4 was designed in 1977, and since then, the growth of Internet use, in terms of the number of users, the extent of their use, and the increase in the number of Internet-enabled devices, means that many more IP addresses are required.

difficult than changing a set of applications or devices that organisation uses. Thus, institutional forces may play a stronger role in the adoption of digital infrastructure, compared to the adoption of other types of IT, which may be driven more by organisation-specific resources or individual utility-maximisation decisions. In contrast to the dominance of variance-based models in existing research, this study adopts a process perspective to clarify the assimilation process that takes place after the initial IPv6 adoption decision.

The goal of the study is to identify the relative impact of the various organisational resources and institutional forces on the process of digital infrastructure adoption and assimilation, and to identify the triggers that lead to these resources or forces being enrolled in the adoption and assimilation process. In the next section, we review the literature on digital infrastructure adoption and assimilation, followed by an examination of IPv6 adoption studies to clarify the gap in understanding digital infrastructure adoption and assimilation. Following that, we discuss institutional forces, organisational resources and process theory, before integrating them. We conclude with a discussion of the research methodology, case analysis, findings and the expected contribution of this study.

LITERATURE REVIEW

Digital Infrastructure Adoption and Assimilation

Digital infrastructure is also known as information infrastructure, IT platform, or corporate IT infrastructure. We use the term digital infrastructure, which is defined as "…the basic information technologies and organizational structures, along with the related services and facilities necessary for an enterprise or industry to function (Tilson et al. 2010)". An example of digital infrastructure is the Internet. Digital infrastructure is recursively composed of "... other infrastructures, platforms, applications and IT capabilities and controlled by emergent, distributed and episodic forms of control" (Hanseth and Lyytinen 2010).

Digital infrastructure differs from IT applications because of its heterogeneous nature and expanding user base; its design context is always changing based on the constant generification of its included IT capabilities (Hanseth and Lyytinen 2010). Therefore, adoption of digital infrastructure is quite different from the adoption of IT applications as "…infrastructures are not just made of networks, data flows and work procedures, but also are embodiments, or "vehicles", or emerging modes of work organization, of new cognitive imageries and institutional arrangements (Ciborra and Hanseth 1998)". In other words, the adoption of digital infrastructure is a more complex process compared to the adoption of an IT application. As digital infrastructure is an organisation's technological platform, the adoption of digital infrastructure affects the entire organisation's functions.

There can only be a partial control over the adoption and assimilation of digital infrastructure due to the fact that it has its own acceleration rates and slow-downs when delays, unintended consequences, sudden oppositions and imperfect attempts to align stakeholder occurs (Ciborra 2001). In addition, the dynamics of digital infrastructure evolution is nonlinear and path dependent where the evolution process is influenced by network effects of people involved (organisation actors) and network of technology involved (technical aspect) (Hanseth and Lyytinen 2010).

Mainly digital infrastructure literatures focus on features and characterisics of digital infrastructure (especially standards as a core element). Some digital infrastructure literatures focus on strategies for developing standards and infrastructure while only a few digital infrastructure literatures focus on the design strategies for infrastructure development (Hanseth and Lyytinen 2010). However, there is limited research on the process of digital infrastructure adoption and assimilation.

In addition, most digital infrastructure literatures do not consider the influence of the external forces and organisational resources on the adoption process. Therefore, we investigate digital infrastructure adoption and assimilation process with the case of an Internet standard (IPv6) to understand the determinants and barriers of digital infrastructure adoption and assimilation process affected by institutional forces and organisational resources to provide a new perspective of the digital infrastructure research.

Not only the adoption process is important, the assimilation process is also crucial. Organisations need to move to assimilation stage from the adoption stage to fully experience an economic value (Rogers 1995), emphasizing the importance of understanding digital infrastructure adoption and assimilation at an organisational level (Lyytinen and Rose 2003). However, little research has been conducted on the adoption and assimilation of digital infrastructure (more specifically, internet standards – IPv6) at an organisational level (Hovav and Schuff 2005).

While the Internet has driven industrial productivity in recent decades, the depletion of IP addresses will hinder and limit the growth of the Internet. The rapid growth in the number of mobile devices highlights the imminent shortage of IPv4 addresses, since every device that connects to the Internet requires an IP address and IPv4 addresses are depleting rapidly. IPv6 was created to replace IPv4 and can lead to improvements such as

simplified configurations, better quality of service, and built-in security. Although it will be impossible for additional Internet devices or services to be connected to the Internet once IPv4 addresses have all been used up, very few organisations have actually started converting their networks to run on IPv6 (Ladid 2006).

Evolution could be a suitable methaphor to describe the adoption of digital infrastructure, in this case, IPv6 (Ciborra 2001). IPv6 adoption is an evolution where the change from IPv4 to the Network Address Translation (NAT) usage (using one IP address to represent a group of computers) to the dual-stacking of IPv4 and IPv6, and finally to an IPv6-only network.

The two self-reinforcing mechanisms resulting from the digital infrastructure adoption- (1) innovation, which results in a new service, and (2) service, which results in more users and profits (Bygstad 2010). Similarly, IPv6 adoption and assimilation provides a platform for new services as well as increase of users and profits. Adoption of a digital infrastructure can provide a competitive advantage to the adopting organisation (Katz and Shapiro 1986; Zhu 2004).

Organisations delaying IPv6 adoption will find it harder to connect with the rest of the world and may forfeit their presence on the Internet, while incurring additional costs and risks from their aging infrastructure and inability to integrate new IPv6-only applications and services (BlueCat, 2011). In addition, IPv6 is an example of an infrastructure technology whereby other innovative technologies can be put in place to take advantage of its capabilities (Hovav and Schuff 2005). While there are many literatures focusing on innovation, IPv6 is not an innovation; instead, as a component of infrastructure, it supports the development and use of innovations.

It is important to differentiate between IPv6 adoption and IPv6 assimilation. IPv6 adoption refers to the initiation IPv6 use when an organisation decides to adopt it and begins planning to replace or upgrade its hardware and software to support IPv6. In contrast, IPv6 assimilation occurs when the new standard is fully deployed in the organisation's networks, applications and other services. Ultimately, IPv6 should be assimilated in an organisation's network infrastructure, application infrastructure and core business applications (Mason and Mahindra 2011).

IPv6 adoption usually begins through test beds or pilot projects to avoid any disruption of services to users. Test beds are used to test the reliability of an organisation's overall digital infrastructure when IPv6 is used. Such pilot projects and test beds are effective in nurturing IPv6 expertise and confidence (Zhang 2012). They also act as a reference and provide guidelines for IPv6 adoption in other agencies (Ramadass 2009). The extent to which organisations have assimilated IPv6 is reflected in their large-scale acquisition of IPv6 capable hardware and software, and a move towards the full deployment of IPv6 across all of their units.

The practitioner literature has identified multiple activities that occur at the stages of adoption, as detailed below. These were used to guide the data collection.

- *IPv6 Initiation and Adoption Stage*:

  This stage includes the process of scanning organisational barriers, determinants and benefits of adopting IPv6. Budgets are allocated for IPv6 project. IT asset inventories are done to achieve IPv6 capabilities. Hardware and/or software are changed or updated to accommodate IPv6. IPv6 adoption planning focuses on the protocol integration and co-existence with IPv4. Operational and governance policies are reviewed to integrate IPv6 into the business and organisational structures to ensure successful assimilation of IPv6. Organisational members (senior management, IT management and IT staff) are provided with IPv6 knowledge or awareness. IT staff are trained through IPv6 training or certification courses. Senior management become aware of: the importance of IPv6, the business impact of not adopting IPv6, the timelines, and the cost of IPv6 adoption. IT management should understand the networks, applications and services affected by IPv6 adoption, and come up with a set of activities for the adoption of IPv6 solutions and services. IT staff should be trained in the IPv6 technology basics, the mechanisms of IPv6 adoption, and guidelines for IPv6-enabled networks and solutions operations and maintenance. During this stage, a test bed (environment) for IPv6 adoption is established to test the organisation's digital infrastructure.
- *IPv6 Assimilation (Adaptation, Acceptance, Routinization and Infusion) Stage*:

  This stage involves a full roll-out of IPv6 services across the organisation. The solutions architected in the previous stage are implemented and IPv6 is enabled across the organisation. The assimilation of IPv6 covers the infrastructure upgrade (of hardware and firmware systems if they are not yet IPv6 ready), establishing IPv6 connectivity with the organisation's peers, and IPv6-enabling various services spread across the organisation. Organisational members are induced to commit to IPv6 usage, and IPv6 is employed in work processes. Increased organisational effectiveness is obtained by using IPv6 in a more comprehensive and integrated manner to support higher level aspects of organisational work.

The literature on IPv6 adoption has identified these barriers to the adoption and assimilation of IPv6:

- Inadequate IPv6 skills and experiences: Most organisations have inadequate access to IPv6 skills and experiences (Dell et al. 2008). A lack of training also hinders them from adopting IPv6 (Hilson, 2012). In contrast, extensive knowledge of IPv6 can lead to early adoption (Hovav and Schuff 2005).
- Perception of IPv6 as being immature (Dell et al. 2008): This is quite normal in the evolution of Internet standards, and IPv6 is expected to evolve over time. This perceived immaturity leads to a perception that it is a high-risk technology choice (Bons 2011).
- Lack of vendor support: Not all hardware and software vendors support IPv6 (Chittimaneni 2011; Mason and Mahindra 2011), making it difficult for firms to firms to switch to it even if they are willing to do so.
- Adoption cost: One of the most common cited adoption barriers is the direct cost involved in the IPv6 adoption itself, along with the additional training costs and the sunk costs in existing IPv4 infrastructure (Hovav and Popoviciu 2009). A survey found that many organisations still consider IPv6 adoption as being more of a cost than a benefit (Computerworld 2010).

These factors support the adoption and assimilation of IPv6:

- Organisational-wide effort: As IPv6 adoption requires an organisational-wide effort, organisations play an important role in the IPv6 adoption process (Grossetete et al. 2008). The adoption process requires close coordination and management (Ladid 2006).
- Government support: Government mandates towards the adoption of a new standard reduce the level of risk and uncertainty about the future of that standard; allowing the standard to become dominant (at least in that country or region) which in return ensures market for related products (Bons 2011). For example, the transition from analogue to digital mobile telephony, as well as digital television, has been a success through a mandate by various governments. Governments in countries such as Korea, China, Japan, Taiwan, and the USA, have mandated, initiated or promoted IPv6 adoption, resulting in successful adoption. This indicates the efficacy of the government "push" approach (Dell et al. 2008).
- Backward compatibility: If IPv6 applications and devices can work with their IPv4 counterparts until IPv4 is phased out, firms will be more likely to adopt IPv6 as this will lower the risk of adoption (Hovav et al. 2004). Compatibility is especially important in the Internet environment because of the need of interoperability across organisations (Hovav et al. 2004).
- Network externalities: The presence of positive network externalities creates an environment amenable to adoption (Katz and Shapiro 1986; Hovav et al. 2004).Such externalities occur when the value of a particular service or product is a function of the amount of the other people using it (Shapiro and Varian 1999). Widespread adoption of IPv6 will lower the barriers of IPv6 adoption for other organisations in the same community/industry as it will make it easier to interact with them.

The factors above can be categorised into three domains: institutional forces, organisational resources, and other factors. Since institutional factors are relevant for IPv6 adoption and assimilation, the next section discusses institutional theory, which is then applied to develop a framework for explaining IPv6 adoption.

Institutional Forces

External entities are important drivers of the adoption and assimilation of a new technology (Damanpour 1987; Hirt and Swanson 2001; Somers and Nelson 2004; Liang et al. 2007), as the above review of the IPv6 field showed. Most research have not looked at institutional factors as an influence of the digital infrastructure adoption and only focused on the technological perspective or "…taken a technological slant at the expense of the institutional perspective to the point that it has looked at their development from a narrow technological perspective to emphasise the irreversibility of the (technical) installed base and the role of technology as an ally (Iannacci 2010)".

In this section, we use institutional theory to classify the various types of effects institutional forces can have on digital infrastructure adoption.

Institutional theory recognizes that organisations seek social success through the accumulation of legitimacy which results in organisations becoming more homogeneous (Nicholas 2012; DiMaggio and Powell 1983). According to this theory, isomorphic change occurs in organisations through three forces: coercive, mimetic, and normative isomorphism (DiMaggio and Powell 1983). These isomorphic pressures may motivate organisations to adopt digital infrastructures (Tschoegl 2010), for example:

- *Coercive isomorphism* occurs when organisations adhere to formal and external pressures exerted upon them by other organisations that they depend upon, or by cultural expectations in the society within which the

organisations functions (DiMaggio and Powell 1983). An example of coercive force in the IPv6 adoption is the government mandates.

- *Mimetic isomorphism* occurs when organisations change because of environmental uncertainty. When organisations do not have the knowledge and skills to adopt IPv6, organisations model themselves after other organisations that have successfully implemented the technology.
- *Normative isomorphism* takes place when organisations change because of professional pressures from their employees. IPv6 events to raise awareness and promote IPv6 adoption causes IT professionals become socialized with the normative beliefs in their industry on the importance of IPv6 adoption.

The next section discusses the importance of organisational resources for digital infrastructure adoption.

Organisational Resources

In the context of IPv6 adoption and assimilation, the resources that are relevant based on prior studies are IPv6 skills and knowledge (human), hardware and software that supports IPv6 (technology), and top management and vendor support (relationship). These resources are required for a successful IPv6 adoption and assimilation in organisations. A study by Fichman (2004) on real options and IT platform adoption presents a model of antecedents of option value in IT platform investments incorporating determinants of real options adoption which confirms the influence of institutional forces and organisational resources in the adoption of IT platform. These determinants are categorized as technology-strategy perspective, organisational learning perspective and adaptation perspective are organisational resources in this study; while bandwagon perspective is an interpretation of institutional factors in this study (Fichman 2004).

The previous sections have identified the institutional forces and organisational resources that influence IPv6 adoption and assimilation organisations. To understand the processes involved in organisations' IPv6 adoption and assimilation, we provide some background on process theory.

A Process Model of Digital Infrastructure Adoption

Variance research is arguably unsuitable for examining dynamic phenomena such as digital infrastructure adoption as it limits the explanation of how variance in one factor leads to variance in a dependent factor (Radeke 2010). The variance theory approach identifies the effects of different factors on IT adoption, but does not show the interactions of those factors and the processes involved in IS implementation (Markus and Robey 1988; Kim and Pan 2006). A process approach allows alternative paths as well as corrective actions to be undertaken in obtaining successful outcomes (Robey and Newman 1996).

A process approach is appropriate for examining the adoption and assimilation of IPv6, because it consists of a series of projects and decisions that eventually lead to a range of outcomes, depending on the extent of assimilation. A process approach also enables the examination of adoption behaviours and the determination of patterns which are effective or ineffective in achieving a successful adoption (Kim and Pan 2006).

Compared to IT applications or devices, standards like IPv6 are much more embedded in an organisation's digital infrastructure making it more difficult to change them in contrast to IT applications or devices. For example, it is relatively easier to upgrade an organisation's email system or desktop operating system, or to introduce iPads into business units, than to change the protocol used to transfer the organisation's data traffic. Since infrastructural elements such as communication standards lie at the lower levels of the OSI model, multiple layers of interdependencies are created in the organisation's IT landscape. This makes them more resilient, which is what organisations seek in their infrastructure, but at the same time, more resistant to innovations. While organisational resources, such as certain IT-specific skills or funds, may be available, they may not be sufficient to motivate the organisation to upgrade its digital infrastructure. In such a case, institutional forces may play a stronger role in the adoption of digital infrastructure, compared to the adoption of other types of IT, which may be driven more by organisation-specific resources.

Limited understanding of how increasing complexity influences the adoption initiatives is an obstacle towards the effective adoption of digital infrastructure (Henningsson and Hanseth 2011). A study by Henningsson and Hanseth (2011) reports the evolving digital infrastructure and how their evolution may be influenced by the demonstration of how digital infrastructure evolution can be seen as a dialetic between stabilizing and destabilizing processes which motivates the usage of process theory in adopting digital infrastructure in this study.

Beyond that, it is probable that since digital infrastructure adoption and assimilation takes place over stages, the importance of each factor may change across the stages. Most IT adoption studies assume that the adoption process is a linear progression and often ignore feedback loop. In this study, we will place special emphasis on examining this, by looking at, for example, how IPv6 adoption and assimilation improves an organisation's status in its industry.

The usage of process theory in the study of digital infrastructure will address the two design problems of digital infrastructure- the 'bootstrap problem' – the ability for digital infrastructure to meet early users requirements, and the 'adaptability problem' – to ensure local designs recognise digital infrastructure unbounded scale and functional uncertainty (Hanseth and Lyytinen 2010).

RESEARCH METHODOLOGY

A series of positivist case studies were used in this study to examine the IPv6 adoption process in four tertiary institutions in New Zealand who are in varying stages of their IPv6 adoption process. Digital infrastructure adoption studies have mostly examined organisations that have adopted the technology, rather than organisations that are in their beginning stages of the adoption process. Comparing the experiences of organisations in differing stages helps clarify the process of adopting new digital infrastructure innovations. Data was collected primarily through interviews with the individuals in charge of the IPv6 adoption process in their respective organisations, and by examining each organisation's IPv6-related documentations. Questions asked during the interview process were mainly on their current stage of IPv6 project, efforts undertaken in relations to IPv6 project, and barriers as well as the determinants of their IPv6 adoption and assimilation project.

This study took place in New Zealand because IPv6 is a critical technology for New Zealand's economy. 72% of its trade partners have mandated the use of IPv6, and so, to ensure that New Zealand is able to be in touch with the global Internet, it needs to adopt IPv6. Countries such as India and China have run out of IPv4 addresses and are developing Internet applications based on IPv6, which will not be visible to New Zealand entities if they do not have IPv6 capabilities (Force, 2012). Despite the effort of IPv6 Task Force in conducting talks for government and industry on the importance of IPv6 adoption, native IPv6 traffic is still relatively small at 0.11%. The IPv6 Task Force's Convenor has mentioned that all New Zealand organisations should be acutely aware of and start planning their IPv6 adoption on their internal networks as not doing is a big business risk (Force, 2012). New Zealand is also an interesting context for this study because, while some large well-known organizations, like Beca and Trademe, have adopted IPv6 and have been sharing their experiences (barriers, problems and benefits), many others have not. This provided a suitable amount of variance in the context. The NZ IPv6 Task Force was approached to helps secure case sites from among its members. In addition, appeals were made through personal and work-related contacts to identify potential case sites.

Summary of Cases

The data collection is still on-going and this research-in-progress paper presents our initial findings from the four organizations we have studied so far. All of them are from the tertiary education sector, and their IPv6 adoption efforts are described below. Coincidentally, they were all at different stages of the IPv6 adoption process, allowing us to compare their experiences.

Institution A

The IPv6 adoption effort by Institution A started in 2004. Institution A has deployed IPv6 internally on its networks. It had external IPv6 connectivity but this has been broken for nearly 18 months because of a lack of vendor support. Institution A was not told by the vendors that extra licenses were required to support IPv6 connectivity when they purchased IPv6-ready equipment.

Institution B

Institution B's IPv6 adoption efforts started in 2013 and they are in their early stages. They have included IPv6 in their border routers. Institution B has come up with a plan that has been circulated within the organisation. They have ensured that their new purchases of network equipment, such as firewalls, are all IPv6 compliant, and this requirement has been placed in their purchase agreements. This institution has also been allocated IPv6 address blocks by the national research and education network, REAANZ. Institution B has been sending its staff to IPv6 seminars and training over the years to gather IPv6 information.

Institution C

Institution C's IPv6 adoption effort started in 2007 where it received its first IPv6 address from APNIC and started researching it. The actual IPv6 adoption process started in 2009. Currently, Institution C's network is IPv6-ready, and is running both IPv4 and IPv6. However, network traffic still has a preference for IPv4 rather than IPv6. Any Internet devices connected to the institution's network will notice it is IPv6 enabled. The current initiative is to upgrade the domain name system (DNS) so that it supports IPv6. Its DNS has slowed down due to the resignation of the technical staff member in charge. Institution C aims to ensure that its public-facing web interface and all sub-interfaces will be IPv6-enabled by the end of 2013.

Institution D

Institution D is currently in the experimental stage: IPv6 is not touching its production services, except when it has been accidently switched on, or is the default option, such as in Windows. This institution is planning to seek help from experts within its own faculty, instead of relying on external support. The next stage for them is to enable IPv6 in their external webservers, and slowly work their way out from there. Besides this, they do not have any more plans in place yet, and they are currently hoping to develop those.

The experiences of the four institutions' (A, B, C, D) enabled us to draw up the IPv6 adoption timeline shown below:

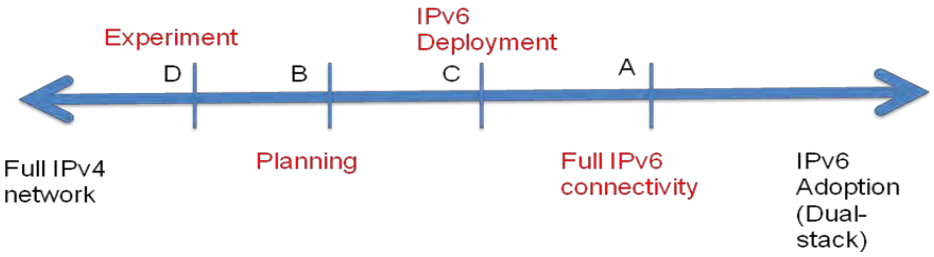

Figure 1: Position of Case Sites on IPv6 Adoption Timeline

Barriers and Determinants of IPv6 Adoption and Assimilation

This section provides a summative finding of the four case studies where the barriers and determinants of IPv6 adoption are discussed. Whenever appropriate, respondents' statements are quoted to illustrate the barriers and determinants. The research findings are summarized in Table 1.

Table 1: Summary of Findings

			Institution A	**Institution B**	**Institution C**	**Institution D**
Determinants	*Institutional Forces*	*Coercive Forces*	√	√	√	√
		Mimetic Forces		√		√
		Normative Forces			√	
	Organisational Resources	*IPv6 skills and knowledge*	√		√	
		IPv6 capable hardware and software	√		√	
		Vendor Support				
		Top Management Support		√		
Barriers			*Vendor support, IPv6 skilled staff*	*Time, internal resources*	*IPv6 skilled staff*	*IPv6 skilled staff*

Coercive Forces

Research and Education Networks

Research and education networks, such as KAREN and REANNZ, have an important role in the IPv6 adoption decisions of tertiary institutions, as they allocate IPv6 address blocks to tertiary institutions in New Zealand. Institution A started its adoption effort when the research and education networks in New Zealand decided to

carry IPv6, as quoted by an interviewee from institution A: "*The incentive to go to IPv6 was that KAREN was going to carry IPv6....We deemed that it is appropriate that we should have IPv6 as well. Ok, that was the decision point that we decided that we were going to do it and then actually doing it, whenever there was an opportunity to enable IPv6, we took it.*" Institution B's interviewee stated that: "*We have REANNZ allocated number on our border router, so that's the research and education network*." Institution C's interviewee mentioned that: "*And obviously we are v6 visible right on the Internet by REANNZ network first, then we moved on to the Internet*." and "*First stage was the KAREN connection, me not being here, understanding it, was that the necessity from IPv6 came from KAREN because it was there…*"

Customer demands

The growing number of overseas students studying in New Zealand has driven tertiary institutions to adopt IPv6. These can be seen in all four tertiary institutions. Institution A stated that "*...KAREN provided us access to South East Asia (China, Korea, Japan and other countries) who have already deployed IPv6 in a productive sense*" and IPv6 adoption is "*a catch material for overseas students*", while institution B highlighted: "*… there is also the awareness that our future international students are going to be in countries like India and China which completely exhausted their IPv4 space, making heavy use of NATing and at some point, if we want to communicate with them for distant learning, we will need to be IPv6 compliant.*" Institution C's interviewee thought of IPv6 adoption as a strategic move: "*I look at it strategically where we are because a lot of our students are from Asia regions, a lot of Chinese people, a lot of those coming are Chinese and Japanese….if they want to go to the website and see where I can study English, they are going to get a website that is not IPv6 capable, we loose out for that year or to years. So we lose out*." Finally, institution D's interviewee stated that: "*… we have a lot of customers which are leading in the adoption and we have to keep phase with that"*.

"Pin on the jacket"

The interviewee from institution C highlighted the need to remain competitive ("*… we know the implications of not being there, being part of it*.") and the value of public recognition as a pioneer "*…everybody wants their name to be noticed, so if we can actually be one of the first to go natively in New Zealand, that's a huge, huge, you know, pin on our jacket*…"

Mimetic Forces

The presence of mimetic force can be seen in the comments of the interviewee from institution B, which plans to model itself after organisations that have adopted IPv6: "*Five years, it will probably be totally easy, there will be more IPv6 transition tools available, external organisations will be available to help you…* " Institution D also was also influenced by: "*…where other people are about and what problems they encounter*."

Normative Forces: Information Exchange

IPv6 seminars and trainings in New Zealand are seen as a means of gathering information, as mentioned by the interviewee from Institution B: "*Knowing what's going on in the wider industry, listening to how other organisations have adopted IPv6 and their problems. So it's been information gathering and a lot of that feeds into what we are doing now*." Institution D's interviewee emphasised that: "*…It's always useful to talk to our colleagues*".

Organisational Resources: IPv6 Skilled Staff

There is a shortage of IPv6 skilled staff. *"...yes, very, we are finding it incredibly difficult to find people in New Zealand that have any of the skill sets we require"* (Interviewee from institution A). This has led to a focus on internal training in some cases: "*…our strategy is to train our existing staff up on IPv6. And that's probably better, because they know the organisation, they know the IPv4 implementation, and it gives them something new and interesting to learn*" (Interviewee from institution B).

Organisational Resources: Vendor Support

Despite being the leader in the IPv6 adoption efforts among all four institutions, institution A faced problems with the IPv6 vendor support. The interviewee stressed the problems the institution faced with regards to the IPv6 adoption as following: "*I think the biggest issue that we came across was that vendors who said their equipment were IPv6 ready and IPv6 capable but when you actually try to use it and it turns out that was not actually the case at all.*" and "*That amounts to, in my opinion, lying to your customers and when you have made a significant investment in a particular technology from a particular company and say, yes we can, and turns out that it cant. And they don't support you after that event. I was not happy about it at all.*" Institution B has not reached the stage of inspecting their equipment to know whether it supports IPv6 or not: "*We still need to do a bit of research around IPv6 readiness of a lot of our systems. We really don't know what we've got that is already IPv6-ready. I suspect not much."*

DISCUSSION

The case studies we have conducted so far provide us with a glimpse of some of the key issues facing firms that are at various stages of the IPv6 adoption process. Although no-one had completely assimilated IPv6, each of them was progressing in some degree. A common driver all of them mentioned was the need to adopt IPv6 to meet the demands of their customers. The four tertiary institutions recently began dealing with a large number of customers who originate from countries which do not have IPv4 addresses left and are currently adopting IPv6. Thus to ensure that they are able to serve this market, they had to ensure that their networks did not contribute to any competitive disadvantage, spurring them to adopt IPv6.

It would have been interesting to trace how this environmental pressure manifested itself in an organisation, and who realised its implications and attracted the attention of their IT departments. However, while we set out to interview individuals from both technical and business backgrounds to understand their perceptions and understanding of IPv6, we quickly realised that only technical respondents knew what was happening with regards to IPv6 in their organisations. Perhaps this experience points to one shortcoming of the adoption campaign: the business benefits and risks of moving to IPv6 or not doing so are not being adequately explained to business professionals at all levels. This is particularly surprising given the amount of practitioner press devoted to IPv6-dependent innovations, such as the Internet of Things. This highlights the difficulty of putting in place enhancements to our digital infrastructure- their lack of obvious presence means that their value as a platform for supporting innovation is frequently not appreciated or understood. For most users, as long as their Internet "works", they will not be interested in examining the underlying systems that make it work. They have been buffered by their IT staff from understanding the complexity of the IT that underlies their work processes, and even if they were keen on pushing for their organisation to shift to IPv6, non-IT staff would find it difficult to obtain traction with their IT management. Network infrastructure upgrades often lie at the bottom of IT investment plans, because being cast as technical issues with little strategic impact, they lack business champions who could advocate their importance to the firm at large. These organisational factors reinforce the physical embeddedness of infrastructure in an organisation's IT systems, and highlight the importance of understanding the network of actors who are involved in supporting the status quo, whether actively or passively.

Another key set of members of this network are the vendors. Vendor support was frequently mentioned as a barrier to the adoption of IPv6. This was surprising as it was not mentioned in the literature we reviewed, especially given the severity of its impact. For example, although institution A has done quite a lot of work on its IPv6 adoption project, it is now arrived at a stand-still because of the lack of vendor support. This finding indicates the unstated assumption in most IS adoption literature that when a technology is ready for adoption, its supporting ecology is also ready to the same extent. The experiences of the firms here point out that this may not be so. Even when organisations are willing and ready to adopt IPv6, they may be held back by the limitations of their vendors. These come in the form of equipment not supporting the protocol when "it said so on the box", requesting for additional license fees when using the same equipment but with the new protocol, or simply not offering any equipment that supports the new protocol. While our literature review uncovered numerous governmental and industry campaigns to encourage IPv6 use, little was found on the vendor side. This finding has motivated us to spend some more time exploring the role that vendors play in developing innovations, educating buyers, and supporting their adoption. At the same time, it would be worth comparing the IPv6 experiences of the organisations in our study with their experiences with other IT infrastructural shifts, such as CDMA/GSM, dial-up/broadband, and web services. This again points to the importance of understanding the attributes of the network supporting an infrastructural component and the motivations of the network's members.

CONCLUSIONS

The next steps in this study are to collect more data, and analyse it in the light of the points made above in the Discussion. Paying more attention to the network of actors involved in making decisions about an organisation's IT infrastructural components, and tracing how these actors manage their competing interests, should shed more light on understanding the slow uptake of IPv6, despite the dire lack of IP addresses. This will enable us to prepare detailed chronologies of the events leading to the current state of the organisation's IPv6 deployment. These chronologies will form the process data that we can use to conceptualise events and detect patterns among those events (Langley, 1999), which in our case, refers to identifying phases of IPv6 adoption and transitions between them.

One aspect of the IPv6 situation that could use more consideration is the benefit of IPv6 to an organization. This project is novel, partially because it addresses digital infrastructure, which is often categorized as transparent to the user (especially after assimilation). However, new infrastructure often enhances capabilities (e.g., a faster internet connection or a new way to transfer and store files, etc.). It is important to understand that at some point, IPv4 will fail; and in order to continue with current business processes (i.e., connecting devices to the internet),

organizations will have to upgrade. These benefits have to be specified in more detail and should extend to is impact on a firm's strategic opportunities.

While most studies on IT adoption focus on firm-specific factors, this study argues that institutional forces may also be relevant in understanding the adoption rate of IPv6, since it is a component of an organisation's digital infrastructure, not an application used by a set of employees or in a particular business unit. The embedded nature of an organisation's digital infrastructure means that changing it is more difficult than changing the set of applications or devices the organisation uses. Thus, institutional forces may play a stronger role in the adoption of digital infrastructure, compared to the adoption of other types of IT, which may be driven more by organisation-specific resources. The results of this study will guide managers and policy makers in their decision-making and planning for IPv6 adoption, as well as more broadly inform policies to promote the upgrading of critical digital infrastructure components that are not centrally controlled or managed.

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