Network Infrastructure Practices in Large Australian Organisations*

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Structured cabling is the network infrastructure embedded within a building's structure. Installing appropriate cable types is important, as changes are costly and disruptive. This study investigates trends in structured cable infrastructure in Australia. Results suggest that many of the established reasons for adopting different transmission media are often not considered. The prevailing view is that there is no clear favourite backbone medium in Australia, which creates uncertainty for those organisations wishing to upgrade or install new infrastructure. Copper, however, is clearly the preferred medium for horizontal connections.

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INTRODUCTION

One of the biggest forces driving increasing network capacity requirements is the improvement in the computing abilities and performances of personal computers (Nassoura 2000). The rate at which this computing capacity increases has become known as 'Moore's Law', which contends that leading-edge computer technology becomes twice as complex, and therefore powerful, over a period of approximately eighteen months (Moore 1965). While initially simply an observation about the rate at which computer circuitry was increasing in sophistication, some believe Moore's Law has become a self-fulfilling prophecy (Schaller 1997). The relationship between computing capacity and bandwidth consumption has led to the observation of a similar phenomenon that has been noted for bandwidth requirements, suggesting that the bandwidth available to consumers is likely to double every 1.9 year (Eldering, Sylla & Eisenach 1999).

This dramatic increase in computing ability enables and promotes a wide application of digital multimedia such as audio, video, 2D/3D graphical simulation and animation, high volume data exchange and processing, and 'real time' communication such as video/mobile conferencing (Nassoura 2000). All these

activities directly or indirectly require higher network capability. Time and speed, as the two most critical factors influencing business performance (Gates 1999), also call for organisations to continually increase their ability to move data from one place to another. The bandwidth of a network depends largely on the capability of the connection media—the cables and wireless systems that form the physical connections of the network.

There are obviously many factors that might influence the choice of network media, and there is no clear industry favourite. This research is part of a program to develop a model based on relationships between different factors in the cable selection process to help minimise the risk in infrastructure decision-making, thus resulting in a more efficient information technology (IT) industry as a whole. This will be of benefit to any organisation that currently faces, or will face in the future, the dilemma of selecting an appropriate physical transmission medium. The current research project is concerned purely with the cable type; encoding techniques and data link technologies are not included in this analysis.

This paper presents the results of a survey of network infrastructure practices in large Australian organisations, making a comparison with findings of related studies from Southeast Asia and China. The following section describes the relationship between structured cabling and business technology architecture. Different types of cabling and wireless networks are then discussed. The following two sections describe, respectively, the long-term objective of the project—to develop a prediction model for cabling trends—and the survey method used in this study. Finally, the paper analyses and discusses the findings from the survey, and makes some conclusions.

BUSINESS TECHNOLOGY ARCHITECTURE

Infrastructure cabling, also known as structured cabling, is that which is embedded within a building and connects network devices around the building. Such cabling is usually enclosed within risers, cable ducts and plena. The backbone connects different wiring closets and floors of the building, and is sometimes referred to as vertical cabling (Clark 2002), while horizontal cabling connects network devices to the backbone, and normally ends at a plate in the wall.

Infrastructure cabling is a part of the business technology architecture, defined by Nassoura (2000) as being comprised of four layers, which are described in Table 1 (opposite). Compared with the top three layers, the installation cost of the cable infrastructure layer is only about 5% of the total business technology architecture cost, which includes all kinds of hardware and software (Loe 1994; *BusinessWorld* 2001). The cabling system, however, is embedded with the building structure, which makes it much harder than the other three layers to replace and update (Desrosiers 1999; Cook 2000). The cost of replacing or updating old cabling in an existing building will be up to four times higher than the installation of a new cabling system at the point of building construction (McElroy 1997). Moreover, this cost is just the system cost and does not include the cost of interruptions to day-to-day business operations (Loe 1994). Thus, most organisations will attempt to avoid the cost of replacing or updating a cabling system, if possible.

In its position at the base of Nassoura's model, the cabling system plays a fundamental role as the basis for the other three layers. A poor cabling system will cause endless problems such as data

TABLE 1
The four layers of the business technology architecture

Layer 1	The applications, programs and software that facilitate day-to-day business operation, this layer has the shortest life cycle (i.e. from several months to one or two years).
Layer 2	The PCs and workstations that contain the first layer of business applications. This layer has a longer life cycle than business applications (i.e. up to three years).
Layer 3	The network connection equipment such as switches and routers. This layer has a life cycle of three to seven years.
Layer 4	The vertical and horizontal cable systems in the building. This layer has a life cycle of fifteen to twenty years.

errors, congestion and disconnections (Smith 1992; Loe 1994; *BusinessWorld* 2001). Inverso (2001) suggests that nearly half of all network faults are the result of poor cabling. Groth, McBee and Barnett (2001) put the figure at nearly 70%, and suggest that the physical layer is the most neglected aspect of computer network design. Clearly, even though the proportion of total IT expenditure is relatively small, if an organisation does not pay careful attention to their structured cabling, they will probably have to pay a huge amount of money in long-term on-going costs and eventual replacement (Haupt 1999; Nassoura 2000; Dell 2005).

Cabling Types

In light of such concerns, it is sensible to ensure that an appropriate cable type is installed (Haupt 1999). Cable can be either copper wire or fibre-optic cable, and there is a range of cable types available. The most common copper cable in use today is Enhanced Category 5 (Cat5e) unshielded twisted pair (UTP), which is up to ten times faster than the Category 5 cable it replaced. Other cables are Category 6 (Cat6) and Category 7 (Cat7), which are increasing in popularity (Cook 2000; Panko 2001). Copper cable is cheaper and easier to install, and although technological developments sometimes confuse the issue, copper cable is slower than fibre-optic cable as distance increases.

Fibre-optic cable has two main types: single-mode and multimode. Single-mode is more expensive and is widely used for transmission over longer distances (Tanenbaum 2003). It is available in several types as engineers develop new techniques to get around distance limitations caused by dispersion. Single-mode fibre carries a single signal, usually emitted from a laser light source. Multimode fibre can be categorised based on its diameter: 50 µm and 62.5 µm are the two most common sizes in use. This type carries multiple signals, often emitted from LEDs rather than lasers (Tittel & Johnson 2001).

A recent study in Southeast Asia suggests there is no clear industry favourite cable (Dell 2005). Cat5e, Cat6, Cat7, single-mode fibre, and 50 µm and 62.5 µm multimode fibre all have their supporters. Thus, any organisation installing structured cabling is faced with the dilemma that the investment they are about to make will remain for up to fifteen years, but the IT industry currently has no clear opinion

to guide such a decision. 'Future-proofing' is a very common idea when organisations are choosing their cables (Cook 2000). Conventional wisdom is that fibre is more future-proof than copper, thus the simplest decision for many organisations is simply to use fibre wherever possible around the building (Haupt 1999). In addition, some current cabling technologies provide a very cost-effective fibre-optic solution, making this an attractive option (Allen 2000).

Conversely, another common perspective is that although the fibre solution sounds like a good idea, it is possibly not the best option (Desrosiers 1999; Cook 2000), and whether it is really necessary to install fibre is something to consider from a business operation point of view rather than from purely technical perspectives (Haupt 1999). Cost-efficiency and result effectiveness are always the necessary concerns of any business organisation (Desrosiers 1999).

The cost of using fibre involves not only the cable itself but also fibre-related hardware such as NICs (Network Interface Cards), jacks, fibre switches, and routers; and because such hardware requires the use of opti-electronics to convert electronic signals into optical ones, it is going to be much more expensive (McElroy 1997). Furthermore, the installation of fibre is also more complex and costly (McElroy 1997; Haupt 1999). Compared with fibre, Cat5e can supply almost the same data-carrying capability as fibre in a horizontal cabling system (Haupt 1999; Cook 2000); and Cat5e-related hardware and installation are much cheaper. Thus, Cat5e is a value-oriented solution (Cook 2000); and while every organisation is different, Haupt's (1999) observation that the cost of running fibre to the desktop is not justifiable is probably true for nearly all organisations.

Wireless Networks

With no agreement on which wiring system is better, the increasing popularity of wireless networking only serves to increase the uncertainty faced by IT managers. Compared with wired solutions, wireless networks have some obvious advantages such as flexibility and portability (*BusinessWorld* 2001), which help to support the increasing demands on network infrastructure triggered by changes in business operations (Cook 2000). Companies are also more frequently reconfiguring their workspaces and furniture layout to meet changing business needs (Nassoura 2000), a situation in which wireless networks also have an advantage. The current trend of maximising open office spaces and reducing traditional closed offices also influences decisions considerably in corporate facility management (Nassoura 2000).

The range of wireless connection standards currently available includes 802.11, 802.11a, 802.11b, 802.11g, 802.11h, 802.11j and 802.16a. The most common Wireless LAN (Local Area Network) standards are 802.11a, 802.11b, and 802.11g, all of which are slower than Cat5e systems (Fell 2001; Ciampa 2002). The 802.16a broadband wireless network is intended for use in Metropolitan Area Networks (MANs), rather than LANs (Raichura 2003), and is not yet widely used. Its signal range is much wider than the other standards (Cooney 2003; Raichura 2003). Other relevant considerations are that wireless networks have greater security problems and operate at lower speeds than their wired counterparts (Ciampa 2002; AirDefense 2003; Wexler 2004).

Trying to predict what cabling types will be dominant ten to fifteen years into the future seems an impossible task, and 100% accurate predictions

are extremely unlikely. Given the amount of cable infrastructure in place, however, across the vast majority of organisations, significant increases in efficiency can be gained if even a fraction of decisions is improved.

A PREDICTION MODEL FOR CABLING TRENDS

This research is part of a larger project that aims to develop a model to help predict future cabling adoption trends. Previous data collection efforts have focused mainly on Southeast and East Asian nations, in particular China, Hong Kong, Singapore and Malaysia; and have revealed a number of trends in the way structured cabling decisions are made.

Findings to date have raised the possibility that cable selection is not necessarily a well-reasoned decision in many cases. Decisions may be based on little analysis, and decision-makers may be influenced by those not motivated by the organisation's best interests (Dell 2005).

If differences in cabling adoption practices exist between regions, the prediction model towards which this project is working will need to take these into account. Possibly, it may not be feasible to develop a single model that is universally applicable, although this would depend on the nature of the differences between regions.

To this end, this paper reports the results of a study of structured cable practices in Australia. Based on the earlier findings, the following hypotheses were tested.

H1: Australian IT professionals are approximately equally divided among themselves in choosing one or another of the four media: copper, single-mode fibre, 62.5 µm multimode fibre and 50 µm multimode fibre, as the backbone medium expected to become dominant within five years.

H2: Australian organisations will adopt the same type of fibre that they believe will be dominant in the future.

H3: Backbone fibre is installed at the same time as either horizontal fibre or horizontal wireless networking in Australian organisations.

H4: Australian IT professionals give the same rationale for the installation of fibre for both horizontal and backbone cabling.

SURVEY METHOD

To test the hypotheses proposed above, the leading 934 Australian organisations in terms of revenue were surveyed by a postal questionnaire in April and May 2004. The sample focused on larger organisations because not only are they far more likely than smaller organisations to use structured cabling systems, but smaller organisations are generally not responsible for the installation of structured cabling, even in cases where they do enjoy its use. This is because structured cabling systems are typically installed in large buildings, either by the building owners or by large-organisation tenants.

Twenty-six questionnaires were undelivered, leaving a total sample size of 908. One hundred and nine responses were received, giving a response rate of 12%. While this response rate is low, it is felt that the number of responses received is sufficient, and that trends in structured cabling in Australia can still be observed.

Responses to open-ended questions were coded into categories, and results were analysed to reveal current trends in Australian organisations' use of structured cabling systems.

Interviews were subsequently conducted, in April 2005, with four Australian IT managers and consultants to validate conclusions drawn from the survey data, and to elicit possible explanations for observed phenomena.

TABLE 2
Backbone media in large Australian organisations

Medium	Usage Level (%)
Copper and fibre mix	35
Copper, fibre and wireless mix	29
Fibre exclusively	19
Copper exclusively	15
Wireless exclusively	1
Fibre and wireless mix	1

TABLE 3
Horizontal media currently in use in large Australian organisations

Medium	Usage Level
Copper exclusively	50
Copper and wireless mix	20
Copper and fibre mix	15
Copper, wireless and fibre mix	11
Fibre exclusively	3

RESULTS AND ANALYSES

Media Currently in Use

Results from the Australian study indicate that the majority (65%) of large Australian organisations uses a combination of transmission media in their network backbone. The breakdown of backbone media is presented in Table 2. The data suggest that no medium is currently favoured over others, echoing the findings from Southeast Asia.

Of those organisations that use fibre in their backbone, there is no clear leader in terms of the type of fibre that is used: 30% uses single-mode fibre; 23% uses 50 µm multimode fibre; and 38% uses 62.5 µm multimode fibre. This creates uncertainty for organisations wishing to invest in a fibre backbone, as there is no certainty that the medium chosen will persist in the market, and thus be supported by a wide range of products in the future.

Horizontal media, however, does not suffer the same problem, as copper is clearly the most popular horizontal medium in large Australian organisations. The survey showed that 96% of respondents uses it, with 50% of them reporting that they use copper exclusively for their horizontal cabling, and 46% indicating that they use it in combination with other media, as illustrated in Table 3.

Media in Use in Five Years

H1: Copper, single-mode fibre and each of the two common forms of multimode fibre will be approximately equally supported in Australia as the medium likely to be dominant in the backbone in five years.

Support for this hypothesis is indicated in Table 4 (opposite), in which data from this study are compared to other sources. Note that the total percentages for each column do not necessarily equal 100% because a proportion of respondents in all studies indicated that more than one medium would be dominant in five years; however, in all studies the number of respondents who indicated this was low.

The fact that this hypothesis is supported endorses the notion that Australian IT managers are uncertain about which media will be widespread in the years to come. It is particularly interesting to note that 7% of

Australian respondents felt that wireless networking would be widespread in the backbone within five years.

H2: Australian organisations will adopt the same type of fibre they expect will become the dominant fibre type in the future.

This appears to be the case where organisations use fibre backbones, but not where copper or wireless backbones are in use. Two possibilities emerge. The first is that those organisations that have invested in a fibre backbone analysed the decision beforehand and installed the fibre type they expected to become dominant. The second possibility is that, when asked about their perceptions of the market in five years' time, those organisations that had already invested in fibre gave an answer that reflected hope, rather than reasoned analysis. Given the findings in Dell (2005) that such decisions are not well reasoned, the second possibility is definitely plausible. Nevertheless, 81% of Australian respondents felt that some form of fibre would be commonplace in five years, while only 32% of respondents suggested copper connections would be widespread. Clearly, there is a widespread belief that use of fibre cabling will be the mainstream in backbone cabling.

Most fibre users are also confident that the particular type of fibre they have chosen will become the mainstream; 58% of single-mode users, 52% of 50 µm multimode, and 60% of 62.5 µm multimode all believed their chosen medium would be the dominant medium in five years. Clearly, not all versions can be in the majority. It seems inevitable that many organisations erroneously expect the cable type they have adopted will become widespread.

Copper users are far less confident (32%), while wireless users have very little expectation that wireless connections are likely to be the dominant backbone connection. This further supports the notion that fibre is widely believed to become the dominant backbone medium in the future.

TABLE 4
Likely backbone media in five years

Medium	Australia (%)	China (%)	SE Asia (%)
Single-mode fibre	28	31	23
50 µm multimode fibre	26	27	28
62.5 µm multimode fibre	27	23	23
Cat5E, Cat6, or Cat7	32	17	25
Wireless	7	13	N/A

(Sources: Australia—present study; China—Ding and Dell 2005; SE Asia—Dell 2005)

While Australian support for fibre may seem high, a comparison between Australian and other responses is also interesting, particularly when considering the fibre–copper dichotomy. The proportion of Chinese respondents (17%) who felt some form of copper would be a dominant backbone medium in the near future was only approximately half that of Australian respondents (32%). Southeast Asian responses fall somewhere in-between, at 25% of respondents.

The reason that so many Australian respondents anticipate a copper-bound future in comparison to other countries in the region is perhaps partially due to the high levels of 'legacy' infrastructure in place in large, Australian organisations. In other words, the level of copper infrastructure that organisations are keen to preserve due to the amount of investment involved leads organisations to anticipate a copper-bound future, despite copper infrastructure now being widely perceived as obsolete.

Twenty per cent of Australian respondents explicitly cited legacy issues as the reason they do not

use fibre in the backbone. In contrast, China's recent, extremely rapid development may account for much lower levels of legacy infrastructure in place.

A final detail is that respondents' views about what may be the dominant backbone in five years appear to be influenced by the size of their IT budgets. A lambda test, using the budget as the independent variable, revealed a statistically significant association ($\alpha = 0.05,\ p = 0.040$) between the size of an organisation's IT budget and the backbone medium they felt would be dominant in five years. Lambda is a proportional reduction in error measure; it indicates the proportion by which error is reduced in a prediction of a dependent variable, given the state of the independent variable (Norušis 1997).

This test resulted in a λ value of 0.211, indicating that the backbone transmission media in use are somewhat dependent on the size of an organisation's IT budget. The higher the budget, the more likely a respondent will expect fibre to be the dominant medium in five years. Respondents with smaller IT budgets were more likely to expect copper backbones to be common.

This relationship between annual IT budget and infrastructure appears much stronger in Australia than in other countries in the region. There was no significant relationship observed in Southeast Asian countries (Dell 2005), and only a very tentative relationship observed in China (Ding & Dell 2005). This finding could explain the suggestion made by Dell (2005), after interviewing Australian IT professionals, that structured cabling decisions may often not be based on sound technical reasoning.

The supplementary interviews conducted with a number of Australian IT professionals provide a possible explanation for this. One interviewee commented that technical managers in Australia often have a business rather than a technical background. Moreover, there is a perception among many Australian business people that 'techies' tend to 'push decisions up for toys'. This may lead to decision-makers disregarding sound technical advice because of where it comes from.

TABLE 5
Likely horizontal media in five years

Medium	Australia (%)	China (%)	SE Asia (%)
Cat5E	14	16.0	6.7
Cat6	43	18.0	28.6
Cat7	21	9.5	27.8
Fibre	9	32.1	35.6
Wireless	36	36.0	N/A

(Sources: Australia—present study, China—Ding and Dell 2005; SE Asia—Dell 2005)

As well as respondents' views on likely backbone media, their views on horizontal media were also assessed. Table 5 summarises these responses in comparison with data from China and Southeast Asia.

Copper is clearly expected to remain commonplace in Australian horizontal cabling. Wireless does have some support, but there is little support for the various types of fibre. The majority of copper users (70%) anticipate some form of copper being the dominant horizontal medium in five years. Those who use fibre horizontally are far less likely to expect horizontal fibre—only 16% of horizontal fibre users thought some form of horizontal fibre would be commonplace. Of respondents who use wireless horizontally, 50% felt that it would become the norm.

As with backbone cabling, it is interesting to compare Australian figures with those from other countries. In a similar fashion to backbone cabling, a far higher proportion of Australian respondents (78%)

expected copper cabling to be the dominant horizontal medium than Chinese respondents (43.5%) and Southeast Asian respondents (63.1%). Legacy issues are again a likely factor limiting Australian infrastructure upgrades, but do not necessarily hinder developing nations to the same extent.

H3: Backbone fibre is installed at the same time as either horizontal fibre or horizontal wireless networking.

This does not seem unreasonable; if an organisation wishes to reduce the amount of disruption due to network downtime, it may seek to upgrade both backbone and horizontal network segments at the same time.

To test this hypothesis, the planned implementation time for both horizontal and vertical infrastructure were tested to determine if a statistically significant correlation between the relevant variables could be found.

When testing to determine an association between the implementation time of vertical fibre (independent) and the implementation time of horizontal fibre (dependent), a lambda (λ) test could not be conducted because the asymptotic standard error was 0. Because the data in these two variables are nominal, other tests of association, such as the Goodman-Kruskal tau, are also inappropriate. A symmetric lambda test was conducted and revealed no statistically significant ($\alpha = 0.05$) association between implementation times for vertical and horizontal fibre ($\lambda = 0.030$, $p = 0.315$). This suggests that backbone and horizontal fibre are installed independently of each other, and does not support the third hypothesis.

Lambda tests were also conducted on the implementation time for vertical fibre and for wireless horizontal networking. Again, a statistically significant ($\alpha = 0.05$) association was not found, regardless of whether horizontal wireless implementation time was the dependent ($\lambda = 0.172$, $p = 0.089$), or independent variable ($\lambda = 0.000$, $p = 1.000$).

Thus, it again appears the third hypothesis is not supported. In the Australian IT industry there does not seem to be any correlation between the installation of vertical fibre and horizontal media, either fibre or wireless.

This is in contrast to both China and Southeast Asia, where strong correlations were found (Dell 2005; Ding & Dell 2005). It seems likely that this is a side-effect of the lower level of legacy infrastructure in developing nations, discussed earlier. In cases where installations are 'greenfield' sites, vertical and horizontal cabling must obviously be installed at the same time. Given that the hypotheses for the Australian study were based on Southeast Asian data, it is not surprising that hypothesis 3 was not borne out in the Australian data.

H4: Australian IT professionals report the same rationale for the use of both vertical and horizontal fibre.

This hypothesis was framed on the basis of responses to the Southeast Asian study, which did not distinguish between speed, reliability and security as reasons for adopting fibre. Furthermore, that study did not allow respondents to provide free-form answers to these questions.

The current survey used a modified version of the instrument to allow respondents to provide open-ended, free-form answers to these questions. First, this was done to allow responses citing speed, reliability and security to be distinguished from each other. Second, it was beneficial to have an open-ended question so that respondents' thinking was not prompted in any particular direction.

The reasons most commonly cited by Australian organisations in support of vertical fibre were bandwidth (53% of fibre users), and distance (36%).

Both reasons do not seem to overlap greatly—only 13% of fibre users cited both reasons. This suggests that Australian organisations use fibre for bandwidth or distance, but not usually for both reasons, implying that it is uncommon for large data volumes to be transmitted long distances over private fibre networks. It is noted that both the cost and regulatory environment in Australia make private fibre networks that span beyond a single site very rare, so it is likely that when respondents cite distance as a factor they are generally referring to distance within a single site.

Other 'textbook' reasons for fibre did not figure highly in Australian fibre users' responses. Only 5% cited security as a concern; 10% cited its immunity to electromagnetic and radio interference; 11% cited reliability; 9% cited electrical isolation; and 9%, future-proofing the network.

The rationale for implementing fibre backbones in Australian organisations does not differ greatly from Chinese organisations—data used by Ding and Dell (2005) also indicate that bandwidth is the prime concern in China. Likewise, the survey of primarily Southeast Asian organisations indicated that bandwidth was likely to be the most important factor, although shortcomings in the survey design make it impossible to be certain about this conclusion.

Given the similarities between responses to all three studies (i.e. the present study; Ding & Dell 2005; and Dell 2005), this paper tentatively concludes that the rationale in support of implementing fibre backbones in Australia is primarily driven by bandwidth concerns; and, in this respect, Australian network infrastructure practices are largely in line with other countries in the region.

Not surprisingly, far fewer Australian respondents reported using horizontal fibre (28%, $n = 31$) than vertical fibre. Of these, only 17 gave a reason for its use, too few for meaningful statistical analysis. Among those who did respond, the reason cited most often was the need for bandwidth ($n = 10$). Horizontal distance requirements were only reported by four respondents. As with backbone fibre, very few respondents cited both bandwidth and distance requirements ($n = 1$).

As with vertical fibre, Australia seems comparable to other countries in the region. In the Chinese study (Ding & Dell 2005), bandwidth was by far the most common justification provided for horizontal fibre. The Southeast Asian study data also suggested that bandwidth was by far the most common justification for horizontal fibre, although the previously noted study weakness prevents a definite conclusion.

This suggests that bandwidth is likely to be the most common reason for the use of fibre in both backbone and horizontal cabling, although any statistical testing for association between the two variables is not possible because of the low number of organisations using horizontal fibre.

This seems reasonable at first glance, as fibre has a reputation for being faster than copper cabling. The bandwidth achieved over any cable, however, is interrelated to the distance covered. Copper cabling can achieve gigabit speeds over relatively short distances—Gigabit Ethernet can operate over Cat5e cable, for example. Furthermore, copper will more than likely be capable of 10 Gbps (gigabit per second) speeds as well; the likely maximum distance over Cat5e is 40–50 m; over Cat6 is 50–70 m; and Cat7 is likely to be able to run 10 Gbps over distances of up to 100 m (Caruso 2003).

It is peculiar that there is not much overlap between bandwidth and distance reasons; one would expect a respondent with a working knowledge of the relationship between bandwidth and distance to mention both factors. Given that copper is capable of high-speed connections over shorter distances at least,

it is also interesting that those organisations using fibre for horizontal connections, which typically run over shorter distances, cite bandwidth as a reason. While not conclusive, this corroborates findings from earlier research that the decision to implement fibre is not considered deeply by IT personnel (Dell 2005).

Also interesting, and perhaps of concern to IT personnel wishing to make their network future-proof, is the tendency to install fibre unnecessarily. Future upgrades to an organisation's infrastructure may well necessitate copper cable, such as if 'power over Ethernet' is required to support Voice over IP. While this is not an issue for backbone cabling, if fibre is installed horizontally an organisation may find itself in the unusual position of having to replace fibre with copper at a later date.

While the fourth hypothesis focused only on fibre, it is prudent to check for the presence of interesting details relating to other media. Lambda tests were conducted between the variables containing the coded responses from the open-ended questions about the respondents' reasons for using the relevant backbone and horizontal media. Of these, only one significant ($\alpha = 0.05$) association was found; there is an association between the reasons cited for using copper in the backbone, and the reasons cited for not using fibre horizontally ($\lambda = 0.313$, $p = 0.041$).

The most commonly cited reasons for using copper in the backbone were that copper is in use because it is legacy infrastructure (34%) and that copper is cheaper (20%). Legacy is an interesting response—almost as if respondents were looking to excuse their use of copper. The term also implies the infrastructure is out-of-date, and that a better, more modern alternative exists. Again, the fact that this is the most common response corroborates the notion that IT personnel work from the assumption that copper is irrelevant, despite the fact that copper is capable of 1 Gbps and likely 10 Gbps speeds over reasonable distances.

The most common reason cited among horizontal copper users for not using fibre horizontally was that copper provides adequate bandwidth (29%). The second most common reason was that fibre was too expensive (21%). As with vertical infrastructure, many relevant factors are not considered when selecting horizontal cabling infrastructure. The survey revealed only negligible response levels for ease of installation and management ($n = 4$) or the requirement of copper for electrical conductivity, such as for voice communications ($n = 2$).

This again reinforces the finding that cable selection decisions in Australia are not thoroughly explored. Only a limited number of factors are considered: cost and bandwidth for horizontal cabling; and bandwidth and distance for vertical cabling. There may be a lack of awareness of the capabilities of copper, and other relevant issues such as electrical isolation and Power over Ethernet.

The legacy burden faced by Australian organisations is possibly greater than that faced by organisations in developing countries. Ding and Dell (2005) found that legacy issues are less common in China, possibly because infrastructure does not have as long a history as in developed countries. It is plausible that similar patterns would be found in other countries if research were to be conducted. This paper flags such future research as required.

It is also noted that a priority for Australian policy-makers should be to develop strategies to deal with the existence of greater legacy barriers than occurs in competing markets. This is especially important, given the length of time that infrastructure can be expected to last, and the apparent lack of consideration Australian organisations put into infrastructure decisions.

CONCLUSIONS

The belief that there is no clear favourite backbone medium for the future, based on earlier findings primarily from Southeast Asia, has been shown to be true in Australia as well. This creates uncertainty for those organisations wishing to upgrade or install new backbone infrastructure.

The question of horizontal connections is not so unclear—copper is clearly the preferred medium. There are similar levels of horizontal fibre and horizontal wireless networks in place in large Australian organisations, although copper is more widespread than both of these combined.

There is no support for the notion that horizontal and vertical cabling are installed at the same time in Australia. This suggests possible differences between installation practices in Australia and Southeast Asia, which may possibly indicate greater legacy factors in Australia than in other countries in the region.

The only factors widely considered when adopting cable are bandwidth, distance and cost. Regardless of whether they are installing vertical or horizontal media, Australian IT professionals generally do not consider a range of factors pertinent to media selection; these include electrical isolation or conductivity requirements, electromagnetic and radio frequency interference, reliability, ease of installation, and security. This may lead to ill-founded decisions and result in inefficiencies, such as if structured cabling needs to be replaced prematurely. The authors recommend that organisations consider these factors when planning a structured cabling system.

Finally, two areas have been identified for future research. First, there is a need to investigate the legacy issues in order to determine appropriate responses by Australian policy-makers with respect to minimising the negative impact that legacy issues might have on Australian organisations. Second, the ways in which Australian IT professionals make investment decisions for network infrastructure should also be investigated further, to enable the industry to improve such decisions.

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