A snapshot of Australian network infrastructure practices

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Abstract

Structured cabling is the network infrastructure embedded within a building's structure, typically within ceilings, walls, and risers between floors. Installation of such infrastructure is costly and disruptive; thus, installing appropriate cable types is especially important. Structured cable often has a lifespan of 15 years or more and the consequences of a poor decision can be significant, especially if the chosen cable does not enjoy widespread support in the future.

Previous research has 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).

Part of a larger research project spanning Australia, China, and south-east Asia, this study investigates current trends in structured cable infrastructure in Australia. Results suggest that many of the "textbook" reasons for adopting different transmission media are often not considered.

1. Introduction

One of the biggest forces driving increasing network capacity requirements is 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 18 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 has been observed for bandwidth requirements, which suggests that the bandwidth available to consumers is likely to double every 1.9 years (Eldering *et al.*, 1999).

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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. Further, time and speed, as the two most critical factors influencing business performance (Gates, 1999), also call for organizations to continually increase their ability to moving data from one place to another. The bandwidth of a network depends largely on the capability of the connection media.

Infrastructure cabling, also known as structured cabling, is that which is embedded within a building and connects network devices around the building together. Such cabling is usually enclosed within risers, cable ducts and plena. The backbone connects different wiring closets and floors of the building together, 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 presented in Figure 1.

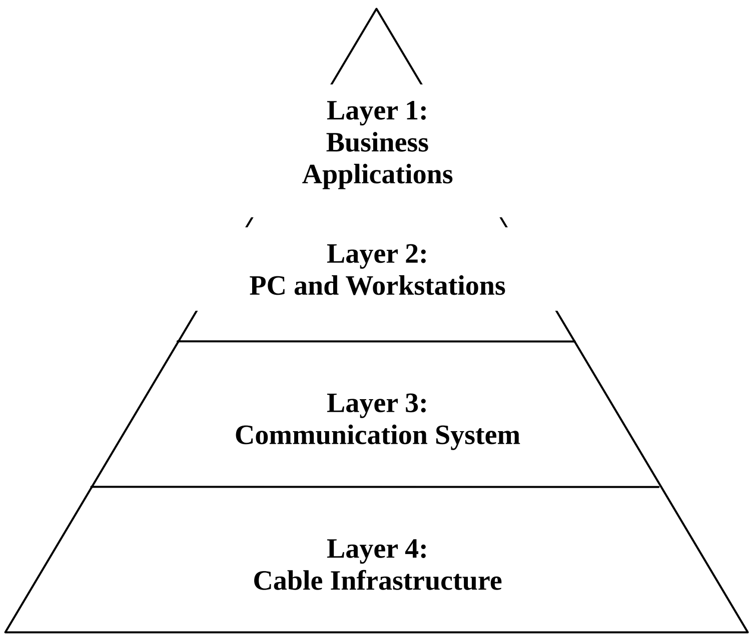

Figure 1: Business Technology Architecture

Source: Nassoura (2000)

The first layer is business applications layer, which consist of all the applications, programs and software that facilitate day-to-day business operation. The second layer consists of PCs and workstations, which housing the first layer of business applications. The third layer is the communication system layer, which includes network connection equipment such as switches and routers. The last layer is cable infrastructure layer, which consists of vertical and horizontal cable systems in the building (Nassoura, 2000).

Further, Nassoura (2000) also pointed out that different layer technology architecture has various life cycles. The top layer, business applications, has the shortest life cycle in comparison with the other three layers, and typically varies from several months to one or two years. PCs and workstations have a longer life cycle than business applications, and might typically last up to three years. The communication system can usually last from three to up to seven years, while cable infrastructure has the longest lift cycle, and can be made to last from fifteen to twenty years (Nassoura, 2000; Phan, 2001; Heather *et al.*, 2004).

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). However, because the cabling system is embedded with the building structure, it is much harder than the other three layers to replace and update (Desrosiers, 1999; Cook, 2000). The cost of replacing or updating an old cabling in an existing building, including removing the old system and installing the new one, 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 organizations will attempt to avoid the cost of replacing or updating a cabling system if at all possible.

In its position at the base of Nassoura's model, the cabling system plays fundamental role as the basis for the other three layers. A poor cabling system will cause endless problems such as data 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 *et al*. (2001) put the figure at nearly 70%, and suggests 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 organization does not pay careful attention to their structured cabling, they will probably have to pay a huge amount of money on long term on-going costs and eventual replacement (Haupt, 1999; Nassoura, 2000; Dell, 2005).

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 fibreoptic cable, and there is a range of cable types available. The most common copper cable in use today are Enhanced Category 5 (Cat5e) unshielded twisted pair (UTP), which is 10 times faster than the Category 5 cable it replaced, as well as Category 6 (Cat6) and Category 7 (Cat7) which are increasing in popularity (Cook, 2000; Panko, 2001). Coaxial cable is old and heavy, but it has it some advantages and is still seen on rare occasions. 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 can be categorised according to two main types: single-mode, and multimode. Single mode, while more expensive, is widely used for transmission over longer distances (Tanenbaum, 2003), and is available in several types, as engineers develop new techniques to get around distance limitations caused by dispersion. These techniques are known as dispersion shifting, and single-mode fibre can be either dispersion shifted or non-dispersion shifted. There are a number of types of dispersion-shifted fibre (DSF). Dispersion shifting is typically only required in really long distance runs; non-DSF is normally satisfactory for structured cabling within a single building.

Multimode fibre can also be divided into two categories, which are based on its diameter – 50 micron and 62.5 micron are the two most common sizes in use. Single mode fibre carries a single signal, usually emitted from a laser light source, while multimode fibre carries multiple signals, often emitted from LEDs rather than lasers (Tittel and Johnson, 2001). This current research project is concerned purely with the cable type; encoding techniques and data link technologies are not included in our analysis.

Currently there is no clear industry favourite cable. Cat5e, Cat6, Cat7, single-mode fibre, and 50 micron and 62.5 micron multimode fibre all have their supporters. Thus, any organization installing structured cabling is faced with the dilemma that the investment they are about to make will remain for up to 15 years, but the IT industry currently has no clear opinion to guide such a decision. Future proofing is a very common idea when organizations are choosing their cables (Cook, 2000). Conventional wisdom is that fibre is more future proof than copper, thus the simplest decision for many organizations is simply to use fibre optics wherever possible around the building (Haupt, 1999). And some current available cabling technologies do provide a very cost-effective fibre optic solution, making this an attractive option (Allen, 2000).

On the other hand, another common perspective is that although 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 business operation point of view rather than purely technical perspectives (Haupt, 1999). Cost efficiency and result effectiveness are always the necessary concerns of any business organization (Desrosiers, 1999). The cost of using fibre is not only the cable itself but also fibre related hardware such as NICs, 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). Further, 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 horizontal cabling system (Cook, 2000; Haupt, 1999), and Cat5e related hardware and installation is much cheaper. Thus, Cat5e is a value-oriented solution (Cook, 2000), and while every organization is different, Haupt's (1999) observation that the cost of running fibre to desktop is not justifiable is probably true for nearly all organizations.

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 helps support the increasing demands on cabling infrastructure triggered by changes in business operations (Cook, 2000). Companies are also more frequently reconfiguring their work spaces and furniture layout to meet changing business needs (Nassoura, 2000), a situation in which wireless networks also have an advantage. The current trend of maximizing open office spaces and reducing traditional closed offices also influences considerably decisions in corporate facility management (Nassoura, 2000).

A range of wireless connection standards are currently available, including 802.11, 802.11a, 802.11b, 802.11g, 802.11h, 802.11j and 802.16a. The most common Wireless LAN standards are 802.11a, 802.11b, and 802.11g, all of which are slower than Cat5e systems (Ciampa, 2002; Fell, 2001). 802.16a is a broadband wireless network 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). Wireless networks have greater security problems and operate at lower speeds than their wired counterparts (Ciampa, 2002; AirDefense, 2003; Wexler, 2004).

There are clearly many factors that might influence the choice of network media, and 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 problem to help minimize the risk in infrastructure decision making, thus resulting in a more efficient IT industry as a whole. This will be of benefit to any organization that currently faces or will face in the future the dilemma of selecting an appropriate physical transmission medium.

Trying to predict what cabling types will be dominant 10 to 15 years into the future seems an impossible task, and 100% accurate predictions are extremely unlikely. However, given the amount of cable infrastructure in place across the vast majority of organisations, significant increases in efficiency can be gained if even a fraction of decisions are improved.

2. Research question

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 South-east and East Asian nations, in particular Singapore, Malaysia and Hong Kong, 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 them into account. Possibly, it may not be feasible to develop a single model which 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.

1. Copper, single-mode fibre, 62.5 micron multimode fibre and 50 micron multimode fibre are expected to be the dominant backbone medium by Australian IT professionals in approximately equal proportions.

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

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

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

3. Method

To test the hypotheses posed above, a survey of the top 934 Australian organisations were surveyed by postal questionnaire in April and May 2004. The sample focused on larger organisations because they are more likely to use structured cabling systems than smaller organisations.

26 questionnaires were undelivered, leaving a total sample size of 908. 109 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 of value, and that trends in structured cabling in Australia can still be observed.

39% of responses came from organisations with an annual budget greater than $5 million. 69% of responses also came from organisations with more than 500 installed network points. That responses would be skewed towards the higher end of both scales was anticipated because of the sample used.

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.

4. Analysis and discussion

4.1. Main media in use in five years

The first hypothesis to be tested was that copper, single-mode fibre and the two common forms of multimode fibre would be equally supported as the medium likely to be dominant in the backbone in five years. This hypothesis appears to be supported, as indicated in the following figures:

Medium	Percent of respondents
Single-mode fibre	28%
50 micron multimode fibre	26%
62.5 micron multimode fibre	27%
Cat5E, Cat6, or Cat7	32%
Wireless	7%

Table 1: Likely backbone media in five years

The total percentage adds up to more than 100% because a number of respondents (22%) indicated that more than one medium would be dominant in five years. The number of respondents who did so was low; only 6% of respondents nominated more than one medium for vertical cabling, and only 8% nominated more than one medium for horizontal cabling.

This finding supports the notion that IT managers making the decision of which network media to install are faced with uncertainty about which media will be widespread in the years to come. It is particularly interesting to note that 7% of the respondents felt that wireless networking would be widespread in the backbone within five years.

Hypothesis 2 predicted that 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 does not appear to be the case where copper or wireless backbones are in use.

83% of respondents felt that some form of fibre would be commonplace in five years, while only 27% of respondents suggested copper connections would be widespread. Clearly, there is a widespread belief that use of fibre cabling will be the mainstream backbone cable.

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-micron multimode, and 60% of 60-micron multimode all believed their chosen medium would be the dominant medium in five years. Clearly, all versions cannot 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 (33%), while wireless users have very little expectation that wireless connections are likely to be dominant backbone connection. This further supports the notion that fibre is widely believed to become the dominant backbone medium.

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 ($\alpha = 0.05$, $\lambda = 0.211$, $p = 0.040$) between the size of an organisation's IT budget and the backbone media they felt would be dominant in five years. 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.

As well as respondents' views on likely backbone media, their views on horizontal media were also assessed. Table 2 summarises these responses.

Medium	**Percent of respondents**
Cat5E	14%
Cat6	43%
Cat7	21%
Fibre	9%
Wireless	36%

Table 2: Likely horizontal media in five years

Copper is clearly expected to remain commonplace in Australia. 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, however – only 16% of horizontal fibre users thought some form of horizontal fibre would be commonplace. 50% of respondents who use wireless horizontally felt it would become the norm.

4.2. Concurrent installation of backbone and horizontal media

Hypothesis 3 was that backbone fibre was 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 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 second 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 second hypothesis is not supported. In the Australian IT industry there does not seem to be any effect between the installation of vertical fibre and horizontal media, either fibre or wireless.

4.3. Rationale for horizontal and vertical media

The final hypothesis was that respondents would report the same rationale for the use of both vertical and horizontal fibre. However, this was based on responses to the previous survey, and Dell (2005) noted that the survey instrument used at the time did not distinguish between speed, reliability and security as reasons for adopting fibre. Further, 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 most commonly cited reasons for 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.

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

Not surprisingly, far fewer respondents reported using horizontal fibre (28%, n = 31). Of these, only 17 gave a reason for its use, too few for meaningful statistical analysis. Among those who did respond, the most often cited reason 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).

These figures suggest that bandwidth is the most common reason for the use of fibre in both backbone and horizontal cabling, although a statistical test for association between the two variables is not possible because of the low number of organisations using horizontal fibre.

At first glance these responses seem reasonable – fibre does have a reputation for being faster than copper cabling. However, the bandwidth achieved over any cable 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. Further, copper will more than likely be capable of 10 Gbps speeds as well; the likely maximum distance over Cat5e is 40-50 metres, over Cat6 is 50-70 metres, and Cat7 is likely to be able to run 10Gbps over distances of up to 100m (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. Further, given that copper is capable of high speed connections over shorter distances at least, it is interesting that those organisations using fibre for horizontal connections – which typically run over shorter distances – cite bandwidth as a reason. While not conclusive, this does corroborate 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 third 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 for 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, 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, a large variety of 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.

5. Conclusions

The belief, based on earlier findings primarily from south-east Asia, that there is no clear favourite backbone medium for the future, has been shown to be true in Australia as well. However, the issue with horizontal connections is not so unclear – copper is still the clear favourite.

However, 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 south-east Asia.

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, including electrical isolation or conductivity requirements, electromagnetic and radio frequency interference, reliability, ease of installation, and security. This may lead to poorer decisions and in may 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.

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