Technical Feasibility of using ADSL Networks to Supply Voice Services that Replicate PSTN Services

Version 1

30 October 2007

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List of Terms and Abbreviations

ACCC – Australian Competition & Consumer Commission

AP – Access Provider

AS – Access Seeker

CAM – Customer Access Module, as defined in the current ULLS declared service description.

CAN – Customer Access Network

Cable Connection Frame – Assembly designed to allow the interconnection of two termination points via the installation of a jumper, typically located in an exchange building, roadside cabinet or large building.

DSLAM – Digital Subscriber Local Access Module

FTTH – Fibre to the Home.

FTTN – Fibre to the Node. For the purpose of this report this is defined as the network architecture used to deliver very high speed data service using xDSL technology. Data rates of up to 24 Mb/s are assumed. New nodes need to be created closer to the end delivery point, thereby shortening the length of metallic cable to enable the higher data speeds to be delivered.

IP – Internet Protocol

Joint – Junction point between two communication wires.

Jumper – a pair of wires used to provide connection between a cable termination and either another cable termination or an equipment termination.

LAS – Local Access Switch, narrowband interface to PSTN, includes Remote Switching Stages and Multiplexers.

LCS – Local Carriage Service

LSS – Line Sharing Service

MSAN – Multi Service Access Node

POI – Point of Interconnection

POTS – Plain Old Telephone Service

PSTN – Public Switched Telephone Network, accessible by the public and uses analogue or digital switching technology.

ULLS – Unconditioned Local Loop Service

WLR – Wholesale Line Rental

1 INTRODUCTION

1.1 This report sets out my opinion in regard to the questions contained in a Mallesons Stephen Jaques brief dated 10 Oct 2007.

1.2 The questions I have been asked to address are as follows:

"a *What are the technical and cost differences in DSLAMs that can be used to provide voice and those that can only be used to provide xDSL?*

b Are upgrade costs (e.g., addition of line cards) to enable provision of PSTN voice services significant?

c What are the costs of installing a DSLAM?

d Would new DSLAMs all have the capacity to provide voice services, or would some of the DSLAMs only be capable of providing DSL broadband?

e Are DSLAMs best characterised as a short-lived asset? What is the economic life of DSLAMs? Is the economic life of DSLAMs likely to increase or reduce over time?
"

2 AUTHORSHIP

2.1 I, Craig Lordan have compiled this document in response to the received questions. I am an Electrical Engineer having graduated from Central Queensland University in 1988. I have 19 years experience within the Australian telecommunications industry and my CV is at Appendix 1. Prior to my current position with Evans & Peck, I was engaged in a number of Access Network roles within Telstra from 1989 through to 2001.

2.2 During that period with Telstra, I specialised in urban and rural Customer Access Network infrastructure including the planning, design and construction of copper, fibre and radio networks. My experience extended from hands on responsibility for individual construction projects through to long term strategic planning and budgeting.

2.3 I also completed international roles while with Telstra. These included the planning and development of customer access networks within Vietnam. Later roles with Telstra included national responsibility for the development and application of Access Network design and construction practices.

2.4 During the past six years as a consultant with Evans & Peck, I have provided advice and support to many organisations in relation to the development and implementation of telecommunication networks. Organisations that have received and implemented advice include existing telecommunication carriers, electricity utilities and government organisations. I have contributed to the Queensland electricity industries' successful implementation of commercial telecommunication service supply. Other major projects have included the completion of technical feasibility reports for the implementation of very high speed access networks on behalf of State and Local Governments.

3 BACKGROUND

3.1 Telstra has asked the ACCC to partially exempt wholesale line rental ("WLR") and the local carriage service ("LCS") from declaration under Part XIC of the Trade Practices Act 1974. The ACCC recently issued a discussion paper (http://www.accc.gov.au/content/index.phtml?itemId=791979) regarding Telstra's application for exemption.

3.2 Before addressing the specific questions, I provide the following comments as background information.

3.3 The metallic (predominantly copper) cable network used to connect customers was originally developed for the purpose of providing voice services. Although fibre optic cable is now an alternative infrastructure option, copper cable is still installed as the network infrastructure in many residential developments.

3.4 For voice services, the pair of metallic cable wires provides low frequency transmission, typically lower than 4 kHz, and DC power between the exchange and the telephone device. A voice service is generally known as a "narrowband service".

3.5 Figure 1 shows the delivery of a voice only service. The network end of the pair of wires is terminated on a switching equipment interface which supplies the signalling, voice transmission and DC power for the telephone device. The Local Access Switch provides the interface to the Public Switched Telephone Network (PSTN), allowing the customer to be connected with any other telephony service.

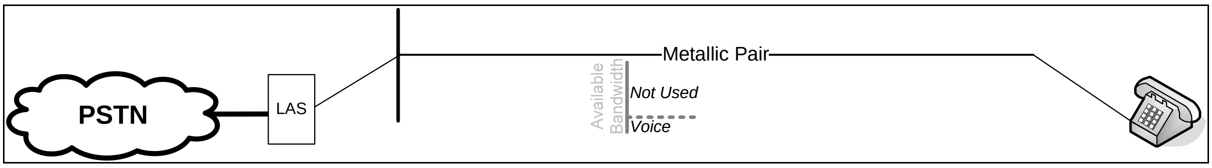

Figure 1 Standard Telephone Service, No Data Service

3.6 As service requirements increased from just providing voice services, the metallic cables have been re-used to deliver data services via the installation of alternative equipment at both the exchange and the customer's premises. Prior to the implementation of shared infrastructure technology, metallic pairs were allocated to either a voice service or a data service.

3.7 Broadband Service is a term generally used to describe data services with a rate equal to or greater than 256 kb/s.

3.8 The introduction of Digital Subscriber Line (DSL) technology enabled the simultaneous shared use of a single pair of wires for both voice services and data services using different bandwidths on the same pair. The available bandwidth on a pair of wires is simultaneously used in parallel by the voice service and the broadband service via different terminal equipment. Each terminal device only receives the correct signal due to a band pass filter installed at both ends of the pair of wires.

3.9 DSL technology includes various technical variants and is known by a number of terms such as Asynchronous Digital Subscriber Line (ADSL), ADSL2 ADSL2+, VDSL and generic terms such as xDSL.

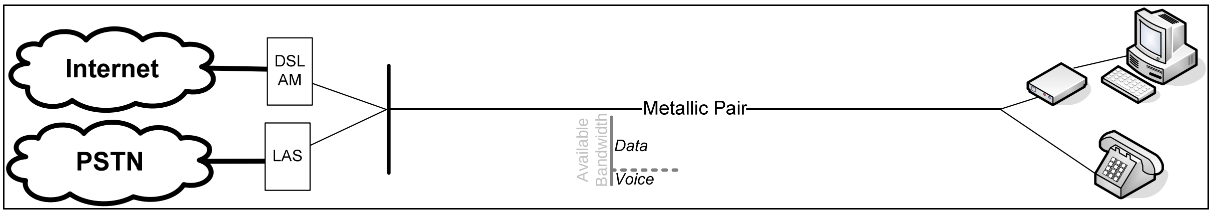

Figure 2 DSL Service using line sharing with existing voice service

3.10 In the circumstances shown in **Figure 2**, the customer premise equipment is comprised of both a standard telephone handset and data modem connected parallel to the one pair of wires. At the Point of Interconnection (POI) a Digital Subscriber Line Access Module (DSLAM) delivers the broadband service and a Local Access Switch (LAS) interface provides the voice service. The DSLAM and LAS equipment may be provided by one or two network owners. The metallic wire pair is connected to two termination ports, one on the LAS and one on the DSL equipment.

3.11 A more recent development is Voice over Internet Protocol (VoIP), providing an alternative to the standard voice service. VoIP service delivery is shown in Figure 3.

3.12 In order to enable access to any other standard telephone service, at some point, the VoIP service must still be interconnected with the PSTN. The Internet Protocol (IP) network will still need to be interconnected with the PSTN. This interconnection can occur at either the same geographic location as the DSL equipment or, as is more likely, in a remote location.

3.13 A VoIP service can be provided over any internet service and is not specifically dependent on the functionality of the installed access network equipment.

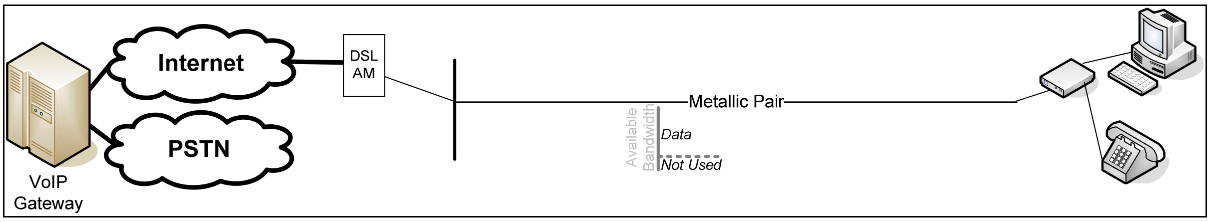

Figure 3 Voice of Internet Protocol (VoIP)

3.14 For the purpose of this report the provision of a Voice Service is defined as the delivery of a Plain Old Telephone Service (POTS). That is the provision of a direct connection between a standard customer telephone device and the PSTN. As the VoIP service provision is independent of the DSL equipment configuration it has been excluded from the discussion of a standard voice service provision within this report.

3.15 Early releases of DSL equipment provided DSL functionality only. More recently developed equipment provides DSL broadband service functionality and also narrowband services such as voice.

3.16 In my experience the term DSLAM is sometimes used differently by different industry participants. For the purpose of this paper the term DSLAM is assumed to mean the equipment capable of delivering xDSL services, whether DSL only services or DSL and voice services.

4 OPINIONS

a. What are the technical and cost differences in DSLAMs that can be used to provide voice and those that can only be used to provide xDSL?

4.1 DSL services can be provided by equipment with only DSL functionality, or by integrated solutions that provide a number of service types including DSL and narrowband service.

4.2 As shown in **Figure 2**, different equipment can be used to provide the DSL and voice services. When the DSL service is delivered using the higher bandwidth component of the metallic pair, the standard telephone service is delivered using the lower bandwidth component. In this option the voice service infrastructure is provided through separate equipment with the DSLAM installed at the POI to provide the DSL service.

4.3 An alternative solution, shown in Figure 4, is to continue sharing the capacity of the metallic pair between the voice service component and the broadband component. However the DSLAM equipment includes the additional functionality in order to provide the voice service.

4.4 The option shown in Figure 4 transfers the voice service functionality from the separate voice service equipment to the DSLAM equipment.

4.5 Depending on the DSLAM owner's architecture, the interconnection of the voice service to the PSTN may occur at a geographic location remote from the DSLAM's location.

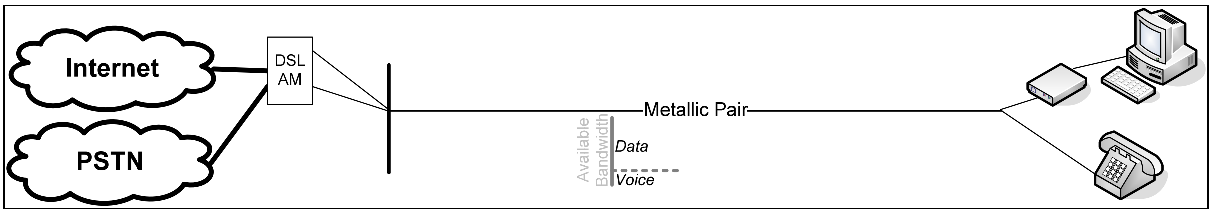

Figure 4 DSLAM Voice termination using line sharing

4.6 Both of the options described in 4.2 and 4.3 allow the use of the existing customer telephony device and a generic DSL modem directly connected to the existing pair of wires.

4.7 A third potential delivery option is to provide the voice service within the same bandwidth as the DSL service. This architecture is shown in Figure 5.

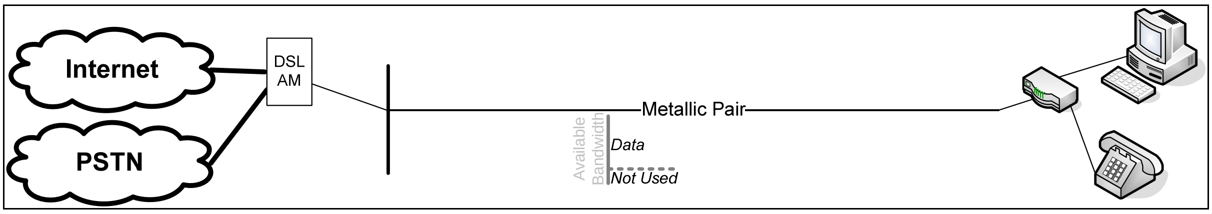

Figure 5 DSLAM voice service provided "in band".

4.8 Under this option the delivery of the voice service within the DSL bandwidth requires additional functionality within the customer termination device. The standard telephone device is connected to the customer termination device rather than to the pair of wires. The customer termination device is specialised, with the inclusion of a interface to provide the telephone service. In my experience, due to the requirement for a proprietary customer premise device, this option has limited current use and for this reason it is not discussed further.

4.9 The major technical difference between a DSLAM capable of delivering only broadband services and an integrated solution providing both voice and broadband services is the inclusion of functionality to terminate the standard voice service within the same device.

4.10 Naming conventions observed for integrated equipment solutions vary between manufacturers, but common terms include DSLAM, Multi Service Access Node (MSAN) and Next Generation Digital Loop Carrier (NGDLC). Some equipment solutions offer significantly greater capability than DSL and voice, such as optic fibre service termination.

4.11 Generally, integrated equipment solutions provide a common sub-rack or chassis into which line cards are inserted in order to supply the required services.

4.12 In modular solutions sub-racks are available in various sizes, allowing for the installation of a number of line cards to typically provide between 30 and 300 ports per sub-rack.

4.13 If a modular DSLAM is to provide both DSL and voice service functionality, some DSL port cards are replaced with voice port cards. If both voice and DSL services are provided, two ports of the device are used.

4.14 It is likely that, in response to network owner requirements, manufacturers will continue to develop DSLAM equipment capability. One such development is expected to be the inclusion of DSL functionality, voice functionality and the band pass filter on a single line card. This would mean that both DSL and voice service could be provided through a single line card port. It is my opinion that the equipment cost per voice and DSL service delivered on a combined line card is likely to be similar to the provision via two ports on separate line cards.

4.15 The purchase cost of DSLAM equipment is dependent on numerous factors including the number of ports, location of the installation, nature of existing backhaul transmission and network equipment and the network operator's architecture.

4.16 The cost of telecommunication equipment to network owners is highly confidential and not publicly available. Sourcing is normally completed through tender and negotiation processes with final rates protected by confidentiality provisions.

4.17 The cost of equipment is dependent on the quantity to be purchased, the tender process and current exchange rates.

4.18 The estimates provided in 4.19 and 4.20 assume that:

(a) The purchase quantity is for a number of installations;

(b) A minimum of 250 ports are supplied at a site; and

(c) The installed sub-rack is fully equipped.

4.19 Based on my knowledge, industry experience and discussion with several manufacturers, in my opinion, an appropriate benchmark rate for the purchase of DSL only capable equipment is $30 per port, excluding the cost of installation and support infrastructure.

4.20 In my opinion, a suitable benchmark rate for the supply of voice and DSL capable equipment is $35 per port, excluding the cost of installation and support infrastructure.

4.21 Due to the common costs, such as that for the sub-rack and control cards, the equipment cost per port would increase if the full capacity of line cards was not initially installed. For the purchase of a voice and DSL capable sub-rack partially equipped with line cards, for example 50 ports, the benchmark equipment cost per port is likely to increase to approximately $60. If the number of line cards initially installed into the sub-rack is increased, the average equipment cost per port would be likely to decrease towards the amount described in 4.20.

4.22 My experience indicates that the current equipment cost for a voice service port and a DSL port are, for practical purposes, reasonably equal.

4.23 For a network owner to provide both voice and DSL service to a customer without a proprietary customer device, two termination ports are used within the DSLAM.

4.24 The cost of providing voice services is not solely dependent on the installation of a DSLAM with the additional functionality. In order to deliver voice services, the DSLAM functionality must be complimented by other network infrastructure, such as a voice switch and additional backhaul transmission capacity within the provider's network.

4.25 DSLAMs that can provide voice services include additional functionality to allow for the dual termination of voice and DSL components of the service. Based on my experience, in my opinion, the equipment purchase cost of providing the two ports for the dual function is likely to be approximately $70 per customer as compared to $30 per port for DSL only delivery.

b. Are upgrade costs (e.g., addition of line cards) to enable provision of PSTN voice services significant?

4.26 Voice services as described in paragraph 3.14 can potentially be provided in some currently installed DSLAMs. Recently installed DSLAM equipment may have the capability to add voice service ports if required.

4.27 Originally DSLAM devices were supplied and installed with DSL only capability that was delivered via sharing the capacity of the pair of wires connected to the existing voice service equipment.

4.28 I do not have data as to the proportion of existing installed DSLAMs with DSL that are capable of being upgraded to deliver voice services. The available functionality is dependent on the manufacturer and the equipment model which was installed. In order to establish the proportion of current voice service capable devices, an auditor survey of all providers would need to be undertaken.

4.29 DSLAM equipment operators have two options if they wish to provide voice service using their own equipment. The first option is, provided that the existing DSLAM equipment is capable and has spare capacity, to install voice ports within the current device. The second option is to install additional equipment to provide voice capability in parallel with the existing DSLAM equipment.

4.30 New voice service equipment may be either a DSLAM with voice and DSL functionality or a device which can deliver voice only functionality. Although it may be a preference for network operators to integrate both voice and DSL delivery in one device it is not a technical requirement.

4.31 For existing installed DSLAMs with the capability and capacity to deliver voice services, in my opinion the equipment cost of supplying voice capability to the DSLAM is likely to be reasonably the same as discussed in paragraph 4.20.

4.32 In my opinion the equipment cost required to add voice capability to an existing DSLAM installation is likely to be $35 per voice service. This estimated benchmark cost assumes a significant purchase quantity by the operator and excludes the cost of installation and the support network infrastructure to deliver voice service functionality.

c. What are the costs of installing a DSLAM?

4.33 The cost of a DSLAM installation varies depending on the location and environment into which the equipment is to be installed.

4.34 The costs associated with the installation of a DSLAM include design, negotiation of installation access, provision of associated network infrastructure, provision of power and interconnection with the existing cable infrastructure.

4.35 In my experience the design, installation and associated infrastructure cost for a DSLAM sub-rack will depend on the physical location and number of concurrently installed ports.

4.36 Based on my knowledge of current market rates for telecommunication construction activities, in my opinion the installation of up to a 300 port sub-rack is likely to cost approximately $2,500. For a larger installation of 1200 ports, in my opinion, the cost to complete the installation is likely to be in the order of $9,000. Both estimates exclude the cost of equipment.

4.37 The cost of installation is not linear due to common activities such as travel, design and access negotiation. Larger installations generally exhibit a lower per port labour cost than installations with fewer ports.

4.38 My estimate of the likely costs described in 4.36 may vary substantially depending on the accessibility to the equipment location, the geographic location and the selected installer.

4.39 The estimated costs quoted in paragraph 4.36 only provide for the installation of the DSLAM equipment and do not include the cost of network management, power supply, backhaul transmission infrastructure, carrier management and service activation required for services to be delivered.

4.40 In summary, whilst costs are dependent upon a number of factors, in my opinion the installation costs for a 300 port DSLAM is likely to be approximately $2,500 and a 1200 port DSLAM is likely to be approximately $9,000.

d. Would new DSLAMs all have the capacity to provide voice services, or would some of the DSLAMs only be capable of providing DSL broadband?

4.41 Not all currently available DSLAMs have the integrated capability to deliver a standard telephone device, as defined in paragraph 3.16.

4.42 Although equipment with multi service integrated voice and DSL functionality is available, DSL only equipment is still provided by some major suppliers.

4.43 By way of example, Huawei, a major international supplier of telecommunication equipment, provides both DSL only equipment and integrated voice and DSL equipment. The Huawei naming convention is for the DSL only product to be described as a DSLAM with the integrated functionality being described as the MSAN product. Further detail can be found at http://www.huawei.com/products/access_network.do.

4.44 Another example of the alternative equipment solutions provided by manufacturers is the product range available from Alcatel-Lucent. Alcatel-Lucent offer DSL only equipment such as the "Stinger DSL Access Concentrator" along with a multifunction device known as "AnyMedia Line Access Gateway" that can deliver both POTS and DSL. Further detail of the Alcatel-Lucent product range can be found at http://www1.alcatel-lucent.com/products/productsbyfamily.jsp?category=Access.

4.45 In my opinion, it is likely that the DSL only equipment is still supplied to satisfy demand from incumbent operators throughout the world where the existing equipment provides voice service capability.

4.46 Depending on the planned service delivery model, network owners have the opportunity to purchase DSL only capable equipment or integrated voice service and DSL capable equipment.

e. Are DSLAMs best characterised as a short-lived asset? What is the economic life of DSLAMs? Is the economic life of DSLAMs likely to increase or reduce over time?

4.47 I understand the term economic life to have the meaning of the time within which income can be expected to be derived from the provision of service via the equipment.

4.48 In my experience, the technical life and economic life of DSLAMs are quite different. The expected technical life for telecommunication equipment is generally 10 years, with manufacturers normally supporting products for this period of time.

4.49 With the currently experienced rate of change in customer functionality requirements and the continuing growth in bandwidth demand, it is my opinion that the economic life is likely to be significantly less than the physical life of the DSLAM.

4.50 However as the data capacity to be delivered increases, the viable distance for metallic cable is reduced. The requirement to reduce the distance of metallic cable is the basis of the fibre to the node and fibre to the home network architectures. New network architectures propose the installation of broadband equipment closer to the customer location or the complete removal of the metallic cable from the access network.

4.51 The current DSLAM equipment will need to be either replaced or relocated in order to deliver the generally expected growth in data bandwidth requirements.

4.52 Due to the rate of change in service and functional requirements, I would expect that the economic life of most active telecommunication assets, including DSLAMs, would be significantly shorter than the physical life.

4.53 It is my opinion that, despite the current DSL equipment still being able to operate effectively, the current service capacity is likely to be exceeded by new customer service requirements within five years.

4.54 Unless the purchased DSL equipment allows for upgrading to deliver significantly higher capacity and the equipment can be easily relocated, in my opinion that the economic life is likely to be in the order of five years.

4.55 Based on my experience of the telecommunication industry, the rate of change in technology and service requirements continues to increase. In my opinion it is reasonable to expect that the economic life of active electronic equipment will decrease over time.

5 SUMMARY AND CONCLUSIONS

5.1 My responses to the questions in the brief are summarised in the following paragraphs.

a. What are the technical and cost differences in DSLAMs that can be used to provide voice and those that can only be used to provide xDSL?

5.2 DSLAMs that can provide voice services include additional functionality to allow for the concurrent termination of voice and DSL components of the service. Based on my experience, in my opinion the equipment purchase cost of providing the dual function is likely to be approximately $70 per customer as compared to $30 per port for DSL only delivery.

b. Are upgrade costs (e.g., addition of line cards) to enable provision of PSTN voice services significant?

5.3 In my opinion the equipment cost required to add voice capability to an existing DSLAM installation is likely to be $35 per voice service. This estimated benchmark cost assumes a significant purchase quantity by the operator and excludes the cost of installation and the support network infrastructure to deliver voice service functionality.

c. What are the costs of installing a DSLAM?

5.4 In summary, whilst costs are dependent upon a number of factors, in my opinion the installation costs for a 300 port DSLAM is likely to be approximately $2,500 and a 1200 port DSLAM is likely to be approximately $9,000.

d. Would new DSLAMs all have the capacity to provide voice services, or would some of the DSLAMs only be capable of providing DSL broadband?

5.5 Depending on the planned service delivery model, network owners have the opportunity to purchase DSL only capable equipment or integrated equipment.

e. Are DSLAMs best characterised as a short-lived asset? What is the economic life of DSLAMs? Is the economic life of DSLAMs likely to increase or reduce over time?

5.6 Unless the purchased DSL equipment allows for upgrading to deliver significantly higher capacity and the equipment can be easily relocated, in my opinion that the economic life is likely to be in the order of five years.

5.7 Based on my experience of the telecommunication industry, the rate of change in technology and service requirements continues to increase. In my opinion it is reasonable to expect that the economic life of active electronic equipment will decrease over time.

Appendix 1 CV Craig Lordan

CURRICULUM VITAE
CRAIG LORDAN

POSITION: Senior Associate

QUALIFICATIONS:
B.E. (Electrical) Central Queensland University
GCM Southern Cross University

EXPERIENCE SUMMARY:
19 years in the Telecommunications Industry in Australia and Vietnam

EXPERIENCE HISTORY:

EVANS & PECK

2001 – Present **Position:** Senior Associate

Role: Specialist consulting assignments in the Tele-communications and Infrastructure fields including assessment of commercial issues, procurement, bidding strategies and strategic advice

Assignments:

- Feasibility Analysis for the construction of a capital city wide very high-speed open access telecommunications
- Procurement of telecommunication capacity for major corporate users within Queensland
- Establishment of Telecommunications Network and Commercial Operation for Queensland Government Owned Corporations
- Detail analysis of NSW Government Department work management performance in response to claim made by major contractor
- Technology application strategy advice and customer engagement policy formulation for major local government body
- Cause Analysis of failed Mobile Network Rollout for legal proceedings
- Activity pricing analysis for prominent Telecommunications Constructor during contract negotiation
- Project Management of Proposal Development for the construction of Townsville Gas Fired Power Station
- Facilitation of Post Implementation Review for a major Intelligent Traffic System installation project
- Strategic advice to a Queensland Government GOC Utility regarding the commercial opportunity to enter the telecommunications industry

GLOBAL CONNECT CONTRACTS, TELSTRA

2000 – 2001 **Position:** National Operation Improvement Manager

Role:

- Leadership of the National Operations team responsible for high level analysis of existing process, contractor relationships, tender submissions, IT System Strategy and performance measurement for Global Connects Contracts
- Introduction of an improved work management and scheduling system, increased linkage between capital investment plan and day to day operations, and the development of a revised contract management strategy

Assignments: Tender analysis including ongoing price negotiations and introduction of the present Access Network Contractors and the redevelopment of GCC Communication Process

ACCESS RENEWAL, TELSTRA

1999 **Position:** National Strategy Development Manager

Role: The primary responsibility of this position was, with a small team, develop strategies improving the efficiency of capital expenditure in the Telstra Access network and manage IT System improvements. Major achievements, via business analysis, were introduced of new processes and project management tools for managing the investment program, development of previously lacking process reporting measures and the

		recommendation of improved structures for the next financial year
	Assignments:	Development of an innovative, efficient National System to identify Network, which is substandard either due to maintenance or insufficient capacity, to facilitate a $250M capital investment program.

TELSTRA

1998 - 1999	**Position:**	National Reporting Manager CAN2001
	Role:	The initial requirement of this position was to contribute to the development of the business case for submission to the Telstra Board for additional funding to rehabilitate Telstra's Customer Access Network. After approval of the project I was responsible for the national reporting of progress against the Business Case to Telstra Senior Management and delivery of operational reports to allow management of the project. While occupying this position I also complete an information exchange program with NTT in Japan
	Assignments:	Development of dynamic solutions for capturing contractor performance information

TELSTRA

1997 – 1998	**Position:**	Expert Decision System Development
	Role:	Through analysis of a number of Telstra Customer Access Design centres a high degree of variation in network build solutions was identified as a major issue for the company. To overcome this problem an approach was developed to provide a universally consistent design result. To solve this problem, a software based Expert Design tool from initial concept through the project management of the system build was developed. The IT Solution (CANDO), delivered standard solutions, process improvement via automated data acquisition, improved in process measurement and network investment efficiency
1994 – 1996	**Position:**	Central Vietnam Plan and West HCMC Business Plan
	Role:	As part of a three person team, a 10 Year Telecommunication Network Development Plan for the Central Vietnam Region was developed and presented to the Vietnam Telecommunication Department (VNPT). The plan covered all facets of developing the Telecommunication Network with my prime responsibility being the Customer Access Network, Customer Radio, Local Switch and Transmission plan. The second major task that I was involved in was the planning and costing of the customer access section of a bid by Telstra to build the network for half of Ho Chi Minh City. This work involved the development of a network strategy, developing a project plan and costing of the bid
	Assignments:	▪ 10 Year Telecommunication Network Development Plan for the Central Vietnam Region ▪ Customer access section of a bid by Telstra to build the network for half of Ho Chi Minh City
1992 – 1994	**Position:**	Senior Engineer Area Planning and Development (N&ITI)
	Role:	Responsibilities included the planning and project management of the Customer Access and Local Switch Network for Central Queensland. This involved the planning of conduit, copper, optic fibre and both internal and external switch technology. Investments were justified on a financial basis and operation within a fiscal budget with limited supervision was required. The planning and project management of several large commercial projects for the supply of infrastructure within coal mine developments was also completed

1989 –1991	**Position:**	Engineer Customer Access Network Design
	Role:	The primary responsibility of this role was to design network augmentation projects to be built. Design roles included rural customer radio, copper cable and conduit design, optic fibre, transmission, RIM and pair gain systems design. A period of time was also spent in the Lines Practices group working on the development of field practices and quality measurement projects