PB ASSOCIATES

TECHNOLOGY REVIEW OF POWERLINE COMMUNICATIONS (PLC) TECHNOLOGIES AND THEIR USE IN AUSTRALIA

Final Report

Prepared for

The Department of Communications, Information Technology and the Arts

***PB Associates** Quality System:*

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This study has been prepared for the exclusive benefit of the Client and no other party.

1. GLOSSARY

802.11b	A standard protocol for wireless networks
Access Network	The network by which a consumer accesses a service
Ascom	Swiss company – developed early PLC broadband solutions
ADSL	Asynchronous Digital Subscriber Line
AMR	Automated Meter Reading
Backbone	Major trunk connections to the world
CAT5	Category 5 Cable
CeBit	The largest Computer and IT trade show in the world
Dark fibre	Unused fibre optic capacity
dB	Decibels
DS2	Spanish Company – supplier of DS2 PLC chipset
E1	European equivalent of US T1
EMC	Electro Magnetic Compatibility
EnBW	A utility in Germany situated in the city of Stuttgart
ETSI	European Technology and Standardisation Institute
FSK	Frequency Shift Keying
HV	High Voltage – in Australia <33 kV & > 240 volts
IP	Internet Protocol
ISP	Internet Service Provider
ITU	International Telecommunication Union
Kbps	Kilo bits per second
kV	Kilo Volts
kVA	Kilo Volt Amp
Last mile	Final connection to home or local loop
LV	Low Voltage – in Australia 240 volts
Mbps	Mega Bit per Second
MV	Medium Voltage – term often used overseas for HV and subtransmission
MVV	A German utility situated in the city of Manheim
NEC	National Electricity Code
NEM	National Electricity Market
OFDM	Orthogonal Frequency Division Multiplexing
PLC	Power Line Carrier or Power Line Communication
RF	Radio Frequency
RWE	A utility in Germany situated in the city of Essen
SCADA	Supervisory Control and Data Acquisition - system used for data capture relating to network performance
SDH	Synchronous Digital Hierarchy
SNR	Signal to Noise Ratio
Subtransmission	In Australia 33 to 66 kV electricity lines
SWER	Single Wire Earth Return
T1	Trunk Type 1
T2	Trunk Type 2
T3	Trunk Type 3
US FCC	US Federal Communications Commission
VoIP	Voice over Internet Protocol
VSAT	Very Small Aperture Terminal
XDSL	x Digital Subscriber Line

EXECUTIVE SUMMARY

PB Associates (supported by BIS) has prepared this report on the status of PLC and its applicability for Australia.

Parsons Brinckerhoff Associates (PB Associates), supported by Bender Information Systemtechnology (BIS), was commissioned by the Department of Communications Information Technology and the Arts (DOCITA) to assess the current status of Power Line Communications (PLC) development and its applicability for Australia. The review was focussed on PLC systems that operate on the electricity distribution networks, rather than solutions already available for use within the home or office. The main features of this report are therefore: an international comparison of PLC vendor equipment, an assessment of the technical issues for PLC deployment, comparison of PLC services against other broadband systems, and consideration of the impediments to PLC development and implementation within Australia.

PLC stands for Power Line Communications and involves using electricity wires to carry communication signals.

For the purposes of this report: Broadband is > 1 Mbps. Narrowband is < 128 Kbps. In between is High Speed Internet.

PLC Broadband systems potentially offer services comparable to or better than competing products such as ADSL and cable.

PLC is often referred to as the "last mile" solution as it offers an effective customer connection that integrates with other systems to provide a total communications network.

- PLC refers to the simultaneous utilisation of electricity wires for transmitting communication signals and power. This can be categorised into narrowband (utilising lower frequencies and transmitting at slower speeds – useful for simple applications such as hot water tariff switching, alarm systems and electricity system monitoring), and broadband (utilising higher frequencies and able to transmit at higher speeds – useful for applications such as video conferencing, high speed Internet, video on demand, broadcasting, etc).
- PLC offers potential levels of service that are generally comparable with or in excess of competing solutions such as ADSL, cable, wireless and satellite.
- Broadband PLC is an emerging technology that is now gaining world interest.
- PLC systems utilise electricity wires and, therefore, safety will need to be a fundamental consideration in any implementation programs.
- The Australian electricity network connects to almost 9 million customers and includes around 900,000 km of line.
- PLC is often described as a "last mile" solution as its most attractive feature is that it can take advantage of the electricity network connections to most premises.
- Using the electricity network means that the service will be available to all connected customers on each enabled line and the PLC broadband capacity is "shared" by those customers.
- PLC narrowband systems have been in operation for decades. In the later half of the 1990's, however, new research and development in Europe led to enhancements of PLC that have enabled production of broadband systems available today. Broadband PLC is an emerging technology that is undergoing rapid development, testing and implementation throughout the world.
- There are many examples of broadband PLC deployments around the world, including substantial customer numbers in many European countries, particularly Germany, France and Sweden. In South America the main market is in Brazil, but first trials have been installed in Chile and Venezuela. In Asia the leading country is Singapore, although China now has a number of trials installed. The Philippines and Malaysia have also recently decided to venture into PLC.
- Existing PLC implementations have been based predominantly on systems from Ascom and Mainet, with speeds of between 1Mbps and 2 Mbps.

PLC Broadband can now deliver up to 45 Mbps in both directions using the new DS2 chipset. A 200 Mbps product is expected before the end of 2003.

- Analysis of recent international PLC developments and equipment shows that the "DS2" chipset manufactured in Spain is now attracting significant attention as it is capable of providing the platform for up to 45 Mbps shared between customers on the LV network.
- No substantive commercial "DS2" implementations have been undertaken at present, however there are agreements in place for commercial deployments in

France, Sweden and Singapore over the next few months and many trials in progress.

- International PLC deployments to date have concentrated on high-density population areas where average deployment costs are low, transmission distances are relatively short (less than 300 metres), and backbone carrier networks are convenient. In particular, PLC systems have been most prevalent in broadband enabling large residential or commercial buildings, which can then utilise the internal LV electricity reticulation networks.

Australian electricity network would appear to be suited for broadband PLC.

- It is anticipated that the next generation of the "DS2" chip will provide a system capacity of 200 Mbps and will be available before the end of 2003.
- Australia would appear to offer a suitable technical environment for PLC implementation.

Indoor PLC broadband systems are already on sale in Australian Retail stores.

- Indoor PLC equipment is already commercially available in Australia from most large electrical retailers. These systems are not naturally compatible with outdoor systems and some effort is required to ensure effective integration. This has been achieved overseas and highlights the importance of PLC standards.

Potential technical challenges for PLC include signal distance constraints, line noise disturbances and radio interference.

- The potential technical impediments to development and implementation of PLC within Australia include signal distance limitations, high temperatures, high humidity, line noise from salt static discharge or transformer discharge, and other line noise interference. All of these issues appear to be manageable.
- There are some concerns regarding interference levels produced by PLC, mainly raised by amateur radio users. Various tests and studies indicate that although this issue theoretically does arise, evidence from commercial deployments have not confirmed these concerns. The Australian Radio Frequency Spectrum Allocation Chart shows that current PLC systems do not intrude on protected frequencies. A review of interference levels would be necessary prior to large PLC deployments.

Other challenges for PLC deployment include electricity industry structure and regulations, availability of backbone communications networks and cooperation between vendors, electricity distributors, telecommunications companies and content providers.

- Other significant challenges for PLC development and implementation within Australia include the structure of the electricity industry, uncertainties regarding commercial incentives for electricity distributors, the diversity of participants needed to be aligned for a commercial PLC deployment, lack of PLC standards, commitment of major telecommunications carriers to alternative technologies, the ability for PLC solutions to access high speed backbone networks outside major centres, and relatively low average population densities.
- Research to date indicates that Australian electricity grids are generally well suited to carry broadband and narrowband PLC signals. However, a comprehensive grid analysis is essential before embarking on any PLC deployments. This will identify areas where PLC is viable and where PLC is not viable. In this regard it is not that the PLC technology itself is likely to be unsuitable, but that the cost of installation is not commercially sustainable.
- PLC is best viewed as one product offering that can be implemented in conjunction with other broadband communication mediums to provide an overall integrated communication solution to the market.
- Issues that may warrant further consideration include:
  - The development of guidelines and standards for PLC, which specifically address Australia's requirements.
  - Participation in the International PLC Forum to ensure awareness of PLC developments and to represent Australia's interests.
  - Monitoring of the deployment of PLC in conjunction with other broadband solutions.
  - Providing appropriate commercial incentives for electricity distributors for the utilisation of existing infrastructure for telecommunication services.

- Avenues for independent testing of PLC equipment to assist in the development of industry standards and effective business models.
- Other potential regulatory barriers to the deployment of PLC, including the performance requirements for the "standard telephone service" and the application of State, Territory and local government planning and environment laws

2. SCOPE OF WORK

The Department of Communications, Information Technology and the Arts (DOCITA) engaged Parsons Brinckerhoff Associates (PB Associates) to review the current state of development of PLC technologies and their applicability for Australian conditions.

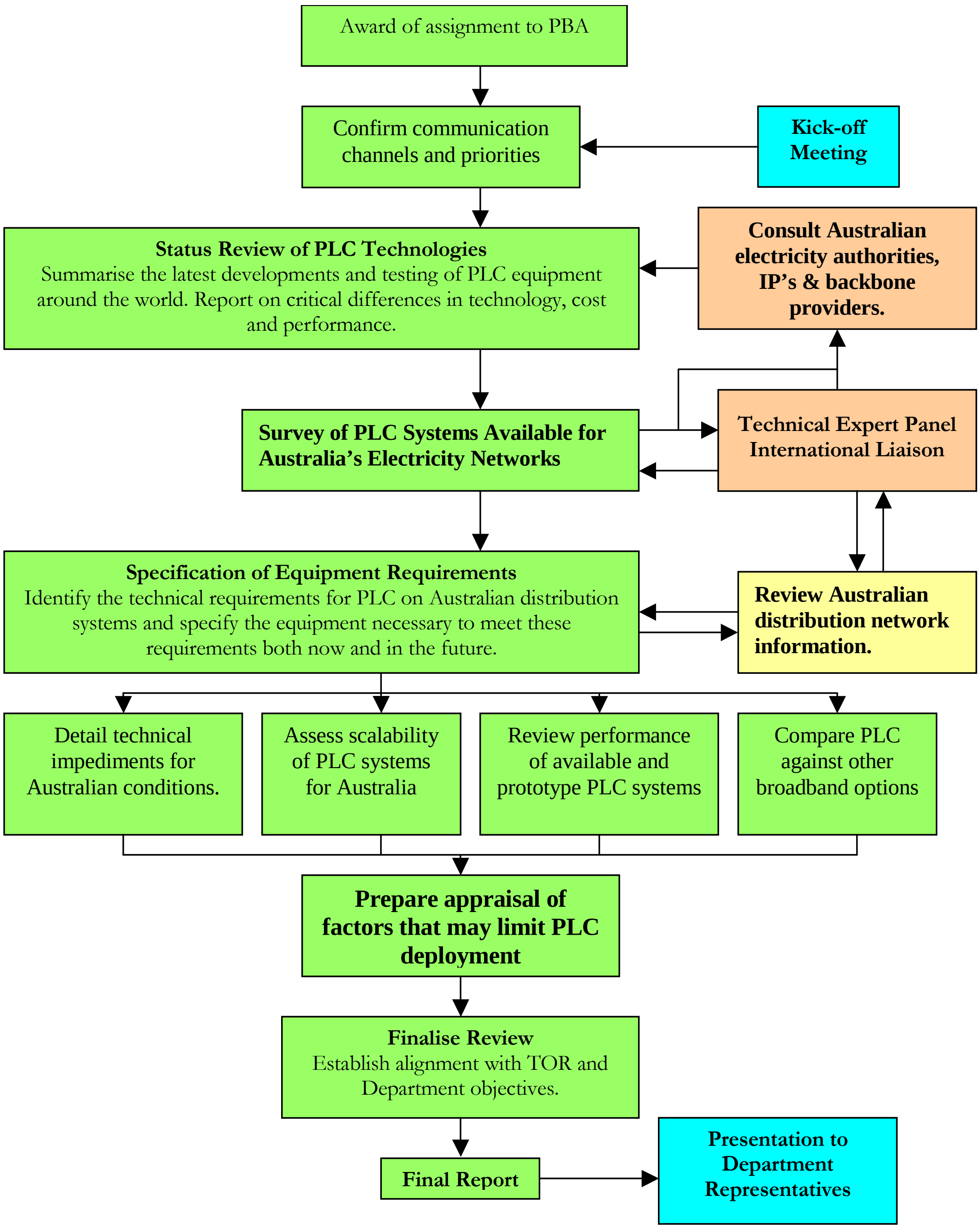
The Terms of Reference for the review were:

- a review of the current state of development of PLC technologies and their deployment worldwide;
- a survey of current PLC technologies available for the delivery of communication services over Australia's electricity distribution networks;
- a description of the technological requirements and the equipment necessary for the delivery of communication services in addition to the expected time that commercial deployment could proceed by;
- the detailing of technical impediments to the implementation of PLC technologies across Australian electricity distribution networks (metropolitan, regional, rural);
- an assessment of the scalability of PLC systems for deployment across Australian electricity distribution networks;
- a review of the quality and reliability of service provided by the various PLC technologies currently available or under trial, including data speeds and the distance that a service can be delivered over;
- a comparison of the capabilities of PLC technologies against existing communication service technologies including ADSL, cable and wireless; and
- an appraisal of the factors that may limit the wide-scale deployment of PLC systems, including issues associated with PLC generated interference and regulatory requirements and a review of measures to address implementation problems;

In essence the Department is seeking to gain an understanding of the progress in PLC development and whether PLC offers a potential solution for broadband communications within Australia.

2.1 WORK PLAN

PB Associates adopted the following program in undertaking this review.



The major work components of this program are described below.

Kick-Off Meeting

An initial meeting was held with DOCITA officers in Canberra to establish communication channels and priorities.

Status Review of PLC Technologies

The team prepared a summary of the latest developments and testing of PLC equipment from around the world. This information was used to compare the range of PLC technologies and indicate critical differences against specific performance criteria. The program included inquiries to all Australian electricity distribution businesses, in conjunction with input from vendors and relevant overseas organisations, to obtain a full understanding of emerging PLC developments and potential issues. Responses from Australian electricity distribution businesses are included in Appendix B.

Survey of PLC Systems Available for Australia's Electricity Networks

The team undertook an assessment of the unique features of the Australian distribution network to identify characteristics of the various PLC offerings that are consistent with Australia's requirements. This information, in conjunction with the status review, provided the context for evaluating which PLC systems offer potential, in our view, for deployment across Australian distribution networks.

Specification of Equipment Requirements in Addition to the Expected Time for Commercial Deployment

Technological developments in digital communications are occurring at an increasingly rapid pace. This raises the potential that PLC systems deployed today may become outdated quickly. This is often the case with IT hardware and protocols and an assessment of that risk and the possible methods of mitigating such risk have been provided in this report.

Detail technical impediments for Australian conditions

An essential component of this review is the detailing of known and potential technical impediments to the various PLC technologies available or presently under development. In particular, Australia's vast distribution networks in regional, rural and remote areas and our voltage configurations (240V, 5/11/22/33/66/110/132 kV distribution systems) offer technical challenges that may vary from those of other countries. These issues are considered in the context of key performance measures.

Assess scalability of PLC systems for Australia

The different features of Australia's distribution system relative to overseas and the different approaches to PLC delivery offered by the various equipment providers make it essential that we consider the way in which PLC solutions could be applied in this country. Once again, the vast nature of our distribution system outside of major city centres will affect the viability of various PLC configurations and how amenable they are to phased implementations.

Review performance of available and prototype PLC systems

The status review of existing and emerging PLC technologies includes information regarding the known or believed performance of those systems. The performance of various technologies is fundamental to a consideration of the most appropriate systems for deployment within Australia. The relative performance statistics of the various PLC technologies and any recognised idiosyncrasies of those technologies have been captured in this review.

Compare PLC against other broadband options

In the long term the critical factor for any PLC deployment will be its competitive position relative to other forms of broadband communication systems and the willingness of customers to pay the costs of providing such services. There are presently a number of mediums for delivering broadband communications, all of which have their various advantages and disadvantages. A broad comparison of these systems against PLC solutions has been provided.

Prepare appraisal of factors that may limit PLC deployment

The assessment of PLC technology includes consideration of factors that may impede its successful deployment within Australia. This covers the technical challenges discussed earlier, along with the obvious questions regarding economies of scale and population density that clearly impact on the commercial viability of broadband, the level of competition and the service expectations of consumers, and regulatory issues.

3. PLC TECHNOLOGY AND ITS DEPLOYMENT

3.1 WHAT IS PLC ?

The abbreviation PLC derives from the original term **P**ower **L**ine **C**arrier. In recent years it has also come to stand for **P**ower **L**ine **C**ommunication. The basic concept of PLC is to transmit information and electricity simultaneously along electricity lines as an alternative to constructing dedicated communications infrastructure. In general, electricity lines are made from similar conductive materials as those used for telecommunications.

PLC stands for Power Line Communications and involves using electricity wires to carry communication signals.

In essence, PLC offers the use of the electricity grid to carry communications signals between service providers (broadcasters, Internet providers, etc) and their customers.

Definitions of Broadband vary. In this report: Broadband is > 1 Mbps. Narrowband is < 128 Kbps. In between is termed High Speed Internet for this report.

Although PLC has been in operation for decades as a narrowband system carrying only small amounts of data, it has become more significant in recent years due to developments which enable its use for broadband communications. Whilst there are some differences in the definition of these terms, for the purposes of this report narrowband is taken to mean data transmission rates of less than 128 Kbps and broadband means data transmission rates greater than 1Mbps. The broadband level of 1Mbps is considered to be the minimum required to enable multi media applications. The range between these definitions is termed "high speed Internet" which offers many of the features of broadband but may be limited for future applications.

PLC systems enable power grids to carry data by providing a standardised interface (Ethernet – TCP/IP). The principle behind every PLC solution is to modulate a carrier frequency on top of the existing 50/60 Hertz on the electricity lines. The frequency and the coding algorithms used then determine the actual amount of data that can be carried. This is very similar to a DSL modem.

PLC systems enable the grid to be used by customers and service providers for a vast array of existing and potential functions, from broadcasting to home automation.

PLC systems can then be utilised by service and content providers to reach their customers and provide a wide variety of applications. These applications can include entertainment, conferencing, home automation, surveillance, security, as well as assisting electricity utilities to monitor their grids in terms of demand management, system automation, asset management, quality of supply, load control and remote meter reading.

3.2 ELECTRICITY DISTRIBUTION

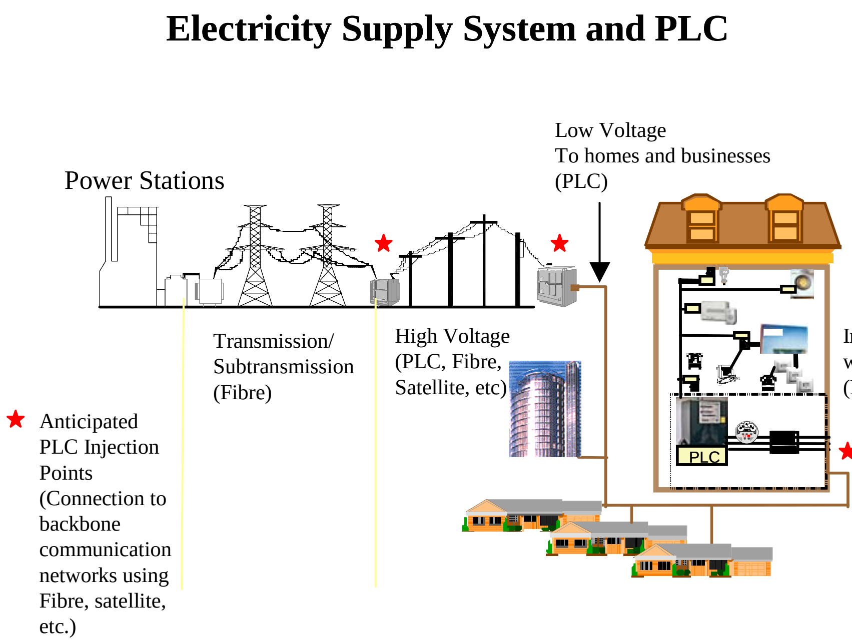
PLC systems are constrained by the distances they can travel. Use on LV lines in Metropolitan and regional areas is easiest. HV applications are emerging.

Diagram 1 below shows the general configuration of the electricity distribution system.

The electricity distribution chain begins at the power station where electricity is generated. The power leaves the generator and enters a transmission substation at the power plant. This substation uses large transformers to convert the power to extremely high voltages, which in Australia are typically from 110 –500 kilo volts (kV) for long-distance transmission on the transmission grid and/or 33kV – 66kV for subtransmission. Very high voltages are employed for the long distance transmission of power in order to reduce power loss during this stage.

For the power to be useful in a home or business, these very high voltages must first be reduced or stepped-down for delivery. This requires the power to be passed through transformers, which reduce the voltages to 22kV or 11kV for wider reticulation. This part of the distribution network is referred to as the "high voltage (HV) network". Finally the power is transformed further to reduce the voltage to 240V and is reticulated to individual households. This part of the network is referred to as the "low voltage (LV) network".

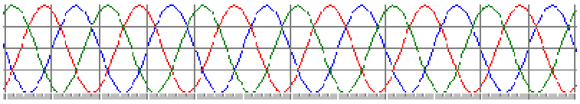
Diagram 1



Generators connected to Australia's transmission and subtransmission grid normally produce what is called 3-phase alternating current (AC) power. To understand 3-phase AC power, single-phase power will be discussed first.

Single-phase power is usually what you have in your house. If you were able to view the power found at a normal outlet in your house, you would observe an oscillating wave pattern, sometimes referred to as a sine wave. The rate of oscillation is 50 cycles per second or 50Hz. The oscillating nature of the power is the reason this type of power is generally referred to as AC, or alternating current. The alternative to AC is DC, or direct current, which does not oscillate.

However, the generator produces three different phases of power simultaneously, and the three phases are offset 120 degrees from each other. If you were to look at the three phases on a graph, they would look like this:[1]



The advantage of 3-phase power is that at any given moment one of the three phases is nearing a peak and this is useful for operating large electric motors in industrial applications.

The implication of a 3-phase supply on Australia's distribution network is that each phase is carried by a separate line. On the HV network, it is likely that only one of the three lines would be used for PLC signals. However, on the LV network, the signal would need to be provided on each of the 3 lines to ensure that it is available to all customers. This is because customers could be connected to any one of the 3 phases and connections along the street are alternated to balance the load on each line.

PLC systems generally operate on the low voltage network and throughout the home or office. PLC can also operate on some high voltage networks and recent developments are enhancing this capability.

In this context, PLC is often described as providing a "last mile" broadband solution, which then needs to interconnect with other communications networks through an optical fibre, a wireless connection, a satellite link, or other systems in order to establish an end-to-end network.

For example, in Diagram 1, possible points for connections to backbone communication networks (injection points) are marked. These would normally occur at the beginning of either the HV or LV networks. However, PLC signals can be injected at any point along the electricity network depending on availability of backbone networks, signal distance limits and capacity requirements.

3.3 AUSTRALIAN ELECTRICITY DISTRIBUTION INDUSTRY

As PLC relies on the electricity network, a discussion of the features of the Australian electricity grid and industry is essential to any consideration of PLC for this country.

Australia's electricity network has evolved in response to customer demand and changing population densities. The result is that today customers are broadly categorised as Metropolitan, Regional, Rural or Remote. For the purposes of this report we have defined these groups as being generally:

[1] http://people.howstuffworks.com/power1.htm

- metropolitan - more than 100 people per square km;
- regional - between 1 and 100 people per square km;
- rural - between 0.1 and 1 person per square km; and
- remote - less than 0.1 people per square km.

The features of the electricity network reflect the need to balance the costs of reticulation with service level requirements. In metropolitan and regional centres the network is designed to provide a level of backup and increased reliability reflecting the larger numbers of customers affected by any interruptions. In rural and remote areas the same level of redundancy is not economic. Reticulation in rural and remote areas also tends to be at higher voltages to reduce electricity losses during transmission. As a consequence, transformers are often required for individual customers. These differences will have a significant impact on the deployment of PLC systems as both distance and transformer couplings affect communication signals.

There are around 9 million customers connected to the Australian electricity network and almost 900,000km of lines.

SWER is single wire earth return power distribution. Instead of using 3 wires to distribute electricity. SWER uses one wire with the return path through the ground. This is cheaper and easier to build and maintain.

The Australian electricity grid connects to around 9 million premises nationally using almost 900,000 kilometres of cable. Typical configurations of electricity transmission and distribution in Australia consist of transmission from major power stations at 110 kV to 500 kV, and distribution at subtransmission voltages (33 kV – 66 kV), high voltages (11 kV – 22 kV, including Single Wire Earth Return (SWER) - see side box for definition.) and low voltage (240 volts - normally 3 phase). (It should be noted that there are some network areas that work to different configurations, particularly in older networks or remote areas.)

The tables below show the distribution of those lines between voltages and the numbers of transformers in each class[2].

Table 2: The length of overhead power lines in the Australian electricity distribution network.

Overhead Lines (Circuit km)					
STATE	**Transmission 110 - 500 kV**	**Subtransmission 33 - 66 kV**	**High Voltage Incl SWER**	**Low Voltage**	**Total**
NSW & ACT	15,633	16,429	167,214	69,546	**268,822**
VIC	6,332	6,346	88,742	37,705	**139,125**
QLD	14,601	13,397	124,603	30,179	**182,780**
SA	5,541	4,870	46,312	15,659	**72,382**
WA	5,370	7,389	56,154	10,830	**79,743**
TAS	3,424	125	14,878	8,600	**27,027**
NT	339	425	2,807	1,760	**5,331**
Total	**51,240**	**48,981**	**500,710**	**174,279**	**775,210**

[2] Electricity Australia 2002, Electricity Supply Association of Australia Ltd

Table 3: The length of underground power lines in the Australian electricity distribution network.

Underground Cables (Circuit km)					
STATE	**Transmission 110 - 500 kV**	**Subtransmission 33 - 66 kV**	**High Voltage Incl SWER**	**Low Voltage**	**Total**
NSW & ACT	817	1,058	11,204	15,691	**28,770**
VIC	11	83	4,081	12,484	**16,659**
QLD	94	562	3,509	8,225	**12,390**
SA	8	125	2,764	5,346	**8,243**
WA	9	61	2,634	6,892	**9,596**
TAS	12	2	784	780	**1,578**
NT	0	21	600	1,694	**2,315**
Total	**951**	**1,912**	**25,576**	**51,112**	**79,551**

Table 4: Number of transformers in the Australian electricity distribution network

Numbers of Transformers				
STATE	**Transmission 110 - 500 kV**	**Subtransmission 33 - 66 kV**	**High Voltage Incl SWER**	**Total**
NSW & ACT	519	1,410	174,827	**176,756**
VIC	0	430	145,945	**146,375**
QLD	227	1,543	104,513	**106,283**
SA	115	1,850	63,673	**65,638**
WA	148	3,018	54,794	**57,960**
TAS	104	15	26,240	**26,359**
NT	8	31	3,296	**3,335**
Total	**1,121**	**8,297**	**573,288**	**582,706**

Table 5: Number of customers connected to Australian electricity distribution networks.

Numbers of Customers and Relative Customer Density			
STATE	**Customers**	**Customers per km Line**	**Customers per transformer**
NSW & ACT	3,076,397	10	17
VIC	2,218,712	14	15
QLD	1,655,507	8	16
SA	744,128	9	11
WA	810,568	9	14
TAS	247,899	9	9
NT	72,167	9	22
Total	**8,825,378**	**10**	**15**

The extensive high voltage and SWER networks demonstrate the relatively low customer density in Australia and suggests that for PLC to provide an effective broadband solution for this country it will be necessary for the development of an appropriate mode for the delivery of communications signals over long distances and across voltage transformation points using the electricity network. Alternatively the PLC systems deployed in Australia will need to find means for connecting last mile PLC solutions with backbone communications networks.

Australia's relatively low density of 10 customers per kilometre is highlighted when compared against figures for other countries as shown in Table 6. This can have a profound impact on the economics of broadband systems to customers and emphasises the importance for Australia of finding communication systems that can leverage off existing infrastructure.

If economical solutions for integrating PLC systems with backbone communication networks can be found, then PLC may be considered as providing a very competitive "last mile" solution in Australia.

However it is useful to note here that although Table 5 shows the average number of customers per transformer in Australia is 15, normally in an urban residential environment the number will be around 50, but can range anywhere from 20 to 120 depending on the local network. In rural and remote areas, the reticulation is largely HV (including SWER), with individual customers receiving supply from their own transformer or shared with one or two others.

Most customers take supply from the LV network. In metropolitan and regional areas the LV transformer (referred to as the distribution substation) may vary in size, typically from 200 kVA up to 750 kVA. For residential customers, electricity distributors will normally base the size of the transformer on the local customer density and expected coincident demand.

Table 6: Customer density comparison.

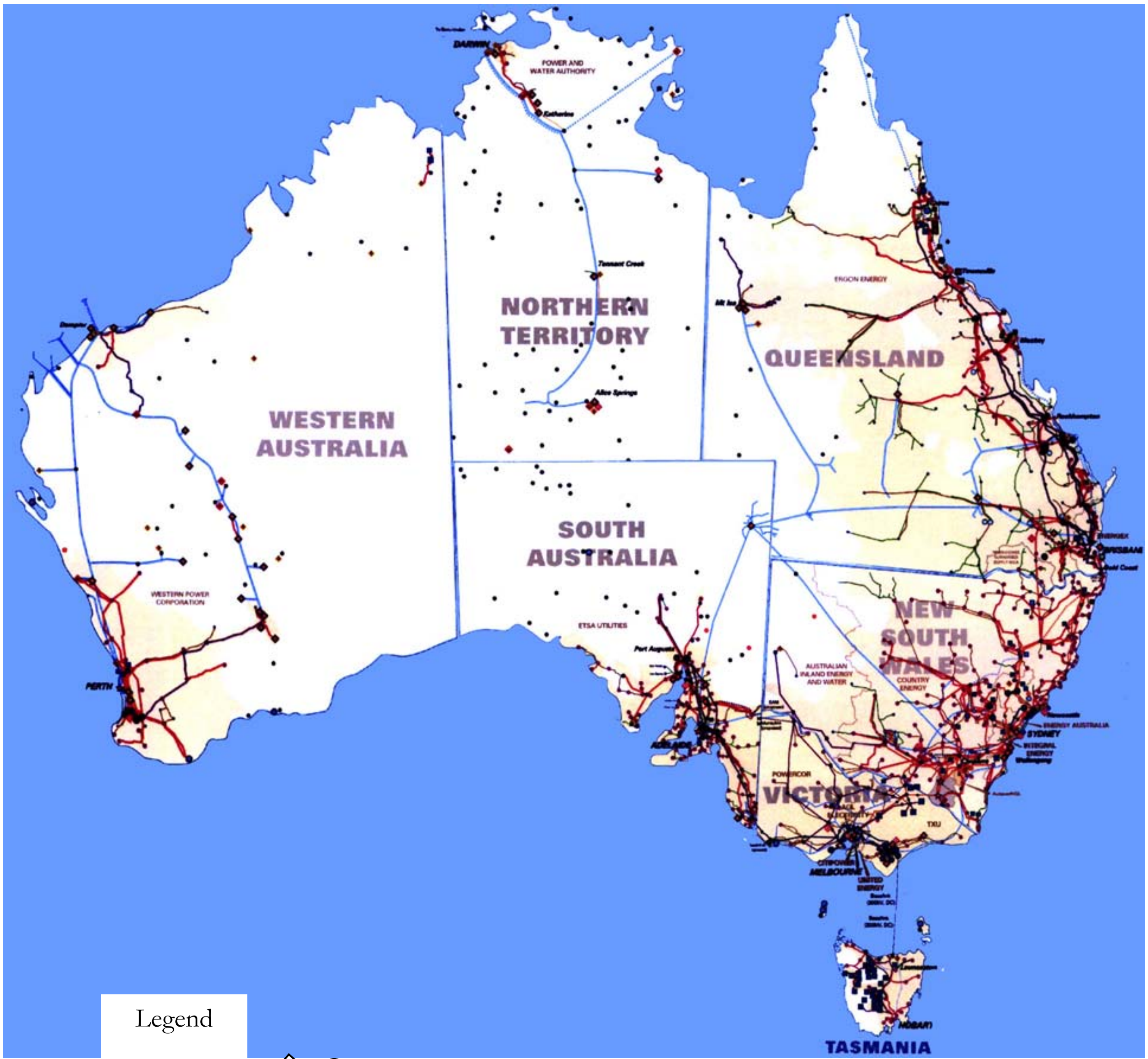
Australia has an average of around 10 customers per km of line, which is low compared to many other countries.

Customer Density Comparison			
Country or Distributor	**Customer Numbers**	**Length of Lines (km)**	**Customers per km of line**
Mid American Energy, Iowa, USA	666,000	53,800	12
New Zealand*	1,684,312	135,711	12
NS Power, Canada	440,000	29,250	15
Kansas CP&L, USA	463,000	22,531	21
United Kingdom*	26,447,000	760,489	35
Israel Electric	1,999,000	23,658	84
TEPCO (Tokyo)*	12,800,000	140,000	91
Bewag, Berlin, Germany	4,693,626	39,591	119

Electricity Prices and Cost Factors , Productivity Commission, Staff Research Paper, <http://www.pc.gov.au/research/staffres/epacf/index.html>, Aug-01
* Comparisons based on proprietary information and customer definitions may vary slightly

In spite of the low average population density relative to kilometres of electricity lines, there are still concentrations of lines across the east coast of Australia, as shown in Map 1. The overlaid transmission grid demonstrates the high concentration of electrification between Victoria, NSW, the ACT and Queensland, with a further significant centre around Adelaide in South Australia. This reflects Australia's population distribution as represented in Map 2.

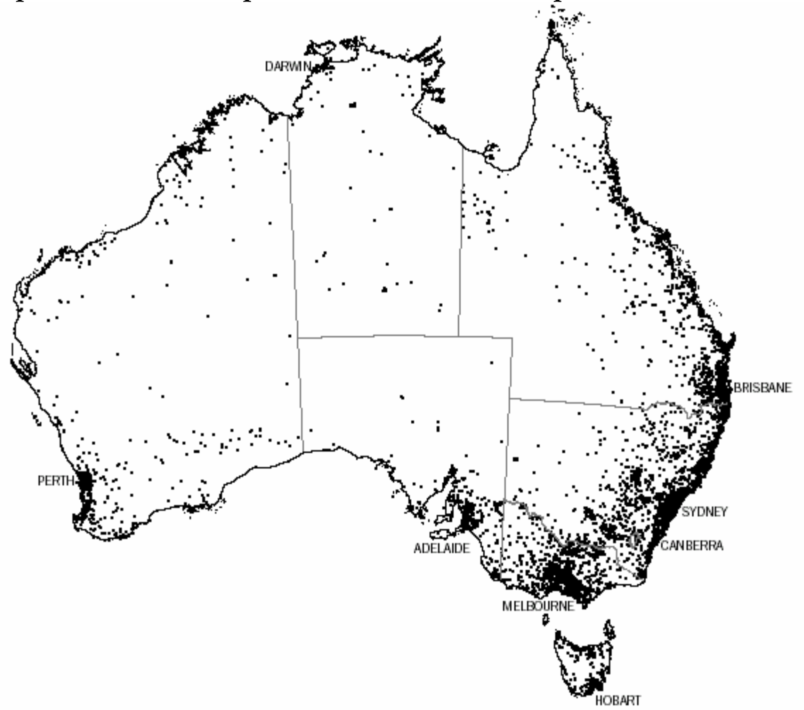
Map 1: Gas and Electricity System Supply Map (ESAA – Electricity Supply 2002)



Gas Pipelines | Generation sites | 500 kV | 330 kV | 275 kV | 220 kV | 132 kV | 110 kV | 88 kV

66 kV | 33 kV | 22 kV | Proposed | Distribution Boundaries

Map 2: Australian Population Distribution Map - 2002[3]



Source: Australian Bureau of Statistics - Regional Population Growth, Australia and New Zealand (3218.0)

LV transformers in metropolitan and regional residential areas can serve between 20 and 120 customers (typically around 50). In rural and remote areas customers will often have a dedicated transformer.

The importance of this information is that areas of high population density generally provide a more commercially attractive and contestable environment for service providers and greater scope for a range of competitive broadband solutions. Lower population density areas often involve higher average costs for services, which inhibits demand. Therefore, the ability to leverage off existing infrastructure such as electricity poles and cables will be crucial in determining the speed at which broadband services are delivered to regional, rural and remote customers and the quality of those services.

The above figures demonstrate the key strength of PLC - that with electricity connections to most homes and businesses in Australia, PLC could enable the existing electricity infrastructure to be used to provide an alternative to Telstra's customer access network (CAN) for broadband communications.

Regulation of electricity authorities is a critical factor for the development and implementation of PLC, as these organisations can play a crucial role in facilitating broadband access.

The distribution of electricity within Australia is regulated by the States and Territories. With the introduction of the National Electricity Market (NEM) over the last 10 years, eastern states have signed onto the National Electricity Code (NEC) and jurisdictional regulators largely comply with and enforce these requirements. These States and Territories are NSW, Victoria, Queensland, South Australia, Australian Capital Territory and Tasmania. The regulation of electricity distribution is considered important to the development and implementation of PLC technologies. This is because the manner by which jurisdictional regulators apply the NEC for both technical and economic regulation can have a significant impact on the commercial incentives for distributors to deploy PLC. These issues are discussed in more detail in Section 7.1

[3] Year Book Australia, 2002, Australian Bureau of Statistics, Regional Population Growth, Australia and New Zealand (3218.0)..

3.4 POSSIBLE PLC CONFIGURATIONS.

Although the Australian electricity grid infrastructure is similar in many ways to those of other countries around the world, a comprehensive grid analysis is essential before embarking on any PLC deployments. Work carried out by the PB Associates team on behalf of various organisations over the last two years has shown that Australian electricity grids are generally well suited to carry broadband and narrowband PLC signals.

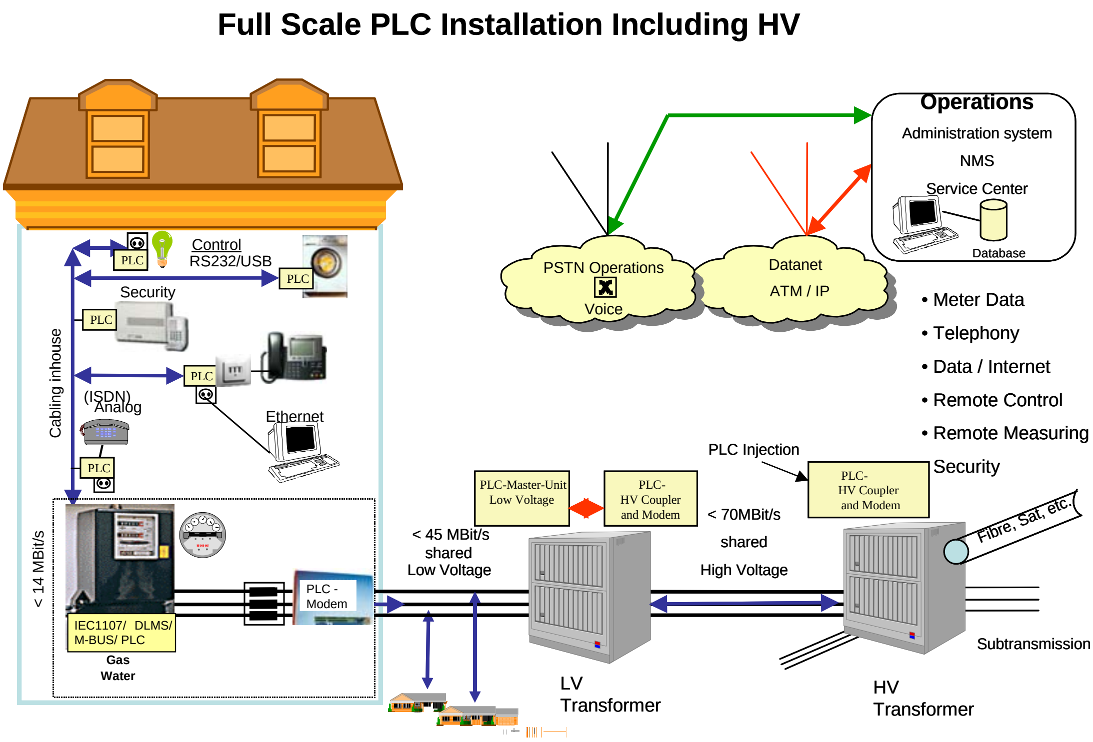
This subsection outlines three possible PLC configurations that could be deployed for different situations within Australia. The scenarios differ depending on the availability of economical backbone connections, HV PLC, and the role of local electricity distribution businesses.

Integrated High Voltage-Low Voltage Configuration
Diagram 2 on the next page depicts a PLC installation utilising both the high voltage (HV) and the low voltage (LV) distribution networks. This is not a highly likely scenario for metropolitan areas where the HV lines may feed thousands of customers, as the diversified demand for broadband services at these points may exceed the capacity of a proposed integrated HV-LV PLC system. It is also more likely that backbone communication networks will be more accessible in metropolitan areas. HV lines in rural and remote areas can, however, have lower numbers of connected customers. Whilst the number can vary substantially, it is reasonably common to have between 100 and 500 customers on a rural feeder, which may be within the capacity range of existing and proposed PLC systems. Where this is the case an integrated HV-LV PLC system could be more economical than construction of additional backbone infrastructure.

An integrated HV-LV PLC system may be useful in metropolitan areas where narrowband systems are in operation serving utility-specific applications such as AMR (Automated Meter Reading) or demand management, which do not require significant bandwidth capacity.

In Diagram 2 a coupling device is connected at the substation to one of the phases (capacitive coupling is used and is described further in section 4.2) and a PLC master modem (which injects and receives PLC signals), is connected to the coupler. On the HV grid a single phase coupling is sufficient, since the phase is clearly identifiable.

Diagram 2



Typically, PLC modems (including PLC master modems) are internally divided into digital and analogue sections. The digital section is responsible for the modulation scheme and the coding algorithms of the data. When it comes to reach, however, the most important part of the modem is the analogue section. This includes the coupling device and the transmitter/receiver unit. The sensitivity of this unit has a major impact on the distance the PLC signal can cover.

The backbone interconnection is located at the subtransmission (zone) substation. Depending on the type of backbone used - for example a fibre or satellite connection - different routers or media converters are required to interface with the PLC modem. For example, a Synchronous Digital Hierarchy (SDH) Bridge (translating the data transmission protocol on fibre networks to the Ethernet standard) may be required for interconnection with a fibre backbone connection or a Broadlogic card may be required for interconnection with a satellite connection. Establishing a backbone interface at a zone substation is generally straightforward, as there is easy access to the injection point into the electricity network and effective sheltering is available for equipment.

The PLC signal is required to travel greater distances over HV lines than it is over LV lines, which would enable coverage of a large area. With this configuration the signal will be available to all transformers supplied from that feeder. Since a zone substation usually has multiple feeders, it can be assumed that in a commercial environment multiple couplers and the respective PLC modems will be installed which share the one backbone connection available. However, in some cases it might be necessary to install intermediate repeaters along the grid to ensure the signal quality at every transformer served by the zone substation or feeder.

At each transformer a similar coupling device as that required for the zone substation is connected to the 11kV supply on the HV (primary) side picking up the signal. Since a PLC broadband signal can not pass through a transformer it is necessary to bridge the PLC signal to the LV side (secondary side) of the transformer, where it is then re-injected onto the low voltage grid. This re-injection is undertaken using one of the standard PLC systems discussed in section 4.3. On the low voltage side of the transformer the PLC signal will be injected on all three phases to ensure the availability of the signal at every premise and each wall outlet.

The installation at the customer's premises will vary depending on the type of PLC system used. Some systems (ASCOM, Xeline, MainNet) require a home gateway to be installed at the meter board. Other DS2-based solutions normally do not require a home gateway. A detailed account of these systems is provided in Section 4.3.

In the home itself, the customer's PC is connected to a PLC modem. If more than one device is to be used in the home, then they should be networked or each connected to the Internet. A variety of possibilities are available. Either each one of them requires a PLC modem, or they can be networked with alternative technologies (eg wireless, CAT5, etc) and the one PC connected to the PLC system acts as the gateway.

The network management, customer care, billing etc. as shown in the diagram can be anywhere because of the nature of the TCP/IP protocols used.

Low Voltage Configuration

Diagram 3

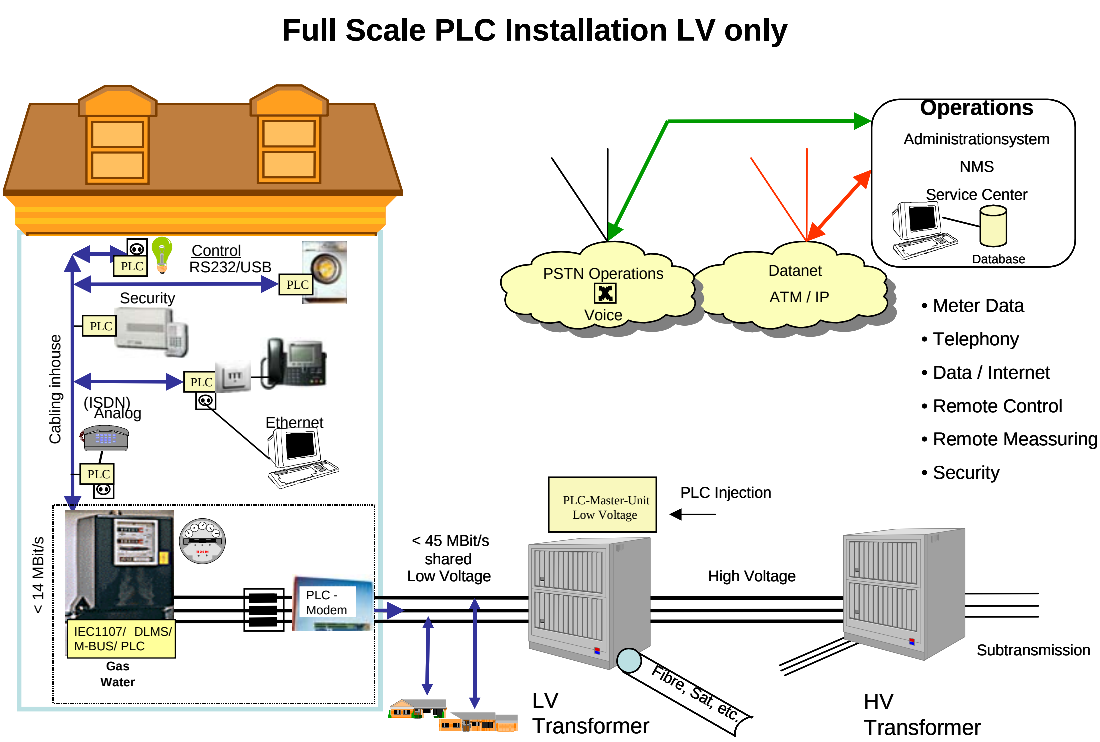


Diagram 3 depicts a PLC installation that only utilises the LV distribution network. This is typically the scenario found in areas with a high population density, or where the number of customers per transformer is sufficient to support the costs of this configuration. Here, the backbone communications connection needs to be made available at the LV transformer. Installations for pad mount transformers, which are transformers that are located on the ground, are generally easier than for pole mounted transformers. However, in either case it is likely that a shelter will be required next to the transformer to protect the electronic equipment needed for connecting the PLC signal to the selected backbone media. Also in this scenario a satellite based backbone connection is difficult because of the environmental and security issues of such an installation.

In addition to the different configurations of PLC implementation, eg. HV or LV injection, there are also a variety of architectures available for the LV layout of PLC systems depending on the vendor equipment chosen. Broadly speaking, these can be grouped into those that require a "gateway" at the customer's premises and those that do not. A gateway is a device placed at the entry point of the customer's premise that acts as an interface between the PLC master unit - located somewhere upstream on the LV network (in Diagram 3 at the LV transformer) and the customer's indoor PLC network.

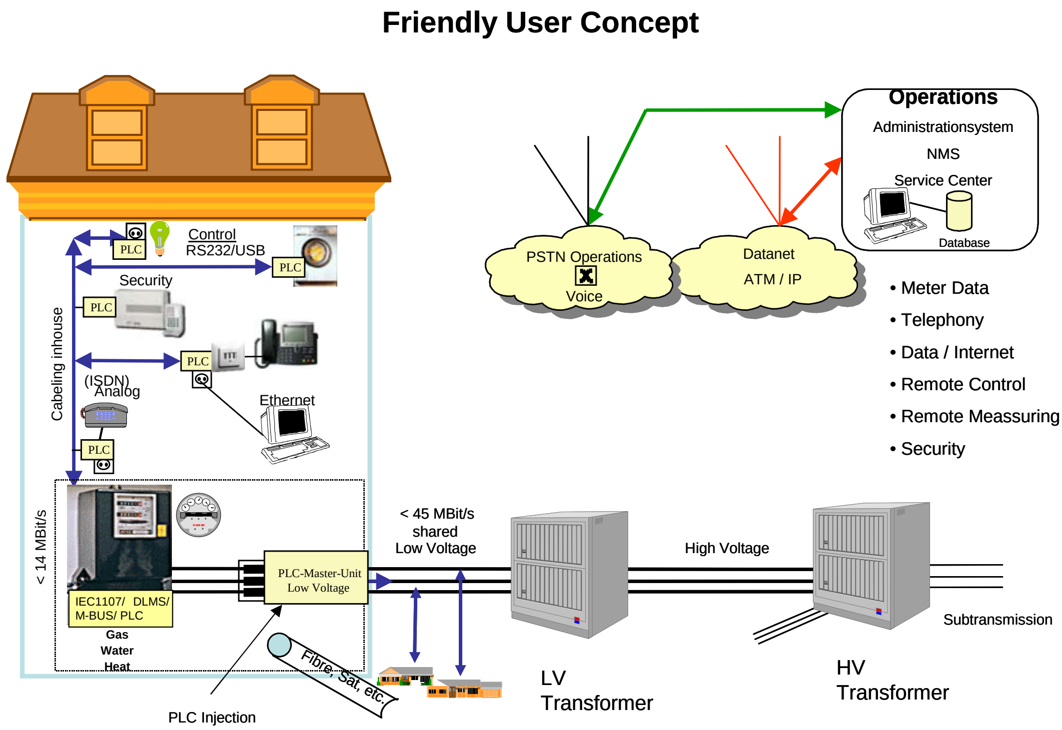
The installation effort at the LV transformer is the same irrespective of the choice of the PLC products available. Current products commercially available or in development are outlined in section 4.3 of this report.

The PLC master resides close to the LV transformer and the signal is injected on all three phases, as discussed earlier.

The set up at the customers' premises is the same as in the previous diagram.

Friendly User Configuration

Diagram 4



The friendly user concept shown in the diagram above is commonly used in Europe. It follows the idea of selecting one customer whose premise houses the PLC master unit. The backbone connection is also brought into this customer's premise (in this case satellite is also an option). This has the advantages that, firstly, no further effort is required to shelter the equipment and, secondly, it can be set up by any qualified and trained electrician without involving staff from the electricity utility or accessing the transformers on the grid.

The PLC signal is basically reverse injected into the LV grid and all other customers on that line can obtain access and are set up in the same way as in the previous diagrams. As already mentioned, a PLC signal cannot pass through a transformer and this prevents the signal from travelling to other customers beyond this point.

As mentioned previously, although the Australian electricity grid infrastructure is similar in many ways to those of other countries around the world, any commercial venture would be required to undertake a comprehensive grid analysis before embarking on any PLC deployment. Work undertaken by the PB Associates team on behalf of various organisations over the last two years has shown that Australian electricity grids are generally well suited to carry broadband and narrowband PLC signals.

To guarantee successful installation of PLC systems it will be important to conduct extensive measurements and surveys prior to undertaking field trials, and this clearly should precede any commercial rollouts. Technical characteristics of electricity grids for PLC application tend to vary significantly even if they are in line with the standards of a particular power utility. Measurements need to be taken to ensure the correct adaptation of PLC hardware and optimal performance.

3.5 PLC TECHNOLOGY - HISTORY AND CURRENT STATUS

PLC is a technology that has been in existence for many years. In fact, the first patent on PLC was registered in the USA in 1894. However, it was not pursued because at that time telecommunication consisted of only simple telegraphic signaling.

The concept behind that patent, however, is still valid. The wires that carried electricity had some broad similarities with those that carried telegraph signal. They were made of the same copper and attached to the same poles. The problem they encountered was that the electricity wires were carrying a strong current, much stronger than the one required for the telegraph signal. As such, there was an obvious and serious safety issue for telegraph operators if the electricity wires were to be used for communications.

PLC uses the electricity lines, which imposes certain safety measures.

This highlights a major challenge for PLC. Electricity on LV lines operates in voltages between 110V – 240V with 50/60 Hertz while telecommunication applications operate with less than 3 volts and at frequencies greater than 20kHz for signal transmission. It is essential that the communications equipment be made safe for users. In today's environment, however, electricity reticulation is carefully monitored to ensure the safety of workers, customers and the general community. There is also a need to ensure that PLC systems can be effectively incorporated into this environment. This includes the coupling across transformer points and incorporating coding and decoding devices into the LV or internal reticulation systems.

3.5.1 Early Developments

Narrowband applications have been used for decades, particularly by utilities for load control, data capture and simple communications.

In the 1950's the first commercial PLC systems were introduced by power utilities. Their purpose was mainly for the distributors' own requirements and these systems were not publicly available. Already, the first PLC telephony systems were in use. Engineers who were laying the high voltage cables across country transmission lines had devices enabling them to talk to each other from tower to tower. These phone devices are still in use today, despite the fact that reliable radio transmitters are available. Also for many years the utilities have been using PLC systems for ripple control signals, mainly to activate hot water heaters during off peak periods. Other PLC systems in use but relatively unknown are in mining or on oil platforms.

The first commercial PLC product became available in the 1970's. The "Babyphone" was a PLC solution consisting of a baby monitor plugged into the power socket of one room and a speaker plugged into the power socket of another. This enabled noises from the child to be heard from other rooms of the house. One problem of the device, which highlights another challenge for PLC systems, is that other users of the product could receive the signal from other parts of the building. This can be a serious network security issue, which is addressed in current versions of PLC systems.

During the early 1990's the telecommunication industry underwent considerable deregulation in Europe with the result that prices for telephony dropped by more than 80%. When the European Union decided to deregulate energy markets the utilities feared that electricity prices would plummet as they did with telecommunications. In Germany, the utilities started to explore alternative revenue streams. The connection between power lines and telecommunications networks was obvious, and they began to explore ways of utilising electricity cables for high-speed communications. At that time most of the electricity transmission grids already had fibre in their earth cables, allowing the utilities to establish effective backbone carriers. This led to research into last mile solutions, as only electricity distributors and telephone companies had wires into every household.

Broadband PLC systems were developed in the late 1990's in Europe and initial deployments provided speeds of up to 2 Mbps.

In late 1996 RWE in Germany (one of Europe's largest energy utilities) was the first utility in the world to form a project team to explore the feasibility of utilising the LV power lines for broadband data transmission. Their goal was to achieve at least a capacity of 2Mbps. No products capable of delivering this capacity were commercially available, so in early 1998 an R&D partnership with the Swiss based company ASCOM was formed to develop a broadband PLC solution for the LV grids. In early 1999 they developed the so-called "PLC Demonstrator", which was on show during CeBit that year. It successfully trialed a 2Mbps backbone at a transformer station connected to a PLC Master Modem and five units in an apartment building about 380 metres from the transformer. The PLC capacity at the time was 1.3 Mbps, and given that ADSL had not been introduced to the market yet, it was a very promising solution. However, the system demonstrated was tailor made and far from commercially viable.

In parallel to the ASCOM/RWE project, other utilities across Europe started similar activities. The most active of these were ENEL in Italy, Endessa in Spain, Sudkraft in Sweden and EnBW in Germany. ASCOM/RWE, however, with a budget of more than 50 Million Euros for the project, remained at the forefront of development. Electronic companies such as Siemens, MainNet, Keyin Telecom and NorWeb started to show their first prototypes of PLC Modems around this time.

After its first success, the project at RWE went into its second phase with the goal to launch a major trial. At CeBit 2000 the first trial installation was announced with more than 450 customers using PLC as their broadband Internet connection. Meanwhile, the activities in Germany had received considerable attention from utilities all over the world, particularly in Asia and South America. By the end of 2000, PLC trials were installed in Singapore and Brazil.

The main hurdle for the commercialisation of PLC was now its regulation. Although the International Telecommunication Union (ITU) had formulated a recommendation for broadband PLC to operate in the frequency range of 1MHz – 30MHz, it took until the end of 2000 for the European Technology and Standardisation Institute (ETSI) to define a PLC regulation. The corresponding documents are attached in Appendix C. By July 2001 the national German RegTP converted this into a national regulation, which was documented in NB30. The definitions in NB30 followed the general ruling of the ETSI documents in defining much more restrictive emission levels. That then paved the way for the commercial roll out of PLC and today tens of thousands of end users are receiving their broadband services via PLC in Germany and other European countries. These commercial activities will be discussed in more detail in the next subsection. NB30 and an even more restrictive ruling introduced by the British Government (with emission restrictions that were unable to be met by any PLC equipment) were declared invalid by the competition watchdog of the European Union because the declared emission levels were considerably below emission levels allowed for other telecommunication applications like ADSL. Although NB30 is still in place due to the fact that the EU has not as yet processed their new regulation paper, it is not enforceable.

3.5.2 Current Status of PLC Overseas

PLC is now a recognised broadband solution and is well supported by organisations like the 'International PLC Forum' and the 'Homeplug' organisation. Members to these organisations include Government departments, in addition to companies such as Microsoft, Sun Microsystems, CISCO, Motorola, IBM, Philips, France Telecom, Sony and Samsung, which all have considerable interest in deploying their services via broadband networks.

Broadband PLC implementations have now been undertaken in many areas of Europe, the US, South America and Asia. Trials are underway in most parts of the world.

Many countries around the world today are either trialing PLC systems or have already begun commercial installations.

Europe still remains the leading market for PLC applications with more than 100,000 end users. The equipment mainly being used in Europe is primarily supplied by ASCOM or MainNet. However, Spanish electronics company, DS2, has developed a sophisticated chip that is the basis for a number of PLC systems capable of providing a capacity of up to 45Mbps.

The main service providers are EnBW (the third largest utility in Germany), MVV (a regional utility in the south west of Germany), RWE (the largest utility in Germany), BEWAG (a regional utility in Berlin), ENEL (the largest utility in Italy), EDF in France and Vattenfall in the north of Sweden. Sudkraft in the south of Sweden and Endessa in Spain were the first utilities in Europe using DS2 based solutions. Early this year Russia rolled out an ASCOM PLC system in the St. Petersburg area with 25,000 end users.

Singapore Power with its daughter company SPTelecom in Singapore recently finalised its market trial and announced a commercial roll out with more than 50,000 end users in the first step to be finalized by the end of the year. During the various trials in Singapore initially equipment from ASCOM was initially trialed but by mid last year it was decided that the final solution needed to be DS2 based.

China has various trial installations, mainly from ASCOM and Xeline. All installations are in the range in between 50 – 100 users and in various provinces of the country. Last year their Ministry of Energy has installed a PLC office for the standardisation and commercialisation of PLC.

There are also a number of trials currently underway in the Asia Pacific region. In Auckland, United Networks, one of New Zealand's largest network infrastructure companies has installed a DS2 based solution. In Indonesia there is a small trial using MainNet technology, while in Taiwan a trial is being conducted by a company called Elster Electronics. The Elster Electronics trial began using ASCOM, but recently started to change to a DS2 based solution. In Malaysia, the national utility TNB with its daughter company Fibrecomm have just recently agreed to roll out trials in four different areas of the country using DS2 based solutions. A project is currently under review in the Philippines but no decisions have been made so far.

In South America, COPEL, a utility in the Brazilian state of Parana is using ASCOM PLC technology, while another utility, CEMIG, in the Brazilian state of Minas Gerais is using MainNet systems. However, COPEL is likely to switch to DS2 based solutions in the next few months. Venezuela has a trial running with ASCOM and Chile has a DS2 based installation in the Santiago region. Other South American countries such as Argentina (EDTS in Tucuman), Peru (Luz del Sul in Lima) are also investigating implementations.

3.5.3 Current Status of PLC in Australia

There are around 7 million Australians using the Internet and some 420,000 broadband or high speed Internet connections.

In the 2001 Australian Census, there were almost 7 million people (37% of the population) using the Internet for either business or recreation. The most recent quarterly report of broadband connections in Australia, prepared by the Australian Competition and Consumer Commission[4] (ACCC) and released in June 2003, shows that growth between July 2001 and March 2003 was almost 350%. The vast majority of this growth was in ADSL, other DSL and cable subscriptions. Whilst this suggests that there is still some scope for other mediums such as PLC to play a significant role in the provision of broadband access, it is also clear that the window of opportunity for such technologies is likely to close relatively quickly as telecommunications companies increase their investment in other mediums.

[4] ACCC, *Snapshot of Broadband Deployment as at 31 March2003*, June 2003

Table 7: Broadband penetration figures in Australia[7]

	Broadband Deployment					
	Cable	Satellite	ADSL	Other DSL	Other	Total
Jul-01	92,500	2,200	26,600	1,400	100	**122,800**
Mar-03	191,900	12,600	160,600	58,200	300	**423,600**
Growth	**207%**	**573%**	**604%**	**4157%**	**300%**	**345%**

No commercial deployments have been undertaken in Australia, however, 4 electricity distributors have acknowledged participation in trials and testing of various PLC systems.

In Australia PLC broadband technologies have been reviewed by various utilities (refer Appendix B) but no significant trials have been conducted to date. However, PLC systems have been in operation throughout Australia for many years for narrowband applications. These technologies did not provide for speeds that would enable large-scale commercial data transfer for commercial or residential customers. Its use was restricted mainly to frequency injection for off-peak heating systems, electricity system automation, and for some meter data capture and SCADA.

LV PLC systems are available and developing rapidly. For Australia's rural and remote areas, PLC will need to evolve to operate on the HV network over longer distances. Such systems do currently exists but will require further testing and development.

For Australia, a significant challenge for PLC deployment will be the ability to develop systems that accommodate the transmission of high-speed communications across long electricity distribution lines. Many distribution authorities within Australia have been exploring the potential for PLC but are recognising some of the technical limitations of existing PLC offerings. In particular, access to backbone connections for regional and rural customers is claimed to be an issue, along with providing signal strengths for "last mile" PLC systems that can service customers who are geographically dispersed. In addition to the difficulty associated with signal delivery over extended distances, climatic extremes which can affect some PLC solutions, make Australia a challenging market for PLC deployment. Lower population densities also make broadband business cases more difficult to substantiate. Whilst PLC solutions may have an advantage from their ability to leverage off existing electricity infrastructure, low population densities are still a hurdle.

A further challenge, shared with other broadband providers, is to combine the technical provision of access through PLC with the perceived value by customers for the content or services they could receive.

PLC development will be dependent on the commercial cooperation of vendors, electricity distributors and service providers.

The market separation of access or carriage providers (such as electricity distribution companies) and content providers (ISPs, security firms, home automation, and others) makes it difficult for proponents to be willing to make the necessary capital investments, particularly for research and development. These investments are highly speculative and electricity asset owners are largely State Government organisations (with the exception of Victoria and ACT). However the potential benefits for the enormous range of additional services, such as in the education and health sectors, make it attractive for government organisations to ensure appropriate incentives or safeguards are provided to electricity distributors and others for the correct levels of investment in PLC technologies to emerge.

3.6 ACCESS TO BACKBONE NETWORKS

Whilst there are some technical challenges still facing PLC technologies, the most significant hurdle to wide scale implementation is likely to be establishing connections to backbone networks.

The success of PLC technologies, as with any broadband system, relies on high-speed backbone connections to the Internet. These backbones consist of broadband mediums such as optical fibre that have extremely large data carrying capabilities and link Australian customers to each other and with the rest of the world. In general, while backbone capacity is available, a key challenge is connecting homes and businesses to it. While less of an issue in the metropolitan areas, where there are greater opportunities to interconnect with backbone facilities, this is certainly an issue in less populous rural and remote areas.

Even within larger cities, gaining utilisation of dark fibre optic cabling (unused fibre capacity), laid in more optimistic times, can be a problem due in part to a lack of broadband cabling to the end user premises. This gap between backbone systems and customers (the so called "last mile") is a key challenge and an area that all broadband service and content providers need to overcome. PLC is a possible solution and achieves improved utilisation of existing infrastructure (power lines, dark fibre, etc), potentially at a relatively low cost for utilities, fibre cable companies, satellite owners and teleports, ISPs and telephone companies because it utilises cables that already exist. Since power lines are already connected to most homes and businesses in Australia, PLC could offer broadband connections to almost all end users.

Having said this, interconnection between PLC systems and the backbone telecommunications network may also raise issues, in that telecommunications and electricity networks do not always coincide physically. Additional infrastructure may therefore be required to connect PLC networks to the backbone, or, conversely, to extend backbone telecommunications networks to PLC networks. This has cost implications for the deployment of PLC. In metropolitan areas this may be less of an issue because both electricity and telecommunications facilities are more densely located. In rural and remote areas, this is generally less so.

In terms of connections for more remote customers, where fibre and cable backbone systems cannot economically be integrated with PLC systems, it is likely that satellite technologies will still be required if a cost-effective service is to be made available. Advances in satellite technology and related ground equipment appear to offer the potential to connect remote communities to backbone services, with savings accruing if these costs can be shared. The use of PLC to provide the "last mile" connection to customers from a shared satellite facility has been trialed in Germany and the US. Also this will be the standard for the PLC roll out in Fiji to take place in September 2003.

The last few years have seen Very Small Aperture Satellite Terminals (VSATs) and IP-related satellite services become significantly cheaper. In combination with PLC systems, satellite could provide an integral component of the broadband solution for some customers as trialed in Europe and the US, but only where appropriate satellite bands are available.

4. SURVEY OF AVAILABLE PLC TECHNOLOGIES

4.1 OVERVIEW

Since the advent of broadband PLC systems in the late 1990's, many companies have sought to develop products to take advantage of the huge potential market. In order to fully appreciate those developments and their unique characteristics it is necessary to evaluate each against specific technical and performance criteria, as well as other commercial factors. Appendix A contains a summary of those comparisons and criteria, however in this section we explore some of the background for these developments and their intended applications. In particular, this section discusses progress in using PLC on the HV network and then discusses LV PLC systems, separating indoor and outdoor products for detailed vendor analysis.

4.2 HV PLC DEVELOPMENTS

PLC signals can be either:

- *Capacitive – using the "live" electricity line, or*
- *Inductive – using the earth wire.*

As already stated in this report, narrowband solutions either on the LV or HV circuits have been available for many years and are widely used throughout Australia. While the intention of this study was to examine PLC systems in the context of providing broadband solutions, particularly in terms of their ability to provide last mile access to communications services, there have been some narrowband developments in recent years that should be highlighted.

Developments in narrowband PLC have taken place, particularly in the coupling technology for the HV mains. Injecting a signal on power lines can be done in two ways, either the so-called "inductive coupling", (signal is on the earth wire) or the "capacitive coupling", (signal is on the live phase). Coupling on the earth wire does not impose many additional technical challenges and is, therefore, the main solution for most narrowband PLC systems currently in use. However, one great disadvantage is the limitation in reach and also in many cases HV distribution lines do not have a separate earth wire. For a broader penetration of communication it was necessary to introduce capacitive coupling technologies. In the past these couplers were bulky and very expensive.

HV coupling developments are providing cheaper and more effective access to HV PLC applications.

In recent years new coupling devices have been developed by Eichhoff and ABB, which overcome these problems. These coupling devices now also offer interfaces to both narrowband and broadband PLC modems. According to tests undertaken by Country Energy in 2001 in the Tamworth area (regional NSW), the ABB couplers appear suitable for Australian rural conditions. Although no specific tests have been conducted in Australia using the Eichhoff couplers, anecdotal evidence suggests that they would also be suitable for Australia. This assumption is based mainly on highly successful installations in China and Taiwan under relatively similar conditions. Both couplers can deal with a variety of narrow and broadband modems. Other vendors currently offering broadband HV solutions are MainNet, Toyocom, Ambient, PowerNetze and Ilevo, and these are discussed in more detail later in the report.

4.3 VENDOR ANALYSIS

4.3.1 Outdoor Broadband

As already mentioned in this report, the development of this technology started in the latter half of the 1990's and today a variety of vendors claim to have commercially available solutions. Following is a summary for each of these vendors in the order they appear in the attached spreadsheet.

Ascom
Ascom, a Swiss based manufacturer of telecommunications equipment, started to develop their solution in 1997 in co-operation with and major funding from RWE in Germany. The first prototype was shown on CeBIT 1999, providing a capacity of 1.3 Mbps. The Ascom technology is based on a Master / Slave concept. Typically the Outdoor Master is installed at the transformer site and the Outdoor Slave and Indoor Master are installed at the metering point of a home. The Indoor Slave is then connected to the PC of the user. This concept has the major advantage that the indoor communication can be separated from the outdoor communication. In a commercial environment, however, the disadvantages seem to be outweighing the advantages, particularly the need for two boxes at the metering point, which makes this solution more expensive.

Today Ascom provides a capacity of 3.4Mbps. In some cases this is sufficient, however in tests carried out in Singapore on high-rise apartment blocks, this technology did not prove to meet customer demands in the high density, high penetration area. This highlights the limitations associated with a shared bandwidth technology, such as PLC.

The Ascom equipment also has a limited temperature range and in particular the Outdoor Master needs to be installed in an acclimatised cabinet in regions where temperatures exceed 35 degrees Celsius.
Mid last year Hong Kong based Infrastructure Company, CKI, bought the assets and intellectual property rights of Ascom. The operations in Switzerland were shut down and only a handful of engineering and technical personnel remain to provide R&D services to CKI.

MainNet
This company based in Israel had its first successes in 2000 in conjunction with MVV AG, a leading German multi-utility company. In the meantime there were numerous installations of their "Rplus" product around the world. This technology is based on the Itran chipset providing a capacity of 1Mbps. The concept of the system is to set up a master unit at the transformer and the end user unit at the home. To ensure the quality of the signal, a number of repeaters can be installed to suit the conditions.

Today MainNet has joint ventures in Germany and the US for the distribution of their technology. Just recently they have announced a partnership with Sydney based service company, Savant Corporation, to introduce their technology into Australia.

The MainNet solution is very reliable and it is one of the few vendors that have a HV solution available. However due to the need for multiple repeaters, depending on distance and line quality, it is difficult to estimate the costs for installations. More importantly the bandwidth available may not provide a long term competitive PLC solution. MainNet has not disclosed its future plans.

Xeline

This South Korean company first appeared as Keyin Telecom and changed its name to Xeline in 2001. First prototypes of its product were available in early 2000. In fact, the RWE PLC Demohouse in Germany was set up using Xeline equipment. Although privately owned, Xeline relies heavily on a Korean Government funding program, which is believed to expire in April 2004. Initially they had planned to have a commercial product available in 2001, but due to delays in the chip design the product was not available until late 2002 and Xeline's plans to deliver a 32Mbps solution did not eventuate. The current version of its product provides 8Mbps. Currently Xeline has a very strong focus on the Chinese market, with trials in Beijing and Shanghai.

Recent tests indicate that their product delivers a plausible solution and pricing is competitive.

DS2

DS2 is an electronics company based in Spain that has developed a highly sophisticated chip as a basis for PLC, providing a system capacity of up to 45Mbps. This is now viewed as the market leader and is setting the standard worldwide for PLC outdoor systems. With the exception of the initial trials conducted with Endessa in Spain, DS2 does not provide a complete PLC modem. DS2 provides licences for its chipset to interested companies, a reference design and engineering support. Based on this package, DS2 licensees must develop their own final solutions. The principle challenge is to develop the analogue front end, and that is where the main differentiations emerge between DS2 licensees, particularly in obtaining sufficient signal strength and distance.

The following vendors have all based their PLC products on the DS2 chipset. They are, therefore, all compatible and differences only lie in their functionality, add on features, support, pricing and most importantly the quality of the analogue component of their modems.

By the end of this year it is anticipated that DS2 will release its new chipset with a capability of 200Mbps. It can be expected to take the licensees approximately 6 – 8 months to incorporate the chip into their commercial products.

Easyplug

Easyplug is a joint venture between French company Schneider Electric and the US company, Thompson. Easyplug started ambitiously in late 2001 with the aim to have their first commercial solution available by mid 2003. However, the development has been slower than expected and today only prototypes are available, which exhibit a lack of reach and in particular the transformer unit is still very bulky and needs a separate housing or cabinet.

Ilevo

This is an offshoot of telecommunication giant Ericsson in Sweden and has an advanced product on the market. Ilevo started to commercially deploy their solution early this year. EDF in France, SPTelecom in Singapore, Sudkraft in Sweden and also Vector in New Zealand have all chosen Ilevo as their primary vendor. Ilevo's TPE (Transformer Premises Equipment) is 100% weatherproof and can be installed in extreme climate conditions without further protection. The current Ilevo long reach product covers 400m – 500m without the need for repeaters and home gateways.

Ilevo also provides a HV solution with their own coupling devices, which have the capability to bridge the transformer's primary side (e.g. 11kV connection), and the secondary side (240V output) of the transformer currently providing the 45Mbps.

Toyocom

A subsidiary of Moritani in Japan, Toyocom was launched early 2002 and is expected to deploy its product within the next few months. No detailed information is available at this time regarding the quality of the Toyocom product, but recent tests with the prototypes did show that their solution seems to overcome the distance problem related to the DS2 reference design.

Ambient Corp.

Ambient Corporation is a publicly traded company, head-quartered in Brookline, Massachusetts. Ambient is a technology development company, pioneering and innovating PLC solutions for the special needs of the US electricity grid infrastructure. In the residential market, Ambient focuses on the deployment and commercialisation of PLC technology on both high and low voltage distribution power grids. Although initial projects have been signed with ConEdison and Southern Company, a utility in Alabama, Ambient appears to be some distance from having a commercial product available. In the past it has focused on coupling units for the US HV grids but only inductive couplers are available at this stage. Ambient has recently announced a cooperative agreement with a utility in Chile.

Mitsubishi Electric

For more than a decade Mitsubishi has provided various PLC based industrial SCADA applications. It has not, in the past, entered the domestic consumer market with these products. In an attempt to review the potential of broadband PLC for Mitsubishi Electric's current industrial activities, it obtained a DS2 licence late last year. At this stage it has not released plans to deploy its technology for the residential market.

Sumitomo

This is a group of companies involved in a diversity of business ventures in Japan and other Asian countries. At CeBIT 2002 Sumitomo announced the licensing of the DS2 chipset and cooperation with TEPCO (Tokyo Electrical Power Company) for the deployment of broadband PLC in Japan. In the meantime it has developed its first commercial solution, which is currently being tested on TEPCO's grid. Up to now Sumitomo has made no efforts to export its technology, but it is expected that it will do so in the future. Neither TEPCO nor Sumitomo are disclosing more technical details at present.

PowerNetze

This is a German company only recently formed. It is expected that PowerNetze will require at least another 12 months before it will have developed any viable PLC solutions.

Tecnocom
A Spanish technology company with a strong presence in South America, Tecnocom only obtained the DS2 licence in April this year. It will take Tecnocom at least another year before a suitable solution could be formulated. However, the fact that Tecnocom is closely linked to DS2 may assist it to rapidly develop PLC products and it is advisable that its progress be monitored closely. Although it can be expected that Tecnocom's main focus will be the South American markets, its technology could well be suited for Australia, as conditions are comparable in many respects.

Amperion
This US based company has taken a very different approach because of the characteristics of the US electricity grids. In the US the main distribution system is a HV grid and transformers only serve 2 – 4 customers. This makes the availability of a HV PLC solution essential for a cost effective PLC deployment. Amperion supplies two different systems, being for overhead or underground cabling. It does not provide a PLC connection to the home, but a wireless 802.11b from the HV lines.

Although the wireless connection from a HV line to a home does not appear to be a feasible solution in Australia, Amperion's HV PLC system does offer some potential.

Defidev
This is a French company concentrating mainly at this time on delivering PLC services to hotels. Defidev obtained its DS2 license recently and little information is available regarding the status of product development.

EBA PLC Corp.
This is a Brazilian company that has also just joined the family of DS2 licensees and announced its foray into PLC earlier this year at the World Telecom Conference in Sao Paulo. There is no detailed information available regarding products; however, it is anticipated that EBA PLC Corp will have equipment available within 12 months.

Inovatech
Inovatech is registered in Hong Kong but has its operations based in Australia and is also a DS2 licensee. Their offices are in Sydney, where they provide demonstrations of their technology. At this stage Inovatech have not developed an independent commercial product, relying mainly on the reference design equipment provided by DS2. Inovatech have focussed on incorporating utility automation, which would be a significant enhancement, particularly for Australia, and is planning to release a product some time next year where the metering functionality is integrated into the broadband outdoor units.

4.3.2 Indoor Networking

There are numerous products available on the world market delivering PLC based indoor data transmission. Most large electronics companies in Australia carry devices that provide the extension of a regular phone line via PLC throughout the home. Whilst it is not within the scope of this review to assess the myriad of indoor PLC products, it is important to note that in this area an unofficial standard has evolved and these solutions are based on the Intellon chipset. The Homeplug Association has defined these solutions as the standard and the most recognised contenders in this environment are Phonex Broadband, NetGear, Corinex and Siemens.

PLC indoor and outdoor systems are not naturally compatible and require integration and alignment.

It is also important to recognise that these products cannot naturally coexist with outdoor access solutions. It requires considerable technical effort to align indoor and outdoor PLC data transmissions. An issue for Australia will be to develop a common standard for PLC that ensures unification of PLC developments and compatible product offerings. This is particularly important given that retailers of electrical equipment are currently stocking indoor PLC products.

4.3.3 Summary

The development of a 45 Mbps chip by DS2 has placed it on the leading edge of the PLC market. As a result, generally speaking those companies utilising this technology are considered to be most advanced and likely to offer the best potential for Australia. In particular, Ilevo has commercial products on the market that appear to offer the most advanced solutions. However, given the relatively recent development of the DS2 product and the imminent release of a significantly improved version, other companies are likely to offer competitive solutions in the near future. Those companies we believe are most likely to become competitive are Toyocom, Mitsubishi, Sumitomo and EBA PLC Corporation. In addition, Inovatech, being Australian based, also has potential and has indicated the development of useful modifications. It may also be worth considering Amperion for possible HV solutions, and although not a licensee of DS2, MainNet could be considered for some isolated installations.

Appendix A shows a summarised comparison of available PLC products and their applicability for Australia.

5. TECHNICAL IMPEDIMENTS FOR PLC

PLC utilises the existing electricity network to provide broadband communications to customers. These lines exhibit features that impact on the quality of those broadband signals and can impede the ability of PLC to offer an effective access network.

The key technical issues that face PLC systems in Australia are:

- Capacity of PLC systems
- Distance (and availability of backbone systems)
- Network configuration
- Interference (noise) on the line

5.1 CAPACITY OF PLC SYSTEMS

PLC systems are a shared media. This means that the bandwidth available has to be shared between users connected to that system. In practice, customers choose different times to make use of their connection and the critical factor for capacity is the coincidence of that customer demand, in other words, the sum of their capacity requirements at the peak demand period. All shared services, such as electricity, gas, water, telecommunications and public transport are required to balance this relationship to minimise investment costs without compromising the levels of service. Tests with early PLC systems in Germany showed that 25 users sharing 2Mbps still received around 1.3Mbps each. The reason is that the idle time of the system is much higher than the actual active time. This is because in general it takes a user much longer to digest the information provided than it takes the system to deliver the information. In cases of heavy downloads, as occurs with video streaming (VoD), techniques such as pre-loading and buffering of the data ensure not only a continuous flow of data, but also ensure that the available bandwidth is not exhausted by individual users. Another technique which can be adopted by systems using Orthogonal Frequency Division Modulation (OFDM) modulation schemes, is service prioritisation. This method allows certain channels to be dedicated to individual services with the result that some channels can be bundled for data traffic with high loads and other channels can remain available and unaffected for standard Internet or telephony services.

45 Mbps is the current maximum PLC capacity offered. Allowing for signal reduction from line noise, this would generally offer sufficient capacity for the shared supply to customers on the LV network.

As previously discussed, DS2 based systems do provide a system capacity of 45Mbps today. This is maximum capacity as it is with any other PLC system claiming the capacity of a certain bandwidth. This maximum bandwidth is only available under ideal circumstances, which rarely occur, particularly on overhead electricity lines. Due to noise levels on the lines or national regulations (frequencies protected for services unique to the relevant country), some frequencies of the PLC system are likely to be unusable, which will reduce the total system capacity. Modern PLC systems, in particular those based on DS2, can be adapted to these circumstances but in practice will still deliver capacities less than the maximum rating. Techniques to enhance the quality of the PLC signal, and hence the overall capacity, also add to the cost and would only be used where the business case warrants such investment. Effective techniques will vary depending on the vendor and their particular products, but examples include strategically positioned blocking filters, which stop the high frequency noise at its source (or close to it), or channel adoption, which means that the PLC system is set up in a way that avoids extremely noisy frequencies. This is possible because a PLC signal is typically transmitted over a wide band of frequencies.

As noted in Section 2.3, there are typically around 50 residential premises served by a LV transformer in urban residential areas of Australia. The diversified demand of this number of customers is likely to fall within the capacity range of the current DS2 systems in most cases, even allowing for significant signal deterioration. Additional capacity can be made available, if necessary, by placing units on each phase, ie 3 units (one per phase). The anticipated release of the "Wisconsin" chip by DS2 later this year will also increase capacity to a maximum of 200 Mbps.

5.2 DISTANCE

The distance a PLC signal can travel varies and is influenced by many factors. The main factors are impedance, attenuation and signal-to-noise ratio (SNR).

The distance a PLC signal can travel along the line depends on the strength of the injected signal (governed by regulations), the impedance of the line and the noise interference competing with the signal on the line.

Impedance is an expression to describe the opposition that an electronic component, circuit, or system offers to electric current.

The metal from which electricity cables are made, possesses a natural physical resistance, referred to as impedance. This resistance is measured in Ohms. The impedance is largely dependent on the type of metal and the diameter of the cable. Copper or steel cables possess comparatively low impedances whereas aluminium has higher impedance. The higher the impedance the shorter the distance the signal will travel along the medium.

Attenuation is simply a reduction of signal strength during transmission. Attenuation is represented in decibels (dB). Attenuation causes a signal to become weaker as it travels through the medium.

SNR, Signal to Noise Ratio is the value in dB in between the natural high frequency noise on every carrier medium and the actual carrier signal itself. A very low signal to noise ratio makes it very difficult to detect the carrier signal from the noise on the lines.

The noise on a line has a huge variety of causes and sometimes it is difficult to determine the source. Known sources are electrical motors as in vacuum cleaners, hair dryers, washing machines, air conditions etc. Another cause is salt on the lines in coastal areas, which can create static discharges when the lines become wet. Poorly maintained transformers can also create noise as do some types of streetlights, electric trains etc. All these factors can have an impact on the distance a PLC signal can travel along an electricity line.

Noise on electricity lines significantly reduces the distance achieved by PLC signals. LV lines are more affected than HV.

Generally it can be said that the impedance and noise factors on HV lines are much less than on LV grids. This is because HV networks have different cable diameters and the metal the lines are made of tends to be more consistent. There are also usually fewer end consumers with electrical motors and other equipment that can impose noise on the lines.

For PLC, LV lines are more critical as this is where most systems are likely to operate. Experiences in Europe with earlier PLC versions have shown that some electrical environments do not allow the PLC signal to travel for distances more than 50 – 80 metres without major enhancements to the coupling devices and the analogue part of the PLC modems. Nowadays PLC systems are available which can deal with these conditions and overcome most of these obstacles, however, they still have an impact and need to be considered before any commercial PLC installation can be undertaken.

When undertaking a comprehensive grid analysis prior to embarking on any PLC deployment, it will be important to collect data on attenuation, impedances and SNR. If these measurements are carried out in multiple areas representing the various grid conditions, the data collected can offer a good indication of the potential for PLC. The areas where PLC is viable can be identified and investments into installations in unsuitable areas avoided. In this regard it is not that the PLC equipment itself is likely to be unsuitable, but that the cost of installation is not commercially sustainable.

In addition to the physical conditions on the electricity lines the signal reach also varies with the technology selected. Systems that operate with modulation schemes like frequency-shift keying (FSK) or spread spectrum are more likely to cover a shorter distance than systems operating under the orthogonal frequency division multiplexing (OFDM) modulation.

Modified DS2 systems achieve signal distances of over 350 metres. HV systems can travel many kilometres.

As outlined on page 20, PLC modems are typically divided internally into a digital and an analogue part. The digital part is responsible for the modulation scheme and the coding algorithms of the data. However when it comes to reach, the most important part of the modem is the analogue part. This part includes the coupling device and the transmitter/receiver unit. The sensitivity of this unit has a major impact on the distance the PLC signal can cover. For instance a DS2 based modem with an unmodified (reference design only) analogue front end covers a distance of approximately 80 metres on underground cables and even less on overhead cables in a LV grid. Some vendors with a modified analogue front end are achieving distances of about 450 metres outdoors with underground cables and approximately 350 metres on overhead. However, the signal can cover distances of many kilometres if repeaters are used.

Repeaters are units, which are installed in between the actual transmitting and receiving modems. Their only function is to pick up the signal and basically amplify it to ensure the quality of the signal remains unchanged over the distance. In radio frequency (RF) technology repeaters are commonly used for normal FM radio, television and any other wired or wireless data transmission. In general, repeaters should be avoided as much as possible as they add to the costs of transmission, which in turn can significantly weaken a business case for a service.

For PLC systems, particularly in rural and remote regions the challenge is to design a PLC roll out with as little as possible usage of repeaters. This can only be achieved by utilizing the 11kV – 22kV grids and the flexibility of satellite backbone connections as previously discussed.

As a reference it should be noted that state-of-art indoor modems cover an average distance of around 80 metres.

5.3 NETWORK CONFIGURATION

The configuration of the Australian electricity network indicates that in metropolitan and regional areas PLC is likely to utilise the LV network, whilst in rural and remote areas HV solutions would offer significant advantages if sufficient distances can be achieved.

As described in Section 2.3, Australia's electricity grid involves transmission, subtransmission, HV and LV networks. PLC signal distances are determined by the strength of the input signal (restricted by EMC regulations), the impedance of the line and noise levels. The low voltage network is considered the most advantageous for PLC as it generally requires shorter transmission distances and no bypass routing of transformers. In Australia, LV reticulation is generally 3 phase with customer connections usually being only single phase. Basically this means that of the three "live" lines running along the street, each customer's service line is only connected to one of them. To balance the load on each phase, utilities vary the phase for each customer connection. The implication for LV PLC is that all three phases must be PLC enabled in order for all customers in the street to have PLC access.

Based on the statistics in Section 2.3, the average number of customers per distribution transformer is around 15. This figure is impacted by SWER and other HV customers who may each have their own transformer. As also noted in section 2.3, in metropolitan and regional areas the number of residential customers per transformer will normally be between 20 and 120.

To cope with the various situations in metropolitan, regional or rural areas the PLC signal can either be injected on all three phases simultaneously (45 Mbps) or if required, onto each phase using three units (3 x 45 Mbps). 45 Mbps provided by the current "DS2" chipset would be considered sufficient to service residential customers in most situations based on today's applications as discussed in previous sections, however, there is clearly some uncertainty regarding future applications like video on demand and their capacity requirements. On the other hand with the anticipated release of the new "Wisconsin" DS2 chipset later this year, providing up to 200Mbps, it would appear that even more data intensive applications could be accommodated by PLC systems with up to 3 x 200 Mbps available to be shared by customers supplied from each LV transformer (distribution substation).

Similarly, the HV network is generally reticulated using 3 phases, with the exception of SWER lines. However, as the transformers are known to affect communication signals, PLC systems need to incorporate technology that will allow signals to bypass distribution transformers in order to provide a solution on the HV network. This is generally achieved using new coupling devices, which enable the bridging of the signal from the HV lines to the LV lines currently in use in South Africa, Taiwan and China. Developments over the last few years indicate that this challenge has largely been overcome.

Zone substations house the equipment where subtransmission voltages are transformed to HV. The HV lines may feed thousands of customers, particularly in metropolitan and regional areas. It is possible that the diversified demand for broadband services at these points will exceed the capacity of existing or proposed PLC systems in built up areas. Therefore an integrated HV-LV PLC solution may not be viable in metropolitan and regional areas and as a consequence, overall systems will require connections to a communication backbone before this point.

HV feeders for more rural and remote areas may have lower numbers of customers connected. Whilst the number can vary substantially, it is reasonably common to have between 100 and 500 customers on a rural feeder, which may be manageable with existing and proposed PLC systems. Where this is the case, the HV network could provide a PLC solution.

5.4 INTERFERENCE

It has often been raised during overseas deployments that PLC creates interference for other communications users. In particular the amateur radio community has expressed concerns that radio signals can be impacted by wide-scale use of PLC. It is true that with high density PLC roll outs there is a genuine potential for some radio bands to be disturbed. However, there is no evidence available from countries in Europe that PLC has caused any major disturbances in this regard.

Widespread implementation of PLC systems could have some effect on radio bands outside crucial frequencies.

Various studies and tests conducted in Europe have shown that there is a potential for interference with short wave radio services caused by outdoor PLC installations. References to these studies are provided in section 10.

In summary, the results of those studies indicate that the levels of interference from PLC on radio receivers cannot be easily defined and there is likely to be some interference resulting from wide scale PLC deployment. These experimental studies show that it is possible, under unfavourable conditions, for interferences from PLC to affect radio signals, especially very weak signals. The results indicate that investigations of these issues in any particular country will be necessary prior to any formulation of national regulations or standards

Overseas experiences have shown little actual interference arising from PLC deployments.

However, it should also be noted that PLC signals are injected using relatively low power output. For instance signals from mobile phones or ADSL are between 10 and 100 times more powerful than a PLC signal. The question about the interference caused by PLC systems does not arise from their output power levels, but from the characteristics of their potential widespread deployment and the frequencies used.

The issue is also not just whether PLC systems can interfere with other systems but also what other systems could cause interferences for PLC, such as modern high-speed trains (eg the French TGV or the German ICE) or many unlicensed CB (Citizen Band) radio stations. In fact this was a major problem for rollouts in Europe and South America.

Having made these comments, an inspection of the Australian Radio Frequency Spectrum Allocation Chart shows that PLC systems in compliance with the ETSI regulations (CE certified) or US FCC Part 15 regulation (FCC certified) (refer to Appendixes C and D) should not generate interferences for crucial radio operations in Australia. However regulation of these aspects of PLC technologies for Australia is a matter for the Australian Communication Authority (ACA). Large-scale deployments overseas have also not demonstrated any evidence of significant interferences, and amateur radio communities have not registered any significant interference. In fact measurements in Germany have shown that interferences caused by the high speed railway trains like the ICE or the French TGV operating nationwide are more than 500 times higher than any PLC interference.

The issue of interference should be addressed at an early stage through comprehensive testing and assessments to ensure that PLC systems are designed and implemented in ways that are compatible with other radio and telecommunications uses.

6. PLC DEPLOYMENT

By utilising the electricity connection to almost all Australian homes and businesses, PLC can provide an alternative means of delivering access to broadband communications. In order for this to occur, however, it is necessary for the PLC signal to link with backbone telecommunications networks to provide an integrated solution. This section explores the issues that determine the most likely PLC deployment strategies and how growing customer demand could affect those deployments.

6.1 PLC AS A "LAST MILE" SOLUTION

The obvious advantage of using existing electricity lines to provide broadband communications is that it does not require the construction of new distribution lines. The costs of duplicating the electricity network with communication cables today would be in the tens of billions of dollars and would take many years to complete.

In enabling the LV network to carry PLC the service is made potentially available to all customers on that line.

Like most reticulated systems, the electricity network uses a graduated system of large capacity upstream cables devolving to a myriad of smaller cables connecting to customer premises. This means that a large proportion of the network (225,000 km or 26%) is comprised of LV lines. If these lines can be broadband enabled through the introduction of PLC units and connected to the telecommunications backbone at a reasonable cost then they offer a substantial opportunity for customers and service providers.

In the absence of any prescriptive regulation or financial inducement, PLC deployment could be expected to commence in higher density areas close to backbone networks.

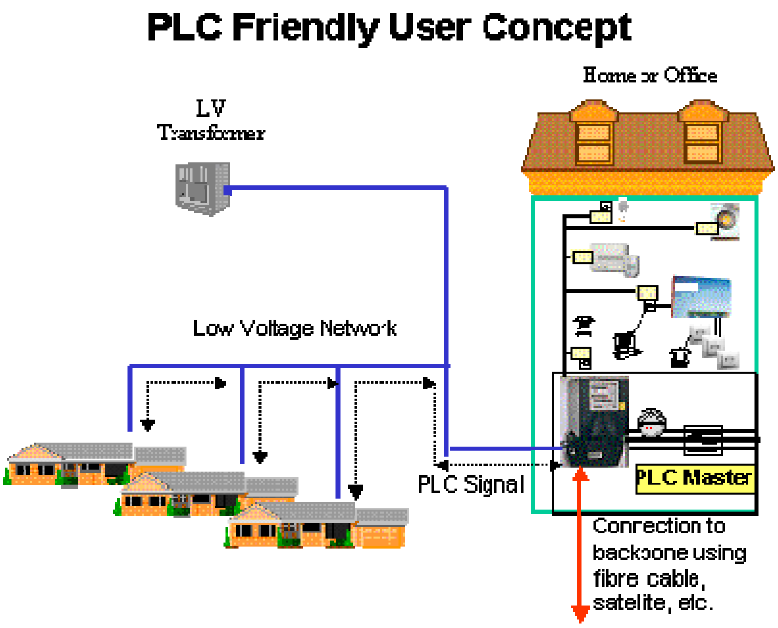
While the number of customers that can be supported by PLC can generally be increased in line with demand, the nature of the PLC equipment and the infrastructure required to provide broadband PLC services is such that significant upfront capital costs are involved in establishing a PLC system. This is due to the substantial costs incurred in establishing connections to backbone networks. The costs per connected electricity customer of enabling the LV electricity lines as the "last mile" broadband access network would be relatively low in metropolitan and regional centres. The issue is, therefore, not scalability (ie starting with smaller capacity installations and gradually increasing this as demand increases), but rather backbone interconnection costs and numbers of PLC injection points. The challenge will be to facilitate service provision in less populous, less commercially attractive markets.

In a staged implementation, those transformers with higher numbers of customer attached, within close proximity of backbone facilities and located within areas of expected high take-up rates would most likely be chosen first. In particular, existing high and medium density buildings where it would be expensive to retrospectively wire for broadband services.

The variety of architectures makes it difficult to describe a "typical" PLC configuration. In general, however, the need for a gateway does add additional costs for PLC deployment and many of the DS2 licensees have designed systems that do not require this device. Instead, they link directly to the customer's indoor equipment.

It is possible, with current PLC systems, for groups of customers connected to the same LV transformer to obtain PLC broadband services without necessarily involving the electricity distribution business. This can be done using the so called "friendly user" where the premises of a customer is selected as the interconnection point to the backbone system and the PLC signal is reverse injected into the electricity grid for other customers connected to the same LV line to receive and send transmissions via that interconnected customer. The interconnection could be by means of fibre, satellite or any other carrier being able to provide a sufficient (at least 30Mbps) capacity. Diagram 5 illustrates how the signal could be received and transmitted along the LV network.

Diagram 5



Although this approach is technically both feasible and quite plausible, it does highlight how PLC implementations could happen in a dysfunctional manner unless appropriate guidelines and standards can be developed and a coordinated approach adopted. This configuration has been adopted in Europe but does raise the obvious questions regarding the impact on electricity distribution authorities and use of their assets.

6.2 INTERCONNECTION TO THE BACKBONE

Connections to backbone communication networks remain the most significant issue for widespread PLC implementation.

Despite the technical challenges facing PLC, the most difficult issue for Australian PLC implementations would appear to be the cost of connecting PLC units to telecommunications backbone networks. It has not been possible in this review to assess the geographical proximity of backbone capacity to possible PLC sites throughout Australia. Nevertheless, it is understood that in many metropolitan regions, sufficient backbone capacity is located within reasonable proximity to LV transformers. Outside metropolitan areas this may not be the case.

The current options for effective interconnection include optical fibre, cable, HV PLC and satellite. Fibre and cable network rollouts can leverage off existing electricity and telecommunications infrastructure such as poles and ducts to reduce the costs of installation. In this event, fibre has a substantial advantage in terms of capacity and there is a strong expectation that the range of services able to be offered through broadband will explode once it becomes widely available and capacity requirements increase substantially. As mentioned earlier, advances in satellite technology also offer considerable potential in many instances where population density (and demand) is lower. HV PLC products are largely still under development, however, especially at the levels of capacity envisaged. As with the LV PLC systems, however, if they can eliminate the need for duplicating network infrastructure they could prove effective.

For HV PLC to be adopted, it will require systems to offer sufficient capacity, cost effectively overcome the line impedance issues for long HV lines and demonstrate effective traversing of transformation points.

As with LV PLC deployment, it will be more attractive for firms to meet the costs of connecting PLC systems to the backbone in more populous, profitable areas and market segments. The capacity of those networks is likely to oversupply initial customer requirements since the marginal costs of that capacity are relatively small compared with the initial set-up costs, and the potential for demand is enormous.

6.3 BROADBAND SERVICES

The potential uses of broadband have not yet been fully explored. Clearly we are aware today of the Internet applications that would benefit slightly from increased capacity. We can also appreciate the benefits for broadcasters and the use of teleconferencing facilities and how these might change the way we work and interact. However, there are a vast array of services that will evolve once the services are available to large sections of the community. A major benefit can be seen for educational and health care systems in remote areas. This has been shown by the project "Schools Online" supported by the German Government. Within the last 2 years about 400 schools mainly in regional Germany have been set up with PLC.

In terms of PLC deployment, broadband applications are a significant issue as service offerings are somewhat dependent on the scale and capacity of broadband availability and investments in access networks is somewhat dependent on the demand from service providers and customers.

Studies in Europe have projected that broadband charges will need to fall to around $25 US per month before large-scale customer take-up rates are experienced.[5]. This, however, is premised on the demand for existing services. As additional value is perceived by customers for new services such as home automation, security, video on demand, etc the value proposition will change and customers may be willing to pay more. This is particularly the case where their broadband connection offers a substitute for other services such as pay TV and telephony.

Significantly, the wide scale deployment of broadband access networks is likely to facilitate more rapid customer acceptance and take-up rates and also lead to the development of many new digitally based services.

[5] Datamonitor, March 2003, http://www.nua.ie/surveys/

6.4 OVERSEAS BROADBAND EXPERIENCES

Broadband and high speed Internet adoption rates overseas indicate that the potential market in Australia is enormous.

Overseas experiences with broadband usage are quite insightful and may provide an indication of potential developments here in Australia, in the absence of further technological developments.

In the US, an estimated 34% of Internet users have broadband connections using mainly DSL and cable links. In Canada the rate is close to 54%.[6]

In Europe there are around 10 million broadband subscribers, approximately 20% of online customers.

In terms of preferred broadband mediums, it is estimated that 62% of broadband modems sold in 2002 worldwide were DSL, up from 57% the previous year. This compares with 33% for cable modems and 5% for fibre, wireless, PLC and other.[7] In all there are some 36 million DSL subscribers around the world.

Figures released on 10 June 2003 by the US Federal Communications Commission (FCC) show an increase of 55% in "high-speed" Internet connections for 2002. They indicate that there are now 19.9 million lines to customers. Of these, 17.4 million are for residential and small business subscribers. "High speed" Internet refers to speeds of 128 Kbps or greater, however, "advanced service lines", offering speeds greater than 200Kbps in both directions, represent 13 million lines or 65%. Subscriptions to these lines have grown by 75% during 2002. Of the 19.9 million high-speed lines, 5.1 million were ADSL and 9.2 million were coaxial cable.[8]

These growth rates do provide an expectation that demand for broadband services in Australia is likely to be extremely high, particularly as the rollout of access networks continues.

The FCC announced an inquiry regarding broadband over powerlines (BPL) on April 23, 2003. The FCC is seeking information, comments and technical data on issues concerning broadband over powerlines. They are also seeking comments related to changes that may be needed to technical rules and the equipment approval process to foster the development of BPL and to ensure that interference is not caused to other services as a result of this technology[9]. That the FCC is also conducting a review of technical rules to enable more spectrum for wireless systems also demonstrates that the US Government is keen to facilitate broadband deployment.

6.5 COST

The success of any broadband solution will ultimately depend on implementation costs relative to the services provided. Whilst it is recognised that there are a vast

[6] comScore Media Metrix, April 2003, http://www.nua.ie/surveys/

[7] DSL Leads Global Connections, Robin Greenspan, March 2003; http://cyberatlas.internet.com/markets/broadband/article/

[8] US Federal Communications Commission Media Release, June 10, 2003 – High Speed Services for Internet Access

[9] US Federal Communications Commission Media Release, April 28, 2003 – Inquiry Regarding Carrier Current Systems, including Broadband over Power Line Systems.

array of services that could be offered through quality broadband solutions, it will be necessary to contain costs to levels acceptable to customers.

As has been discussed throughout this report, it is anticipated that the costs of extending backbone communications systems will represent the major proportion of the initial costs for providing broadband PLC to customers. However, these costs would generally need to be incurred regardless of the broadband medium chosen for connection to customers, ie wireless, fibre, cable, etc.

In terms of a PLC broadband deployment the majority of costs for any PLC solution arise at the interconnection point to the backbone network. These costs include the labour, PLC hardware and the backbone interface. In particular, the cost for the backbone connection can vary substantially depending on the type of backbone. Fibre cables running a SDH protocol probably provide the cheapest connection. Other connections like VDSL, SDSL and broadband ISDN would require a router or switch, where as a satellite connection would require a Broadlogic card or similar device to convert the satellite protocol to Ethernet.

There are many difficulties in providing pricing comparisons between vendor solutions, or even estimating broad setup costs. Backbone connection costs can vary substantially, vendor solutions will require significantly different arrangements and costs and setups will also vary depending on line characteristics for communications, ie repeaters, gateways, customer per PLC unit, etc. In addition, most installations to date have been priced on private contractual terms making it difficult to identify actual costs.

Base on the information that is publicly available, deployments in Europe indicate that DS2 based installations show average connection costs per end user range between $A800 and $A900. This includes the cost at the transformer (using a fibre backbone interface) and the PLC modem for the end user.

Although some suppliers of DS2 based solutions do offer home gateways, they are only required in very harsh environments with extremely high line noise interference. Home gateways with DS2 based solutions are optional and will normally not be needed, however, where they are required, this will generally add around $A1,000 to the connection cost per customer.

If an Ascom based solution is chosen the home gateway is mandatory. PLC hardware costs at the transformer and the costs of the customer's modem are slightly lower, however this is more than offset by the costs of the home gateway installed at the meter point.

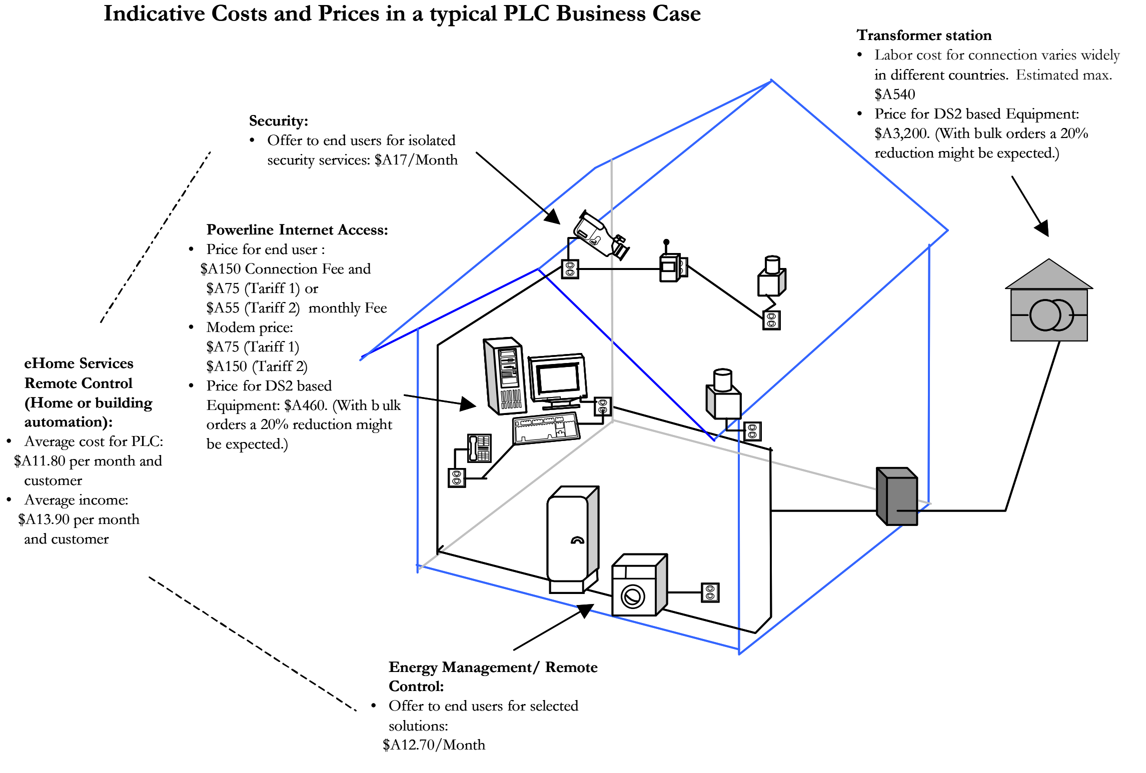
MainNet does not provide unit costs for their equipment. They provide costs for entire projects as these costs can vary depending on the local environment and specific pricing strategies. There is no experience of MainNet deployments in Australia, however, overseas installations indicate an average set up cost per end user of around $A700 – $A800.

In most cases utilities are looking only at the set up cost, which is a one-off investment. Recovery of these amounts may be achievable in relatively short time frames, (15 – 18 month) based on prices and takeup rates in Europe. Experiences overseas also indicate that the maintenance and repair costs of these installations are very low and not a material factor for PLC business cases.

A more crucial factor is the running cost for managing an IP based network, including customer care, billing and guaranteed quality of service. Dealing with high data volumes, large customer numbers, complex technical equipment, substantial data integrity and security issues, potentially complex billing arrangements and a wide range of service providers makes broadband access provision a challenging business to manage. Expenditures on systems to manage these issues is likely to be a substantial cost imposition, even for utilities and communications companies already dealing with some of these challenges. In addition, as with other providers who do not provide their own backbones, the ongoing usage charges of backbone carriers will need to be met. Again, this will depend on the nature of the backbone solutions utilised.

Diagram 6 shows some indicative costing for various PLC components, as well as some rudimentary insight into pricing. The values have been derived from trials in South America, which appear to offer some similarities to the Australian environment. The costs are based on a DS2 solution not requiring a gateway at the customer's premise.

Indicative Costs and Prices in a typical PLC Business Case



The above costing information and discussion is provided for reference only. Clearly it will be necessary for specific testing of lines and systems to occur before optimal business solutions can be formulated. Comprehensive commercial evaluations would be required and would need to include aspects such as:

- Proximity of backbone services;
- Mediums for connecting to backbones (fibre, PLC, satellite, etc);
- Capacity requirements;
- Vendor PLC architectures;

- Content;
- Safety;
- Maintenance;
- Longevity of the technology;
- Consumer research;
- Data, asset and customer management systems; and
- Regulatory requirements.

7. OTHER IMPEDIMENTS FOR PLC DEPLOYMENT

The development and implementation of PLC for Australia faces many challenges in addition to the technical issues discussed in the previous sections. In particular, it is considered that the regulation and structure of the electricity industry and the key role played by electricity distributors in the deployment of PLC, introduces fundamental issues that will need to be addressed for substantial progress to be made and for these developments to occur within the available window before commitments to alternative technologies by telecommunications companies erode profitable markets.

7.1 ELECTRICITY INDUSTRY REGULATION

Regulations for Australian electricity distribution businesses may be crucial for the development and implementation of PLC systems.

In general, the regulation of Australian electricity distribution businesses is based on monitoring performance against technical licence conditions and providing allowable prices or revenues that provide cost recovery and appropriate rates of return. This enables a rudimentary balancing of minimum service delivery and price, and also provides distributors with some assurance of returns on future capital investments.

However, the returns are generally maintained at levels commensurate with very low risk industries and therefore distributors are not provided with incentives to either enhance service potential of their networks or undertake more entrepreneurial research endeavours. Further, any additional revenues derived by distributors from the use of their assets for such purposes as telecommunications, pay TV cabling, joint trenching or shared conduits may be viewed by regulators as a reduction in revenue requirements from electricity consumers.

This provides a climate where distribution businesses may not receive adequate commercial incentives to fully explore alternative uses of their assets. Similarly, any additional complexity imposed on their networks through the inclusion of non-electricity assets, creates additional risks for asset management, maintenance and for system control and these may not be compensated through the regulatory process. This can engender behaviours from distributors to be risk averse, which may impede firstly their interest in undertaking research of PLC technologies, and secondly their enthusiasm to cooperate with telecommunications and PLC companies seeking access to their distribution networks.

To foster an appropriate climate where distributors are encouraged to explore opportunities to leverage off their considerable networks, regulators need to ensure that adequate commercial incentives are offered and that arrangements to provide access to PLC and other users, enable compensation for the additional complexity and risks that ensue.

The Australian Competition and Consumer Commission (ACCC) has competition regulatory responsibilities in both electricity distribution and telecommunications. Its functions include:

- assessing applications from participants in the electricity industry for authorisation of potentially anti-competitive conduct under Part VII of the Trade Practices Act 1974, including, where relevant, changes to the National Electricity Code;

- assessing applications from participants in the electricity industry for acceptance of changes to the National Electricity Market Access Code;
- assessing access undertakings submitted to the ACCC by individual network service providers and approving changes to those undertakings as submitted from time to time; and
- the regulated rate of return.

Trade Practices Act also has specific sections relating to the telecommunications industry, which are the responsibility of the ACCC. In particular, parts XIB and XIC of the Trade Practices Act cover prohibitions on anti-competitive conduct and the telecommunications access regime.

The ACCC can mandate access to a carriage service by 'declaring' that service under Part XIC of the Trade Practices Act. Once a service is declared, providers of the access service must comply with the standard access obligations detailed in section 152AR in the Trade Practices Act. However, there are provisions under the Act for infrastructure owners to seek an exemption from a service declaration even prior to the investment being undertaken.

7.2 INDUSTRY STRUCTURE

Alliances and cooperation between vendors, access networks and service providers will be necessary for an effective PLC implementation program.

Another challenge in promoting PLC development and implementation is the industry structure and regulatory arrangements. PLC relies on the cooperation of access providers (electricity distributors, backbone operators), content providers (broadcasters, ISP's, etc) and equipment manufacturers (PLC vendors, appliance manufacturers, etc). Each of these parties must make a speculative projection of market opportunities before investing in necessary research and product development. What we have seen overseas is that the home market has developed reasonably quickly on the back of available broadband access systems; mainly in more densely populated metropolitan areas. For PLC we have seen the formation of alliance groups such as "HomePlug" who have sought to cooperate to develop standards for the technology and a platform on which all companies can compete effectively, to the benefit of customers.

In Australia, such alliances could be invaluable in assisting various market participants to address the range of conflicting issues and establishing guidelines or a framework that facilitates PLC development and implementation.

The structure of the electricity supply industry in Australia also means that each electricity distributor is likely to play a major role in managing PLC implementations on their networks. The potential obviously exists, therefore, for different approaches to be adopted and a lack of compatibility between systems to emerge. For the general benefit of efficiency in product development and service delivery, it is clearly important that PLC signals are compatible between distributors and it would be advantageous if standards and guidelines were in place to ensure consistency of applications.

The industry structure for electricity has undergone changes over the last decade to separate the access network from the retail (or content) supply. This should facilitate the implementation of PLC systems, as there is potentially no competition bias towards particular content or service providers. However, it may create some uncertainty on the part of other players in forming agreements with electricity distributors to obtain access to the distribution network, as asset ownership, maintenance and other commercial issues may prove difficult to negotiate.

7.3 OTHER REGULATIONS AFFECTING PLC

Overseas experiences have shown the importance of formulating regulations for PLC at the early stages of development and implementation to ensure consistence, compatibility and cost efficiency in the provision of services.

Experiences overseas have also shown that regulation can impede the implementation or operation of PLC systems. This was experienced in the UK when the NorWeb system was seen to emit interference and resulted in reactive regulations. At the time NorWeb was a joint venture between United Electric of the UK and the Canadian telecommunication equipment manufacturer Nortel. The NorWeb system was a very early outdoor PLC solution not comparable with today's systems. A first trial using this system in a street in Birmingham, UK caused substantial interferences for an air traffic control system due the fact that the street lights were connected to the PLC circuit and the metal poles and fixtures matched the exact frequency. The streetlights became perfect antennas for radiating the PLC signal.

Whilst these issues have largely been addressed overseas, it is important that industry guidelines or possibly regulations be developed early in conjunction with market participants so that development and implementation can be fostered effectively. Reactive regulations, particularly where they become product specific as was the case in the UK and partially in Germany, should be assiduously avoided. After some European countries, in particular the UK, had implemented extreme Electromagnetic Compatibility (EMC) regulations for PLC systems, the European Union intervened and released a new general regulation that does not discriminate between communication carriers. Although the US FCC regulations are more liberal in this respect, all current PLC systems on the market do meet the new European standard.

Regulations that impede the entry of electricity distributors into the communications access market should be reviewed to ensure that they are appropriate. In particular, the criteria for "life line" and "low impact facility" need to be considered from the perspective of PLC deployment.

An additional issue that may impact the implementation of PLC solutions (or at least the speed of deployment) relates to the "life line" requirements for a standard telephone service (STS). Whilst PLC offers the provision of broadband services, it also offers an alternative method for delivering fixed line standard telephony services. Such a service could significantly improve the financial viability of PLC deployments. However, electricity distributors have commented that regulations in Australia require the provider of a STS to be able to maintain those services in the event that electricity supply is lost. Since PLC utilises the same line as the electricity supply there would be additional investments necessary to comply with these requirements. For PLC systems to compete directly for the provision of STS, their equipment would need to incorporate backup systems in the event of power supply interruptions such as battery backup systems, mobile phone connections and reconfiguration of PLC connections.

An additional regulatory issue is how property rights and State, Territory and local government planning and environment laws might impact on the deployment of PLC equipment. Except as provided for under Schedule 3 of Australia's *Telecommunications Act 1997*, the installation and maintenance of telecommunications facilities are generally subject to property and State, Territory and local planning and environment laws. Schedule 3 provides some exemptions from these, for example, by simplifying procedures for "low impact" facilities.[10]

Whether or not PLC equipment would be "low impact" needs to be fully considered. An initial assessment is that PLC devices installed at the customer premises and LV transformers would be considered "low impact". However, satellite dishes and additional cabling required for backbone connections may not be "low impact" and this may impede the establishment of end-to-end broadband connections in some areas.

It should be appreciated that a foray into telecommunications for most electricity distribution businesses would be a considerable adventure with considerably different regulations, an environment of more rapid technological development and exposure to volatile and dynamic consumer markets. The challenges for this integration should not be underestimated.

[10] Telecommunications (Low-impact Facilities) Determination 1997

8. PLC VERSUS OTHER BROADBAND SOLUTIONS

The Charts 1 and 2 below illustrate the various broadband technologies and related services. It would be misleading to offer general statements of advantages and disadvantages for these technologies as each has its place in the market. Only if a technology is used in a way that is not appropriate do major issues arise. For example, a standard 56 Kbps dial-up Internet connection offers sufficient capacity for many simple Internet services, however it cannot provide video conferencing or more data intensive applications such as interactive video or video on demand.

For this reason the comparisons offered in this section are based on simple technical relativities.

The goal of broadband communications networks is to offer a reliable connection, effective data transfer for the applications required and competitive access prices.

Generally speaking, optimal broadband services are likely to result from a combination of technologies that address environmental and commercial considerations

The charts below show that PLC systems generally offer comparable or higher data transfer speeds. However, the PLC systems currently available operate 45 Mbps from the LV transformer. This means, that since PLC acts as a shared media, the average data rate per end user will be lower than the total capacity depending on coincident utilization (i.e. the number of users on the system at the same time and the applications they are using). In reality there could be up to 120 customers being serviced by the one transformer. If take-up rates were high and the applications data intensive, additional PLC capacity may be required.

PLC also offers "symmetrical" transmission, which means that the 45 Mbps capacity is available in both directions, i.e. transmitting up the network as well as for downloading information. ADSL, cable and some satellite systems have "asymmetrical" capacity, which means that less capacity is available to transmit data upstream than downstream. Consequently, the upstream capacity of these technologies is less than the figures show. Generally speaking, however, this will still meet the requirements of most users.

In terms of area coverage, there are significant differences and this is an aspect where PLC should be able to establish a considerable advantage. Optical fibre is generally available in metropolitan areas and some major regional centres. ADSL is available in metropolitan and some regional centres (covering around 75% of premises) but only for customers close enough to the local exchange (around 3.5 kms). Cable networks are also only available in some metropolitan areas. PLC, however, is potentially available to all electricity grid connected customers. The challenge for PLC solutions is the cost of building connections back to the telecommunications backbone network.

As discussed earlier in this report, cost comparisons have not been provided, as there are still too many variables for a legitimate assessment within the context of this review.

Chart 1

Alternative Access Networks

Analog connection is still the standard access in the mass market. (<85% of all residential households)

Almost all residential households and businesses have copper and electricity connection

Wireless local loop is being trialed in different locations.

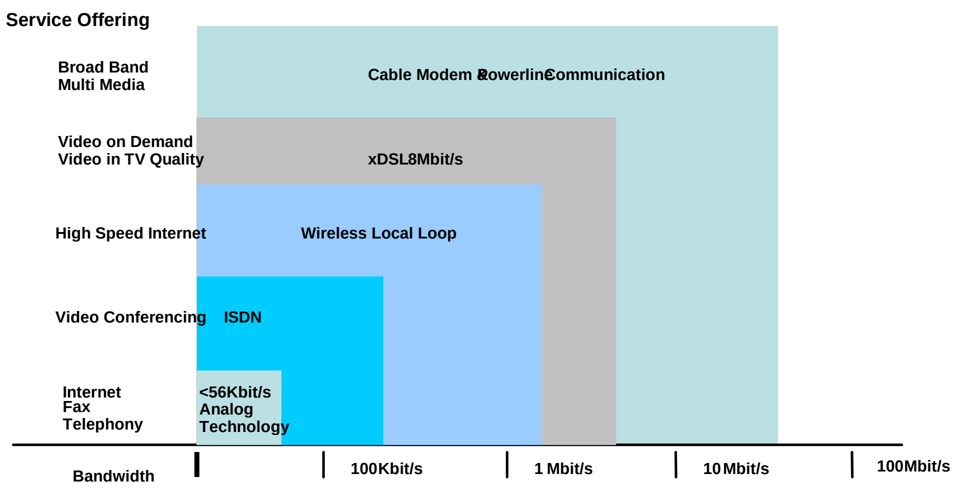
	Max. Bandwidth	Symmetry	Switching	Area Coverage
Copper ISDN	0.128Mbit/s	S	L/P	Low
Copper ADSL	6Mbit/s	A	L/P	Medium
Coaxial Cable/ Cable TV	>10Mbit/s	A	L/P	Medium
Electricity Networks	>20Mbit/s	S	P	High
OpticalFibre	>20Mbit/s	S	L/P	Low
Wireless LocalLoop	2Mbit/s	S	L/P	Medium
Satellites Geostationary	>4Mbit/s	A	L/P	High

S= Symmetric
A= Asymmetric

L= Circuit Switched
P= Packet Switched

Chart 2

Bandwidth Comparison of the various Technologies



9. ISSUES FOR FURTHER CONSIDERATION

A number of important issues arise from this review of PLC technologies that appear to warrant further consideration by both Government and industry so that PLC development and implementation is not artificially inhibited. These issues are:

- Industry guidelines and standards for the development of a PLC platform, which specifically addresses Australia's requirements.
- Representation on the International PLC Forum to ensure awareness of PLC developments and to represent Australia's interests.
- Monitoring of PLC developments and implementations. This might involve representatives from State Governments, electricity distributors and independent technical experts. This might feed into the formulation and implementation of the above mentioned guidelines and standards.
- Ensuring that regulation applying to electricity businesses does not inappropriately inhibit electricity utilities investment in telecommunications and any uncertainties in this regard are addressed.
- Independent testing of PLC equipment.
- Other potential regulatory barriers to the commercial deployment of PC, including performance requirements for the standard telephone service and the application of State, Territory and local government planning and environment laws.

10. REFERENCES

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APPENDIX A
Vendor Comparison Spreadsheet

Manufacturer	Product-name	Chip Set	Modulation Method	Product-status	Datarate	Fequency-Band	NMS	CE / FCC Certified	HV-PLC	LV-PLC	Applications
Landis & Gyr	Amdes	Proprietary	FSK	Available	300 Bit/s	20 - 149kHz	No	Yes	No	Yes	Simple utility applications e.g. AMR and ripple control
ABB	Dartnet DLC-M	Proprietary	GFSK	Available	LV: 2,4 Kbit/s HV: 72 Kbit/s	20-149kHz	Yes	Yes	Yes	Yes	Simple utility applications e.g. AMR and ripple control Has been tested in variuos installations
Görlitz	Enercom	Proprietary	FSK	Available	1,2 Kbit/s	20-149kHz	No	Yes	Yes/No Limited	Yes	Simple utility applications e.g. AMR and ripple control HV only on VPE Cables with inductive coupling only
Enermet	LON	LON Works	GFSK	Available	2,4 Kbit/s	20-149kHz	Yes	Yes	No	Yes	Simple utility applications e.g. AMR and ripple control
Siemens	DCS3000	Proprietary	GFSK	Available	28,8 Kbit/s	20-149kHz	No	Yes	Yes	No	Simple utility applications e.g. AMR and ripple control Has been tested
Pfisterer	PAC-Net	Proprietary	FSK	Available	4,8 Kbit/s	20-149-kHz	No	Yes	Yes/No Limited	No	Simple utility applications e.g. AMR and ripple control HV only on VPE Cables with inductive coupling only
Power - Tec	Power-Tec	Proprietary	FSK	Available	1,2 Kbit/s	20-149kHz	No	Yes	No	Yes	Simple utility applications e.g. AMR and ripple control
Arigo	Arigo	Proprietary	FSK	Available	4,8 Kbit/s	20-149kHz	No	Yes	No	Yes	Home Automation, Telemetric Applications Former IBM Product
Ascom	Ascom	Proprietary	GSMK	Available	2 Mbit/s	1 - 30 MHz	No	Yes	No	Yes	Broadband Internet and Telephony
Main.Net	Plus	Itran	FSK	Available	2 Mbit/s	2-30MHz	Yes Proprietary	Yes	No	Yes	Currently in trial with MVV potential partner for Australia
Xeline	XPAS-100	Proprietary	OFDM (deriv.)	Available	8 Mbit/s	2-28 MHz	Yes Proprietary	No	No	Yes	Broadband Internet and Telephony
Easyplug	Easyplug	DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes SNMP	No	No	Yes	Internet, VoIP, Video Streaming
Ilevo	Ilevo	DS2	OFDM	Available	45 Mbps	1 - 30 MHz	Yes SNMP	Yes	Yes	Yes	Internet, VoIP, Video Streaming
Toyocom		DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes SNMP	Yes	No	Yes	Internet, VoIP, Video Streaming
Ambient Corp.		DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes SNMP	No	Yes	Yes	Internet, VoIP, Video Streaming
Mitsubishi		DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes SNMP	Yes	Yes	Yes	Internet, VoIP, Video Streaming
Sumitomo		DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes SNMP	Yes	No	Yes	Internet, VoIP, Video Streaming
PowerNetze		DS2	OFDM	Available	45 Mbps	1 - 30 MHz	Yes SNMP	Yes	Yes	Yes	Internet, VoIP, Video Streaming
Tecnocom		DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes SNMP	No	Yes	Yes	Internet, VoIP, Video Streaming
Amperion		DS2	OFDM	Prototype	45 Mbps	1 - 30MHz	Yes SNMP	No	No	Yes	Internet, VoIP, Video Streaming
Defidev		DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes SNMP	No	No	Yes	Internet, VoIP, Video Streaming
EBA PLC Corp.		DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes	No	Yes	Yes	Internet, VoIP, Video Streaming
Inovatec		DS2	OFDM	Prototype	45 Mbps	1 - 30 MHz	Yes	No	No	Yes	Internet, VoIP, Video Streaming
Inari	Iplan	Proprietary	OFDM	Available	4 Mbps	4 - 10 MHz	No	Yes	No	Yes	Home Networking, Telephony, Audio, Video
Itran	ITM1	Itran	FSK	Available	2,5Mbps	2-24MHz	No	Yes	No	Yes	Home Networking
PowerTec AG	PowerLan16	Intellon	OFDM	Available	14 Mbps	11 - 28 MHz	No	Yes	No	Yes	Home Networking, Telephony, Security
Corinex	Corinex	Intellon	OFDM	Available	14Mbps	11 - 28 MHz	No	Yes	No	Yes	Home Networking, Telephony
ST&T		Intellon	OFDM	Available	14Mbps	11 - 28 MHz	No	No	No	Yes	Home Networking, Telephony
NetGear	Corinex	Intellon	OFDM	Available	14Mbps	11 - 28 MHz	No	Yes	No	Yes	Home Networking, Telephony
Siemens	SpeedStream	Intellon	OFDM	Available	14Mbps	11 - 28 MHz	No	Yes	No	Yes	Home Networking, Telephony

Legend	Narrow Band Scada Systems			
			AMR	Automated Meter Reading
	Broad Band Access Solutions		VoIP	Voice over Internet Protocol
			NMS	Network Management System
	Indoor Home Networking Solutions		SNMP	Simultaneous Network Management Procedure

APPENDIX B
Letter to Electricity Distribution Authorities and Summary of Responses

List of Electricity Distributors

EnergyAustralia
Powercor
Integral Energy
Country Energy
Australian Inland Energy and Water
United Energy
CitiPower
ETSA Utilities
ACTEW AGL
AGL
Aurora
TXU
Northern Territory Power and Water Authority
Western Power Corporation
Energex
Ergon Energy

Dear

The Federal Government Department of Communications, Information Technology and the Arts (DOCITA) has enlisted the services of Parsons Brinckerhoff Associates to undertake a review of Power Line Communications (PLC) technologies and their potential applications within Australia.

PLC broadband is an emerging technology that is enabling electricity distribution networks to carry high-speed communication signals. These systems are being deployed in various countries around the world and may provide cost effective solutions to high-speed communications for many Australians.

As part of this review, it is necessary to gain an understanding of any experiences electricity distribution companies may have developed with the various PLC technologies and the challenges they face in applying these technologies across their own systems. The DOCITA is keen to develop insights into any technical and regulatory barriers that may exist and potentially deter or impede PLC implementation and development.

In line with these objectives, we are seeking any information you may have that could assist the DOCITA in gaining a better understanding of the applicability of PLC technologies on Australia's distribution networks. We are aware that many electricity distributors have undertaken research into PLC broadband systems and we would welcome any information you could share with us that could help in this review. Your assistance could be valuable in the facilitation of PLC development and regulation within Australia. Clearly it is the interests of all customers that cost effective solutions to broadband communications are fostered, and PLC may provide part of that solution.

It is recognised that this information may be commercially sensitive in some cases. Confidentiality of such information can be maintained where this is the case. It is anticipated that the Government will make the report publicly available.

If you would like to discuss this request further, or are able to provide information regarding your experiences with PLC, please contact Mr Paul Topfer using the details listed below by 28 May 2003. Your contributions would be greatly appreciated and we believe the outcome of this review will be of enormous benefit to all Australians.

Yours Sincerely,

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Summary of Replies from Electricity Distribution Businesses

Seven distributors provided responses and a summary of their key comments is provided below. We were also contacted by UtiliTel on behalf of a number of distributors who are working together to deliver national broadband services.

- Four respondents have conducted various levels of testing and trials within Australia.
- No responses indicate an intention to implement commercial deployments at this time.
- Of those who have trialed PLC systems all have indicated optimism for potential deployment.
- One distributor found that DS2 equipment performance when tested was similar to that experienced in Europe.
- One distributor found that signal distances on underground cables ranged from 100 – 300 meters. On overhead lines the reach was between 0 and 80 meters. Future PLC commercialisation would be dependent on substantial performance improvements over these results. Signal distances of over 500 meters would be required on low voltage lines. Preference is for PLC systems that effectively operate on the high voltage network.

– It is necessary to combine voice and data services in order for any new customer access network (CAN) to be commercially viable. PLC is likely to be capable of delivering the quality of service necessary for both.

– The Government's telecommunications objective of encouraging facilities based CAN competition has had limited success to date. PLC used in conjunction with other technologies is likely to be a valid alternative in some geographic locations.

– PLC use of overhead electricity lines is not defined as "Low Impact Facility" and, therefore, PLC cannot be deployed under Schedule 3 of the *Telecommunications Act 1997*. Also, new easements and planning approvals could be required for PLC.

– Australia should adopt European Standards for emissions regulation.

– Regulatory changes might be warranted to allow PLC voice services not to have to meet the "life line" requirements to be available when a consumer is without power.

– PLC is well suited to provide network management systems for demand management, system automation, reliability and quality of supply feedback and automated meter reading.

– Meter reading facilities that can fulfil the requirements of the National Electricity Market (NEM) are a potentially valuable opportunity for PLC. For this to be realised, the metering requirements of the NEM will need to be formulated appropriately. Proposed implementations of interval metering should also be considered in the context of potential PLC applications. Deployment of interval meters for NEM requirements would be an expensive and lengthy program. PLC could provide a more effective solution.

– The climate for new telecommunications investments is uncertain and the window for deployment of PLC as a competing broadband technology may be closing rapidly.

– PLC offers the Government the opportunity to meet its obligations to deploy broadband services on an equitable basis.

– Technical standardisation of outdoor PLC is likely to occur in 2004 when vendors have redeveloped their products incorporating the "Wisconsin" DS2 chipset.

– PLC is well suited to staged geographic deployments (cherry picking), which offer smaller investment outlays and shorter cost recovery periods.

– It is hoped that the various commercial and regulatory barriers do not prevent Australia from benefiting from the valuable opportunities offered by PLC.

– The Government should view PLC research and development favourably in terms of future funding and tax concessions for maximum national benefit.

– All responses expressed considerable interest in the DOCITA review.

– UtiliTel advised that, "all leading Australian electricity suppliers are working together re plans to deliver national broadband services."

In summary, involvement from Australian electricity distributors in PLC has been limited to a small number of basic tests and trials undertaken by only a few organisations. Indications are that, although there is obvious enthusiasm for the benefits that PLC could offer these businesses, there are many uncertainties over the practical deliverables of existing PLC systems and reluctance to invest significantly where the technical and regulatory risks appear to be high. The involvement and coordination required of the various parties (electricity distributors, telecommunication companies, content providers and vendors) would appear to indicate that the progress of PLC deployment in Australia is likely to be slow in the immediate future.

APPENDIX C

Power Line Telecommunications (PLT);
Reference Network Architecture Model;
PLT Phase 1

APPENDIX D

Power Line Telecommunications (PLT);
Coexistence of Access and In-House Powerline Systems