Whatever Happened to ISDN?

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Abstract: In the 90th year of publication of this, our local journal, it is fitting to look back at some technologies or services that were once popular topics but whose time has now passed. This paper looks at the history of the Integrated Services Digital Network (ISDN) as it is reflected in the pages of the *Telecommunication Journal of Australia* (*TJA*). ISDN was popular in the 1980s: in the period 1984–1990, no less than 15 papers were published in the *TJA*, about 6% of the papers in those years. ISDN quickly disappeared from publications with the rise of the Internet and ADSL in the 1990s. The accompanying historical reprint from 1986 describes the transmission issues associated with providing ISDN customer access and presents some of the design decisions made by Telecom Australia.

Keywords: ISDN, *Telecommunication Journal of Australia*, History of Australian Telecommunications

Introduction

For those who remember ISDN, the Integrated Services Digital Network, it may come as a surprise to learn that Telstra finally shut down ISDN in Australia only in 2022 (“ISDN services exit date”, 2022). ISDN had long since faded from general discourse but, even at the beginning of 2022, there were still a few active ISDN services, delivered through the National Broadband Network (NBN).

ISDN was a popular topic in the pages of the *Telecommunication Journal of Australia* (*TJA*), with no fewer than 15 articles appearing between 1984 and 1990, including a short tail of articles on “Broadband ISDN” (B-ISDN). It was to be the technology that would finally bring all-digital services to telephone subscribers – and it did for some. But then it disappeared. This short paper sets out to answer the question: Whatever happened to ISDN?

ISDN: The Origin Story

During the 1960s and 1970s, with the introduction of T1 digital transmission in the US (and, later, E1 in Europe and Australia), long-distance transmission became increasingly digitised.

https://doi.org/10.18080/jtde.v13n2.1279

This technology established the concept of the 64 kbps voice channel. Digital circuit switching of these channels followed in the late 1970s. The most expensive part of the public telephony network, the customer access network between the local exchange and the customer premises, remained analogue (Kidd & Darling, 1985), with the analogue voice signals being carried on copper twisted-pair loops. (For this reason, the customer access network is sometimes called the "loop network".)

At the same time, digital computing was spreading among businesses; and computer terminals that could be at some distance from the main computer were developed. In the 1970s, new "microcomputers" started to appear for enthusiast exploration, with some business and educational uses and some early games. These small computers could also be used as terminals to large, centralised computers, if a connection could be made. For connections outside the office, dial-up modems and acoustic couplers were developed that exploited the voice channels for carrying data.

These developments caused the telecommunications industry to consider the possibility of digitising the customer access network, to provide end-to-end digital connections. A large survey by Bell Labs of the transmission capabilities of loops on Staten Island, New York, concluded that the majority of accesses could handle two-way digital transmissions up to 160 kbps. Thus, the idea of a digital customer access network at 160 kbps or less was born (Cioffi, 2011).

ISDN Access

The underlying concept

By the 1980s, the expansion of customer requirements had produced a proliferation of service-specific telecommunications networks. Telecom Australia (which became part of Telstra in 1993), for example, had deployed a nationwide circuit-switched telephone network, a packet-switched data network, and several special services networks. It was thought that, through full digitisation, an Integrated Digital Network (IDN) could provide all these services.

For seamless end-to-end service, however, the copper customer access network would also need to be digitised. The challenge to provide international standards for this change was taken up by the CCITT (now the ITU-T) in its 1981–1984 study period. The concept of "ISDN" thereafter became largely synonymous with the CCITT access standards.

After the successful completion of the CCITT standards, there was a flurry of papers in the *TJA* to explain the idea of an integrated, end-to-end network and how the ISDN would deliver a variety of services through a common, digitised access and a set of defined interfaces at the customers' premises. The list of papers included Duc (1984), Duc & Chew (1984) and Kidd &

Darling (1985). The standards also kicked off new research projects, such as an experimental ISDN exchange (English & Bryan, 1987).

ISDN Basic Rate Access

The ISDN access had to provide digital channels and a mechanism by which a customer terminal could signal to the network what services it required. Thus, the standards provided for "B" (bearer) channels, based on 64 kbps voice channels, and "D" channels to be used for signalling (and perhaps some low-rate data services). Two main access streams were defined: a Basic Rate Access (BRA) with two B channels and one 16 kbps D channel; and a Primary Rate Access (PRA) with 30 (or 23) B channels and two (or one) 64 kbps D channels. The BRA at 144 kbps (2*64+16) fitted within the 160 kbps for copper single-pair, two-way access. The PRA was based on core E1 (giving 30 B channels) or T1 (23 B channels) transmission. These ISDN streams used the same standard interfaces at the customer end.

The PRA was mostly a formalisation of already existing arrangements where large businesses had direct access to core networks, but the BRA was entirely novel. For the first time, small businesses and households would have access to a digital service and could connect voice and data services at the same time. The 64 kbps data rate (or, potentially, 128 kbps) was a major step change from the typical 4.8 kbps achieved on analogue voice access at the time.

At the customer premises, if BRA was to become widespread, a cheap terminal adapter would be needed to connect existing analogue phones and other equipment to the ISDN interface. As Riley *et al.* (1986) remarked:

> "... economic Basic Rate Access service can only be offered if the equipment required to carry out the complex line transmission functions can be developed and implemented relatively cheaply. This is by no means a trivial task" (Riley *et al.*, 1986, p. 29).

Nevertheless, there was much published enthusiasm for the features that the new signalling regime would mean for households and businesses. A long "tutorial" on ISDN customer call control was published in two parts (Mikelaitis, 1988a; 1988b). Chin & Dingle (1984) described the end-to-end signalling arrangements, how call control worked, and some of the new services available. (One service to be standardised was "calling party identity", so that a customer could know who was calling before answering a call.) The signalling standards were designed to be extensible as new requirements were identified. This could be contentious: some of the planned extensions were described as "a disturbing trend" in Mikelaitis (1988b), p. 83.

https://doi.org/10.18080/jtde.v13n2.1279

While the initial focus was on "call control" – extending the features of telephony – there was also work on providing new services over the ISDN, such as electronic funds transfer or alarm notifications (Katz, 1990).

For the domestic customer, ISDN provided clear advantages. The voice quality was much improved – anyone who heard an ISDN voice call noticed how much better the voice reproduction was. There was the availability of a second line, enabling teenage children to talk to their friends while the parents could still be contacted. It would be possible to interact with a business's central computer without tying up the telephone line – and at a speed hitherto unachievable. There were many voice extensions, like calling line identity (knowing who is calling before answering a call) (Duc, 1986; 1990).

There were clear advantages for the telecommunications provider too. It would make the provision of many new services much easier than previously. It would avoid possible network expansion due to demand for second lines. (Loop networks were typically deployed with 1.5 pairs per living unit; if more than 50% of customers wanted a second line, then further cables would need to be pulled through ducts to premises.) It would open up a world of new data services from which additional revenue could be obtained.

Pricing was always going to be an issue. This did not make it into print. However, many customers would not want a second line so, if ISDN were to be ubiquitous, it could not be charged as two telephony lines. Would a customer be willing to pay extra for calling line identity? In the regime of call-by-call charging and untimed local calls, there were also problems. If a user and their central computer were in the same local call area, it would be possible to set up a line to the computer and leave it always on: this could prove uneconomic for the provider. ISDN BRA would always be special in some way, differentiated from plain old telephone service.

In the paper reprinted here, it is notable that the first deployments of ISDN by Telecom Australia would be of PRA in central business districts (Riley *et al.*, 1986, pp. 27 & 33). This was for a known market: businesses that already had a PABX or had complex needs for voice and data services. The plan was to provide BRA "over existing cables without intermediate electronics to 99 per cent of customers in urban networks" (Riley *et al.*, 1986, p. 32), but this would come later.

The Outcome

Although there had been some early scepticism that ISDN was not directed at real customer needs (Gale, 1986), in print, at least, it was agreed that the new standards would prove beneficial. A number of issues eventually led to waning interest in ISDN.

https://doi.org/10.18080/jtde.v13n2.1279

The customers

For the large business market, the use of ISDN PRA in the public network depended mainly on the development of suitable PABXs or other complex user terminals. ISDN standards did prove useful for a while in customer premises networks, but the network side mostly developed differently, with the rise of the Internet. Multi-site businesses did make use of ISDN BRA "almost entirely for intra-corporate communications (eg, semi-permanent connections and LAN/WAN connectivity)" (McDonald & Leong, 2001, p. 43).

In the small business and residential market, ISDN BRA take-up was slow. According to a report commissioned by the ACCC, there were only 128,500 active ISDN BRA connections (within about 10 million access lines) in 1999 (McDonald & Leong, 2001, Exhibit 3-6, p. 44), a decade after launch. It turned out that most customers were not willing to pay for improved voice quality. Indeed, later experience showed that many customers were willing to sacrifice some voice quality for other desirable attributes, like mobility. Customers were also unwilling to pay much, if anything, for additional services, like calling line identity. McDonald and Leong (2001) remarked that residential and small businesses "today effectively have no real application for ISDN" (p. 43).

In addition, a fundamental problem turned out to be speed. With the growth of data services and the introduction of PCs, it became clear that 64 kbps was not enough. In the days before always-on connections, much distributed computing was conducted by passing around "files": a PC could retrieve a file from a main computer, work on it, then pass it back. As files grew, the time for file transfer up and down became an issue: for example, a 10 MB file of images would take at least 20 minutes – and probably 40 minutes with error-correction overheads – to download. It was clear that a future built around 64 kbps voice channels was not going to go far.

The telecommunications providers

As the data service demands increased and became more complex, the telcos realised that they needed more efficient networking. Initially, there was not much they could do for access networks, but they could re-engineer their core networks.

There was a new thread of publications around technologies for core networks, many of them under the rubric of "Broadband ISDN" (B-ISDN). Tirtaatmadja & Scott (1990) considered combining various packet-switching and transmission technologies. Littlewood (1989) described the use of an Australian-developed data protocol. Day *et al.* (1989) proposed fast packet switching.

The paper by Day & Dorman (1990) emphasised B-ISDN and noted its evolution from ISDN:

https://doi.org/10.18080/jtde.v13n2.1279

> The drive for Broadband (B-ISDN) standardisation follows essentially the same philosophy as that of the Narrowband ISDN (N-ISDN) — to provide a public network base which can support a range of integrated services. through a unique customer interface and with common customer control and management (Day & Dorman, 1990, p. 4).

They had a warning for the future, however:

> The environment in which B-ISDN is being developed is considerably more uncertain than that in which N-ISDN was developed — uncertainty both in future technology capabilities and in future market demands for broadband services (Day & Dorman, 1990, p. 4).

This was truer than perhaps they realised at the time.

Cable Television

In the US, the old Bell System (the main telecommunications provider and network equipment manufacturer) was broken up at the beginning of 1984 and the newly "liberated" local Bell Operating Companies began eyeing an expansion into cable television (partly in response to the Cable TV companies moving into telephony). They had extensive copper access networks and they wanted to use them to provide television services at, at least, 1.5 Mbps towards the customer. This was well beyond the capabilities of ISDN Basic Rate Access.

Finally, a requirement — video delivery — had been identified that would push copper access to new levels. This would open up new possibilities for the Bell Operating Companies and telecommunications providers worldwide, while also delivering new services and features to end users.

There were attempts to integrate digital video into B-ISDN (Scott *et al.*, 1990). While this was useful in core networks, the ISDN BRA was soon overwhelmed by the need for greater bandwidths.

The Rise of DSL

ISDN BRA was the first standardised Digital Subscriber Line (DSL). It used echo cancellation and a particular transmission line code to achieve its data stream of 144 kbps. Speeds of 800 kbps or more could be achieved with this system for lines up to 3 km long (Cioffi, 2011; Lechleider, 1989).

For higher data speeds, the main effect limiting two-way transmission is near-end crosstalk – that is, where transmissions from the near end drown out the attenuated signals received from the far end. This can be handled at the exchange end, but is expensive to overcome at the customer end (where the cost is not shared).

One way to ameliorate near-end cross talk at the customer end is to use asymmetric transmission – a higher data rate towards the customer and a lower rate towards the network. According to Cioffi (2011), even in 1980 it was realised that asymmetric transmission on a copper loop may achieve higher speeds, but this was only pursued later in the decade, most notably by Joe Lechleider at Bellcore (Lechleider, 1990; 1991). Thus, asymmetric DSL (ADSL) was born.

With ADSL, the copper access was finally unbound from the concept of the 64 kbps voice channel. Instead, it became a "bridge to the network of the future" (Walkoe & Starr, 1991). It provided a pathway to deliver video services on existing access networks.

From the 1990s, browsing the World Wide Web and video delivery – both asymmetric services – came to dominate the traffic on telecommunications networks. In response, network providers pursued network simplification, with end-to-end packet networks using Internet protocols being the basis for all service delivery. The ISDN was swept away by a much simpler concept, the end-to-end Internet.

Concluding Remarks

This paper has resketched the story of the rise and fall of the ISDN concept. It was the last hurrah of networks and services built around the idea of a "voice channel". It was finally swept away when it became possible to provide economical and widespread high-speed access networks. The Internet came to replace (almost) all public networks.

The paper reprinted here (Riley *et al.*, 1986) describes some of the complexities of providing digital data transmission over copper and exhibits the caution of engineers trying to adapt a network built for voice service to a new set of requirements.

But change is still happening, as Australians know only too well from the constant political manoeuvring over the National Broadband Network. As ADSL was starting out, Waring *et al.* (1991) reminded readers that the access future would be on fibre; DSL could provide "a graceful transition" to fibre over "at least the next ten years". As it has turned out, DSL is still very much with us 35 years later. (In Australia, DSL provides the actual customer connection in "Fibre to the Node".)

The widespread use of DSL continues to shape the services on the Internet. There is an underlying assumption in service design that the downstream direction (towards the customer) has more available bandwidth than the upstream direction (towards the network).

https://doi.org/10.18080/jtde.v13n2.1279

This is changing somewhat with the greater symmetry provided by mobile networks and will continue to change as service requirements develop.

As the ISDN saga shows, the customer access network can be both a bottleneck to change and a key enabler of renewal. It deserves as much attention as the other parts of network and service provision.

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The Historic Paper

ISDN — Customer Access Transmission

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This paper is part of a series on ISDN and covers the aspects of Customer Access Transmission. The challenge is to provide an ISDN service by means of the existing transmission network in the customer area. A description of the Basic and Primary Rate Accesses along with the associated difficulties is given.

THE CHALLENGE

For more than 50 years customer access cables in telecommunications networks have been designed and installed to transmit unrepeated 4 kHz bandwidth voice signals from the access exchange to the customer. The high cost of such cable networks has necessitated minimum cost solutions to achieve voice transmission and service objectives economically. Even so, Telecom Australia invests around $400m in developing this network each year. A major challenge in implementing ISDN is how to utilise the same customer access network (CAN) cables to carry ISDN signals, which require much greater bandwidth than analogue telephony signals. Primary Rate Access requires around 2 MHz bandwidth and Basic Rate Access around 100 kHz of bandwidth. This paper describes the challenge and how Telecom Australia proposes to meet it.

A previous paper in this series (Ref. 1) described the ISDN (Integrated Services Digital Network) and the reader is referred to that paper for background information.

IMPLEMENTATION PLANS FOR ISDN IN AUSTRALIA

In August 1985 Telecom Australia made a policy decision to provide ISDN services, commencing in 1988. Initially these will be Primary Rate services based on a 2048 kbit/s customer-network access. Later a Basic Rate service based on a 144 kbit/s customer-network access will be introduced.

The concept of ISDN customer network access interfaces from the customer/network perspective is shown in **Fig. 1.** These Primary and Basic Rate Access interfaces are described in international standards as CCITT Recommendation I.431 and I.430 respectively (Ref. 1). Telecom Australia is, in consultation with local industry, moving to define national standards for these interfaces, based on the currently evolving CCITT standards. The transmission challenge is how to convey signals between the customer end and exchange end interfaces reliably and economically. Other challenges relating to precise definitions of the interfaces and to switching aspects of ISDN will be discussed in other papers in this series.

Telecom Australia outlined its plans for developing ISDN standards at a briefing to industry on 15 November, 1985. The timetable for developing the standards will result in both Primary Rate Access and Basic Rate Access Specifications being finalised by the end of 1986.

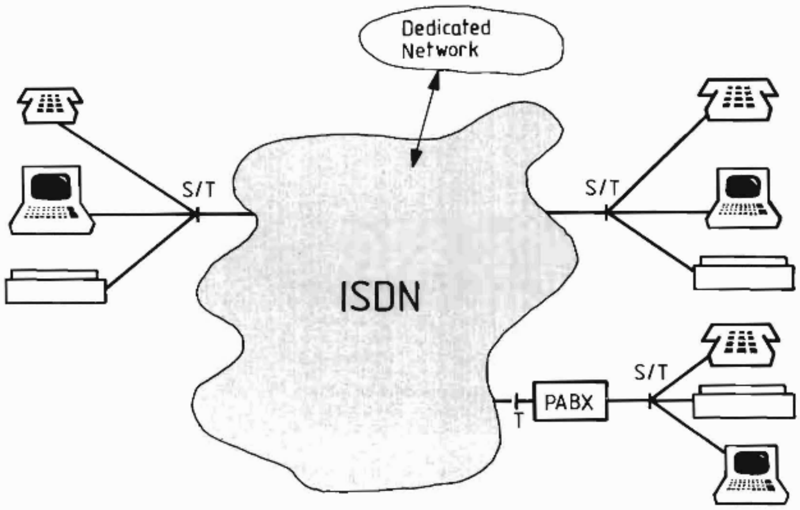

Fig. 1: ISDN Customer Network Access Concept.

CCITT REFERENCE DIAGRAM

This paper refers to interfaces such as U, S, T and V. The CCITT ISDN terminology refers to these as reference points, because they may or may not exist as clearly defined electrical interfaces. **Fig. 2** indicates the location of the reference points in the Customer Access Network. S and T are electrically the same but functionally different; they support complex and simple functions respectively where customer terminal equipment (TE) connects to the network termination (NT). The NT1 provides the "line connection" between customer and network at the so called physical layer. The NT2 provides the more intelligent functions between network interface and terminal equipment; i.e., the so called data link layer and network layer functions, which are necessary for local switching and concentration.

TRANSMISSION ACCESS OVERVIEW

For Primary Rate Access the 2048 kbit/s interface provides the customer with 30B + D channels, each of 64 kbit/s. The remaining 64 kbit/s time slot is used between the interface and the network access to "manage" the access link. Where NT2 is a small business system or a PABX, a Basic Rate Access interface could also appear on the customer side of the primary rate NT2. The Primary Rate Customer Access Network transmission system "transports" two 2048 kbit/s information streams (one in each direction) between the customer end NT and the access exchange LT.

In the case of Basic Rate Access the S and T interfaces are 192 kbit/s, which includes 144 kbit/s being the 2B + D channels commonly referred to in ISDN discussions, (B at 64 kbit/s and D at 16 kbit/s) plus 48 kbit/s used for

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Following his return to Telecom in 1980 he worked in transmission equipment, planning and network design areas. In the field of digital transmission he developed Telecom's engineering rules for introducing primary rate PCM systems, developed the strategy and introduced digital transmission into trunk networks and, as Superintending Engineer Planning, Co-ordination and Projects Branch in Telecom Headquarters' Transmission Division he was involved in the introduction of ISDN. More recently he has taken up the position of Superintending Engineer, HQ Transmission Products Branch.

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ALAN DUBBERLEY: After four years with Marconi UK Alan Dubberley joined Telecom Australia (APO) in 1971 and worked during the next four years in NSW Metropolitan Operations, Subscriber Equipment Branch (HQ) and Network Operations (HQ). He joined Planning Division (HQ) in 1976 and has covered a range of projects related to both customer access networks and inter-exchange networks. When the Planning, Co-ordination and Projects Branch was formed in 1985 he moved from Forward Planning Division to take up the position as manager of the Transmission Networks Implementation Planning Section. This Section has responsibility for the planning and co-ordination of the transmission aspects of ISDN implementation.

https://doi.org/10.18080/jtde.v13n2.1279

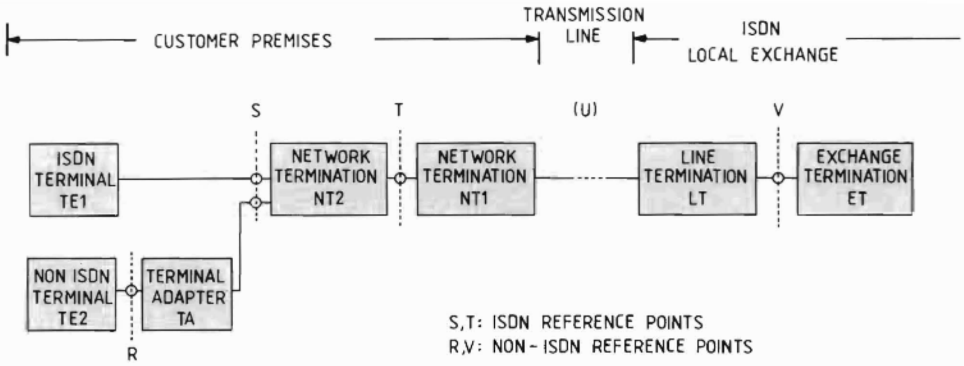

Fig. 2: CCITT ISDN Customer Access Reference Connection.

interaction and "housekeeping" at the interface. The Customer Access Network transmission system "transports" the two 144 kbit/s information streams (one in each direction) between customer end NT and the access exchange LT. When pair cable is used this would typically occupy one pair of wires between NT and LT carrying both directions of transmission.

The international and national specifications of the T interface for each of the Primary and Basic Rate Access options provides a transmission media independent interface for customer access to the network. Naturally there are many transmission media options for this access. Existing pair cables, new pair cables, radio and optical fibre cables could be used. Whilst applications will exist for all of these options, particularly the use of optical fibre cable for Primary Rate transmission, this paper addresses the challenge of utilising the existing metallic pair customer access cables.

Basic Rate Access will, in the longer term, be provided to the majority of ISDN customers, whereas Primary Rate Access will tend to be used for smaller numbers of larger business customers. Hence very large numbers of Basic Rate Access transmission terminations will be required. It follows that economic Basic Rate Access service can only be offered if the equipment required to carry out the complex line transmission functions can be developed and implemented relatively cheaply. This is by no means a trivial task.

Telecommunications administrations, manufacturers and researchers in many countries have been addressing this Basic Rate Access transmission problem for some years as it is central to economic provision of ISDN. Some administrations have adopted their own standard and it is unlikely that international agreement will be reached to standardise the U interfacing transmission technique and/or the necessary LSI chips. Telecom Australia therefore needs to decide upon a practical economic solution for the Australian network.

THE CUSTOMER ACCESS NETWORK

Fig. 3 indicates the geographical layout of a typical segment of an urban telephone exchange network. These are similar to those in other countries, but each network has its own peculiarities caused by differences in cable types, practices, staff structures, policies, electrical environment and population densities. The issues for Australia, which are to some extent different to many other developed urban networks and which impact on ISDN transmission options relate to long lines, multiple connection of some cable pairs, impulse noise and management of the network.

Development over past years has resulted in an Australian urban telephone exchange network structure with particular physical characteristics. The physical layout (refer Fig. 3) follows these general principles:

- Cables from the exchange to the customer may go through a number of cross-connection points such as pillars and cabinets and can use distribution frames in customer premises.
- Small diameter conductors in large size main cables are used close to the exchange (typically 0.40 mm) with larger conductors being provided at the remote ends (0.64 mm or 0.90 mm in extreme cases).
- Transmission and signalling planning limits are for an attenuation of 6.5 dB at 800 Hz and a loop resistance of 1100 ohm.

In this part of the network two types of main cable structures exist; that is, unit twin construction and the older quad layer cable. Naturally there are a great variety of older cable types but unit twin cable is now the most common. These cables have different crosstalk features, which have a significant impact on network design principles. An additional major consideration is the effect of bridged taps and multiples, which were used in the network to provide flexibility.

Closer to the customer the distribution area underground cable is plastic insulated and as it is not air pressurised it is susceptible to water ingress. Openable joints and above ground terminal boxes are used to provide access for customer connection. This part of the network can also have overhead cables and/or overhead customer premises lead-ins, again with different characteristics.

In order to develop sound network design principles a knowledge of the distribution of loop lengths is required in order to calculate a distribution of attenuations. A customer access loop survey was completed in 1979 (Ref. 2), which provided a basis for network studies. For example, it enabled graphs to be produced showing loop length versus cumulative percentage of customer access "loops," **Fig. 4.** This indicates that around 99 per cent of customers in urban areas have loop length less than 5.5 km.

Details on these fundamental transmission issues, and

Journal of Telecommunications and the Digital Economy, ISSN 2203-1693, Volume 13 Number 2 June 2025

https://doi.org/10.18080/jtde.v13n2.1279

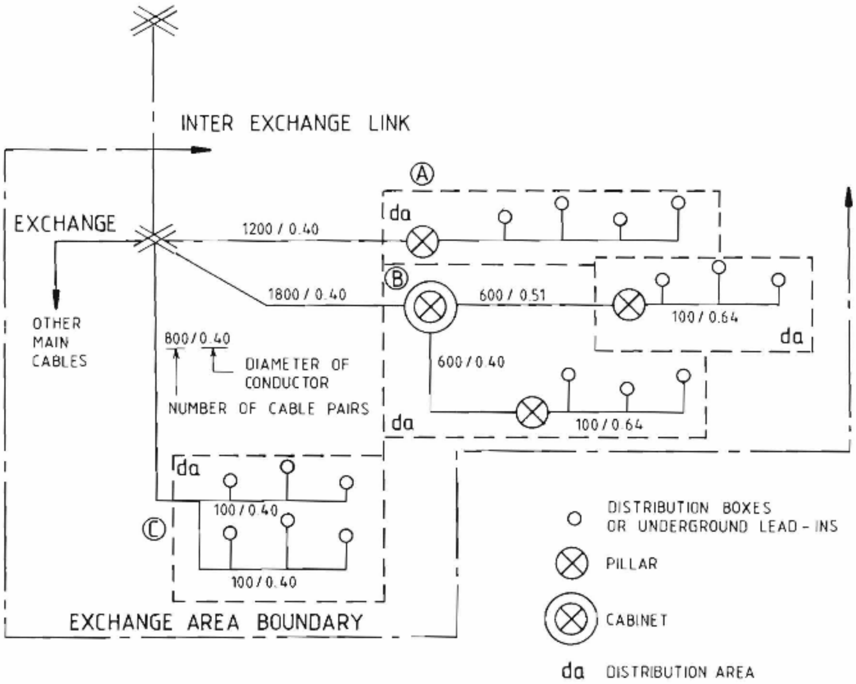

Fig. 3: Urban Exchange Network Layout.

the way which Telecom Australia is addressing them to provide ISDN customer transmission capability, are discussed in the following paragraphs.

CHARACTERISTICS AFFECTING TRANSMISSION PERFORMANCE

The Customer Access Network, as discussed, is basically metallic cables which have been designed for economic installation for analogue transmission. Some of the characteristics of the cable and the systems placed on the cable severely effect the performance of digital transmission.

Studies of the existing Customer Access Network have

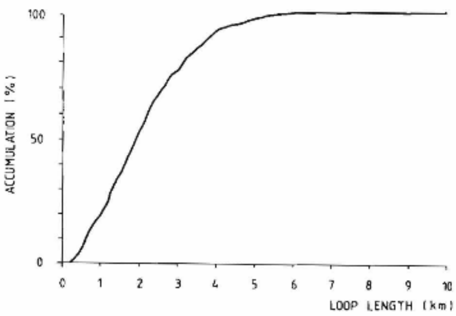

Fig. 4: Cumulative Percentage of Customers Having Loop Lengths Less Than Shown.

been undertaken with a view to determining the extent of likely problems when ISDN is introduced.

The problem areas that have been highlighted are:

- Impulse Noise — noise from both internal and external sources of an intermittent nature. Internal sources such as line signalling events and metering impulses on surrounding pairs can generate impulse noise. Examples of external sources of impulse noise are switching of power for transport systems, welding and RF interference. Telecom Australia has undertaken a programme to identify the sources of interference and the levels of noise in the network, to enable an assessment of the likely performance of digital systems.
- Crosstalk Interference — noise from similar systems on other pairs that is induced into the interfered pair by the coupling between the pairs in the cable. Characteristics of various cables has been undertaken to assess the performance of digital systems under crosstalk conditions. This involves measuring the crosstalk parameters at various frequencies on cables typically found in the network.
- Bridged Taps — this practice is used in analogue cable networks to provide flexibility of use of cable pairs. (Bridged taps are commonly referred to as multiples or tailing-on, depending on the means by which they are provided). This means an open circuit stub may exist across the line of a digital system and the reflection from the stub can cause severe degradation of the signals, particularly at high bit rates. Further degradation may occur on some pairs which have more than one bridged tap.
- Attenuation — this basically limits the range of the

transmission systems. The existing network can be split into urban and rural. The analogue design limits discussed in Section 4 result in an urban network attenuation limit of approximately 40 dB at 100 kHz. However, because of loading and gain devices commonly used in our rural networks, many rural loops have considerably higher attentuation at 100 kHz.

TRANSMISSION TECHNIQUES — PRIMARY RATE ACCESS

Primary Rate Access is possible via various transmission media as outlined in the section titled Transmission Access Overview. Telecom Australia has developed the technology, guidelines and equipment to provide 2048 kbit/s transmission on pair cable and some general comments about this are made in this article. Optical fibre technology is also expected to be used to convey these wideband signals and information regarding this technique will be presented in a future paper in this series.

Existing design guidelines for customer networks using 2048 kbit/s rate of transmission will be applied for pair cable. The guidelines take into account problems associated with crosstalk, impulse noise, attentuation, etc., to provide an economic provision while also taking into account the complex nature of the customer networks as described.

Transmission of 2048 kbit/s rate on pair cable requires regeneration of the signal at regular intervals because of the high attentuation level at these frequencies. Careful design is required to limit the influences of the problem areas highlighted. The factor that influences the design of 2048 kbit/s transmission systems in the customer network most is impulse noise. To avoid this problem the loss limit for the regenerator spans closest to the exchange and customers are limited. As most loops in the urban customer network are less than 4 km the mid-section tends to be relatively short, but it is kept short to avoid problems. As a consequence of reduced regenerator spans there are reduced problems with crosstalk so that pair selection techniques do not have to be used.

Pairs with bridged taps need to be avoided or the tap cut away for 2048 kbit/s working.

Primary and higher transmission rates are also possible on optical fibre in the customer networks, and these are expected to become economical for longer loops, and/or for customers who require higher capacity transmission.

TRANSMISSION TECHNIQUES — BASIC RATE ACCESS

Basic Rate Access is most viable on the existing Customer Access Network; that is using metallic cable pairs and as a consequence this section covers the challenge of using Basic Rate Access on existing cables, using the pair that accesses the customer's premises at present. To develop suitable systems it is necessary to examine the influence of the cable loss as a function of distance and frequency, interference arising from crosstalk and impulse noise, and the constraints of the existing network design.

As the existing access to the customer's premises is via a pair cable, the most viable option is to utilise this access. A design objective for ISDN transmission at the Basic Rate Access in the customer network is to reach 99 per cent of customers without change to the existing network or practices and without any intermediate elecronics. To be able to use the existing network without change, any technique must cope with bridged taps, impulsive noise, crosstalk, etc.

To this end, the two most favoured Basic Rate Access transmission techniques proposed are:

- Time Compression Multiplex — the data is stored and output at a higher bit rate so that the cable pair can be used in a burst — mode fashion from each end. This technique necessitates a line rate higher than the original rate of the combined data stream (usually three times faster).
- Echo Cancellation — a hybrid is used to convert from a four-wire path at the telephone to two-wire transmission, then signal processing techniques are used to reproduce any echoes from the impedance mismatch between the hybrid and line. The echoes that are reproduced are subtracted from the signal to achieve an echo free signal.

The echo cancellation technique has developed to become the most viable technique at present. A block diagram showing the principal functions of an echo canceller is given in **Fig. 5.** This diagram shows the adaptive equaliser which simulates the echo that is formed by the outgoing signal through the hybrid. This simulated echo signal is subtracted from the incoming information signal so that the information can be successfully extracted.

A Decision Feedback Equaliser (DFE) is also included in the system. The DFE cancels intersymbol interference (ISI) and is required in the Australian customer networks as the analogue network design practice was to use bridged taps. The DFE works in a similar way to the echo canceller to simulate the echo from the open circuit of a bridged tap.

The process is more difficult as the DFE must use estimates of the incoming signal to search for echoes — unlike the echo canceller which uses the known transmitter data. The DFE also reduces intersymbol interference due to other impedance changes and mismatches on the cable pair.

Another important part of the receiver is the timing

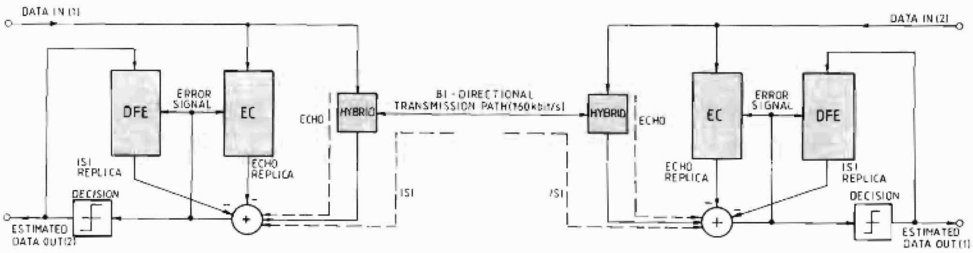

Fig. 5: Block Diagram Showing the Principal Features of the Echo Canceller.

Journal of Telecommunications and the Digital Economy, ISSN 2203-1693, Volume 13 Number 2 June 2025

https://doi.org/10.18080/jtde.v13n2.1279

extraction, from the incoming signal, for the decision instant.

The intention is for ISDN to be a universal service, and for this 100 per cent penetration of customer network cables may be required. Crosstalk guidelines must take into account this requirement, that is, an initial design for a single system, must consider the crosstalk from other similar systems on all other pairs in the cable. The crosstalk and impulse noise performance of a Basic Rate Access transmission system is particularly dependent on the line code that is used. The line code is used to convert the signal to a more useful format for compatibility with the characteristics of the line, and the network. A line code with limited power in the high frequency region is required so that attentuation of the signal is minimised and the bandwidth of the input filter is limited to reduce the received noise power, thus improving the performance of systems under impulse noise conditions.

The graph Power versus Frequency **(Fig. 6)** for various line codes (for description see Table 1) indicates that the more complex line codes (e.g. 4B3T, 2B1Q) have a more confined power spectrum whereas the simpler codes (e.g. WAL1, WAL2) are spread across the spectrum. The more the spectrum is confined to the lower frequency range the greater is the immunity to interference. The echo cancellation transmission technique with a complex line code and a Decision Feedback Equaliser is therefore the most likely contender for Basic Rate Access with present design and technology.

Another key issue that has been considered is the transmit level of the signal. A higher send level can be used to achieve longer reach in the network. This approach must be weighed against the interference caused in other customer access systems existing in the network or proposed in the future.

Many different techniques are possible to implement echo cancellers, some are more suited to certain line codes than others. The more complex line code transmission systems incur a penalty in terms of the hardware implementation. The integration of the technique on to Very Large Scale Integration (VLSI) is more complex than the other techniques and therefore may be more costly or

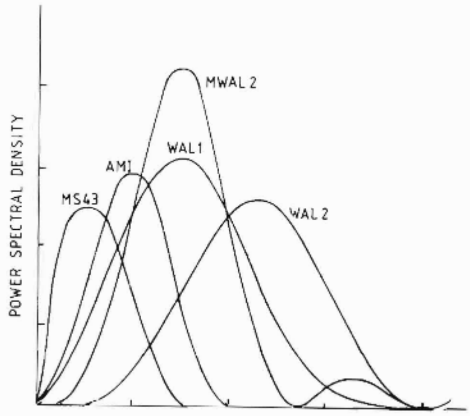

Fig. 6: Power versus Frequency for Various Line Codes.

have technical limitations associated with implementation. A decision on the degree of complexity required is based on a compromise between complexity to overcome noise considerations and the ability to implement the technique in the timescale. The timescale is dependent on worldwide factors (CCITT agreements, manufacturers' lead-times etc) as well as Telecom Australia's policy for the timing of ISDN Basic Rate Access service. At the time of writing this policy has yet to be resolved.

The intention of the Basic Rate Access system to be used, is to provide direct transmission over existing cables without intermediate electronics to 99 per cent of customers in urban networks. In rural networks with very long loops other techniques will need to be developed; some options include radio, regenerators, remote multiplexing and remote concentrators. The decision on these techniques will be based on economic factors, as well as maintenance and operations requirements.

Line Code	Abbreviation	Description
Walsh 1	WAL 1	Represents 1
		Represents 0
Walsh 2	WAL 2	Represents 1
		Represents 0
Modified Walsh 2	MWAL 2	Modification of WAL2 to include timing component and increased transmit power.
Alternate Mark Inversion	AMI	A binary input zero is represented as space. A binary one is represented by a mark which alternates in polarity.
Four Binary — Three Ternary	4B3T (MS43)	Translates four binary digits into three ternary words (several translations available MS43 is one of these).
Two Binary — One Quaternary	2B1Q	Translates two binary digits into one quaternary word.

Table 1: Description of Selected Line Codes

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MAINTENANCE ASPECTS OF ISDN TRANSMISSION (OVERVIEW)

The maintenance aspects of ISDN transmission are particularly important as the intention is to provide a network with the capability of fast fault finding and short restoration time. Also it is necessary to delineate the fault to either Telecom Australia network or the customer's equipment, and in some cases, to identify where in the Telecom network the fault has occurred.

The approach to maintenance facilities can be in either of two basic ways (or combinations of the two).

- loop backs, at various points in the transmission equipment and customer premises.
- in-service monitoring of the bit steam and equipment, raising alarms and extending these alarms to exchanges using spare bits in the bit stream frame.

Loop backs of the total bit stream require the system to be out of commission for tests to be made, and therefore in-service error tests cannot be made. Loop backs of individual channels for in-service error testing are under study to avoid this problem. Monitoring of the bit stream provides less information about the position of a fault in the transmission path, than loopbacks.

The use of the two approaches together gives the most information in a variety of cases, so that this is probably the best, although it also is the most expensive.

The full details of all the facilities required for the maintenance of Primary Rate ISDN transmission systems in customer networks have yet to be resolved by CCITT.

Telecom Australia has proposed a bit-stream approach for Basic Rate Access within CCITT, in line with Recommendation G.803 "Maintenance of Digital Networks".

Telecom Australia is adopting both loopback testing and in-service monitoring of the bit stream and equipment for the initial Primary Rate Access.

SUMMARY

Telecom Australia is implementing an ISDN policy based initially on Primary Rate Access in Central Business Districts. The Primary Rate Access transmission design using pair cable for customer networks is already covered by existing Telecom Australia documents and studies. Optical fibre is also a likely contender for primary rate and higher capacity systems in central business districts. The major implementation problems of Primary Rate Access are associated with switching and maintenance issues.

Basic Rate Access transmission is to follow, the technique most likely to be used is the two wire bidirectional hybrid with echo cancellation, with the line code still to be determined. To achieve Telecom Australia's design target penetration in the customer access network of 40 dB line loss without alteration to the network and no intermediate electronics, a more complex line code of the block code type provides better performance. The line code together with the transmit level determine the penetration and potential reach under noisy conditions of the basic access system. The form of transmission will be suitable for urban networks but other means of extension of access must be considered for long customer loops such as in rural areas.

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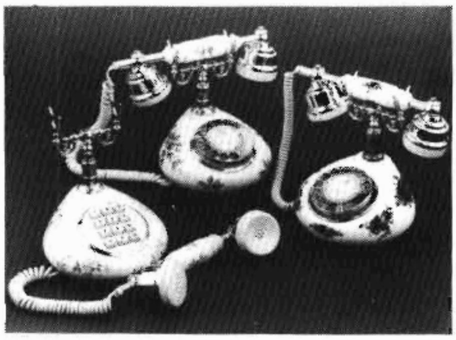
Information Transfer News

CERAMIC TELEPHONES

A range of decorative ceramic telephones from Britain, which incorporate the latest telecommunications technology and can be supplied to conform to the standards of any PTT authority, is claimed to be unique.

Two ranges of ceramic telephones are offered — the 'Royal Albert,' and 'Wedgwood Jasper'. The Royal Albert is available in a choice of five of the Royal Albert Pottery's most popular floral designs. The 'Wedgwood Jasper' has a stoneware base made by Josiah Wedgwood and Sons in Jasper Ware. Decorated with classical bas-relief figures, the Wedgwood telephones are available in a choice of pale blue or pink. All the instruments can be supplied with either a traditional brass dial or a pushbutton keypad with a last-number-recall facility.

Also offered are a range of telephones in wooden, brass, onyx and other finishes. All can be supplied with dial or pushbutton keypad with specifications to conform to the requirements of any country's PTT.



The 'Royal Albert' ceramic telephone from Britain, available in a choice of five traditional floral motifs and with either a pushbutton keypad or conventional dial, can be supplied to conform to the standard of any PTT authority. (Astral Telecom Ltd., Astral House, Clough Street, Hanley, Stoke-on-Trent, England ST1 4AB. Telex: 367450) (LPS)