

# Network Developments at the W.A. Regional Computing Centre 1965-1980

T.A. Reid\*

This paper describes the developments which have taken place at WARCC in data communications over the period 1965-80, culminating in the implementation of a multi-host, heterogeneous packet-switched network, with a gateway to national and overseas networks.

Keywords: data communications, computer networks, packet switching, time-sharing, terminals  
CR Categories: 1.2, 3.81, 4.32

## 1. INTRODUCTION: EARLY DEVELOPMENTS

The developments described in this paper were carried out by the Computing Centre of the University of Western Australia and by its successor, the Western Australian Regional Computing Centre (WARCC). This latter body was formed in 1972 to provide computing services to the University, to other educational institutions and to government departments in WA. This involvement with off-campus bodies is partly responsible for the interest the Centre has had in data communications, and goes back to 1964, when it ordered a Digital Equipment Corporation PDP-6 computer. This was the first time-sharing computer in Australia and the first to be commercially ordered anywhere in the world.

Apart from conventional time-sharing (radical at the time, see Moore, Jarvis and Nicholls, 1966), this computer was used to control a number of experiments on-line; these included a flying-spot scanner in Electrical Engineering, a "direct retrieval computer" in Physiology, and a rat-race in Psychology (Nicholls, 1969). These ventures formed the basis for the implementation of a remote computer link, called a remote central processor (RCP). This software and hardware project enabled the connection, via a serial link over data communications lines, of remote computers to the PDP-6 on its I/O bus. It was a fully bi-directional medium-speed link, and was used to connect additional real-time experiments on campus to the PDP-6; thus, the power of the PDP-6 could be used to control experimental equipment such as a diffractometer and a mass-spectrometer. In 1969, such a connection was made over modem-controlled Telecom lines to a PDP-8 at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Floreat Park (three and a half miles away). This had a card reader and line printer attached to it, and became the first remote batch station to operate in Australia.

In 1973, the PDP-6 was replaced by a PDP-10 (KA10 processor). The standard data communications front-end

for DEC-10s was a DC10, which attached to the I/O bus. Motivated both by a desire to achieve greater flexibility in the front-end and by a shortage of capital funds, the Centre decided to substitute a PDP-11/10 minicomputer for the DC10. This was interfaced to the DEC-10's I/O using a GP10 interface, and communications lines were attached using a multiplexor designed and built by the Centre.

The software running the DC10 emulator handled two of the above 16-line multiplexors, as well as several standard single line interface boards (DL11). Modem control was provided, which was gradually extended to provide dial-up support and then auto-answer. Some of this software was extremely complex, and difficulties were being experienced with supply of the locally-designed multiplexors, so it was eventually decided to install a standard front-end, which by then was the DC76 (based on a PDP-11/40), in addition to the DC10 emulator.

Earlier, however, the decision to use a minicomputer as a front-end had proved invaluable; in 1974, it provided the means of connection to the DC10 emulator of a cluster of terminals situated at the Western Australian Institute of Technology (WAIT) in Bentley (seven miles away). A 4800 bps synchronous full-duplex link was used to connect another PDP-11/10 at the WAIT, to which were attached 16 low speed terminals. A simple-minded approach was taken based on the principle of a time division multiplexor. There was no error correction, and line utilisation was very poor.

As the volume of terminal traffic at the WAIT grew, a more efficient and more flexible data link protocol was devised for this link. This resulted, in 1976, in the implementation of a synchronous link to support the 32 terminals at WAIT, utilising DEC's DDCMP protocol, with full end-to-end control, error recovery, better line utilisation, etc. The experience gained in this project also proved invaluable later (see 4 below).

The Centre's Cyber 72 had been installed in 1972, originally with the intention of taking over all the work from the PDP-6. However, it soon became clear that a better strategy would be to concentrate the batch load on the Cyber (with some on-line file enquiry applications), and to retain a specialised interactive facility. This was what led to the replacement of the PDP-6 by a

\*Copyright © 1981, Australian Computer Society Inc. General permission to republish, but not for profit, all or part of this material is granted; provided that ACJ's copyright notice is given and that reference is made to the publication, to its date of issue, and to the fact that reprinting privileges were granted by permission of the Australian Computer Society."

\*The author is with W.A. Regional Computing Centre, University of Western Australia, Nedlands, W.A., 6009. Manuscript received 25 March 1981.

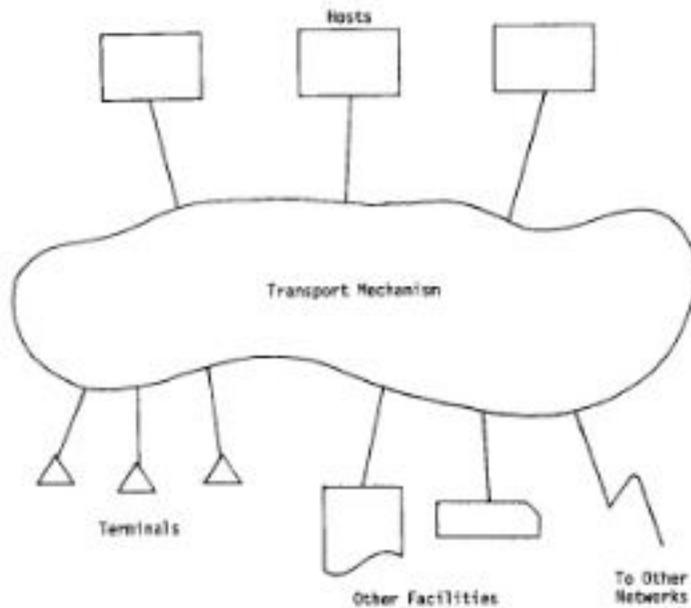


Figure 1. A network concept

PDP-10 in 1973; and our experience has corroborated the views of many that if there is a need to provide good interactive and good batch service, then it will be achieved more effectively (and cheaply) by separate computers than by a single unit. However, it was recognised that an important ingredient in this mix could well be some kind of file link between the two computers, primarily to allow use of the greater power of the Cyber, in batch mode, by DEC-10 users.

Due to manpower constraints, this was not achieved (other than via magtape) until 1977, when a 1200 bps asynchronous link was established over standard data communications interfaces. Each computer considered it had a standard asynchronous terminal at the other end (see Figure 2). The principal components are a program in the DEC-10 which transmits spooled requests for transfers to the Cyber, and a program in the Cyber which receives and processes this flow. This system enables a DEC-10 user to submit a job to any of the Cyber queues (Input, Output, Punch, etc.), or to catalogue a file on the Cyber disks. Thus, a form of "edit and batch submit" was provided; so was the ability to make use of the Cyber printers (either as back-up for the DEC-10 printer, or to make use of the higher speed of the Cyber printers); to make use of the Cyber card punch (one is not provided on the DEC-10); to make use of the Cyber spooler for the off-line plotter (such a spooler has only recently been implemented on the DEC-10); to enable a DEC-10 file to be printed at a Cyber remote batch station; or otherwise to gain access to the wider range of facilities and packages available on the Cyber at the time. An important aspect of this project was, of course, maintenance of account integrity, especially in connection with creating files on the Cyber disk.

Later the same year (1977), another link was established through the DC10 emulator on the DEC-10, this time to an HP21MX. This was essentially a revision of the 1974 remote terminal concentrator, and permitted terminals connected to the HP21MX to connect, through that mini, to the DEC-10 (see Figure 2). The WAIT Links

were removed in 1977 when WAIT acquired their own DEC-10.

These activities span a considerable period, and cover a wide variety of functions. They have provided the experience, and in some cases the basis, for the more ambitious developments described below.

## 2. CYBER EMULATORS

Some of the work described above, and particularly the experience in programming PDP-11s for data communications tasks, suggested several uses directly associated with the Cyber. In particular, given data communications line costs in Australia, and the cost of standard CDC terminals (711, 714), an obvious application was to use a remote PDP-11, connected over synchronous lines to a standard CDC interface, to emulate multi-dropped 711s or 714 clusters. As a bonus, greater flexibility and adaptability would be provided.

Accordingly, in 1975 the first 714 emulator was installed. The immediate rationale was to increase the number of lines on the Cyber, provided by 6671 MUXs. An additional factor was the need to provide support for remote reading, by the Public Works Department, of non-standard paper tapes (containing river-gauging data). The best that can be said for the modifications made to the emulator software to support paper tape is that they were made hastily!

Partly as a consequence of this, it was decided to rewrite the 714 emulator software, and this was accomplished in 1976. On this occasion, great pains were taken to write code which would be easy to maintain and which could be readily modified or adapted. Use was made of

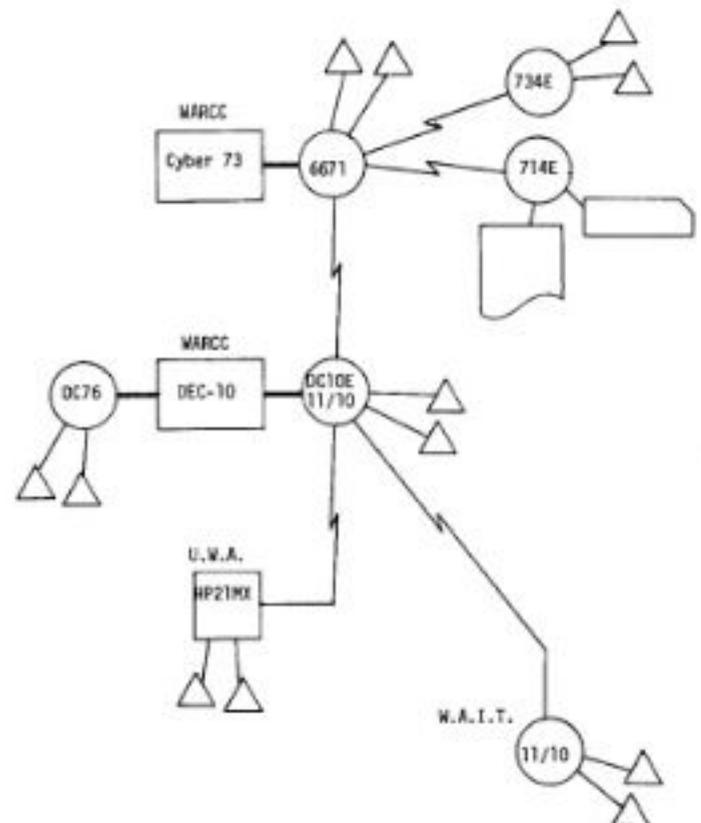


Figure 2. The WARCC network, circa 1977

the Duke University structured macros for the PDP-11 (Herman-Giddens, *et al*, 1975).

At the same time, the software was adapted to provide remote batch terminal (200UT, 734) emulation on the Cyber. The motivation was again to provide a cheaper alternative to the standard CDC equipment, the emulator being several thousand dollars cheaper to purchase (including software), as well as being nearly half as expensive to maintain. At this time, the 714 emulator was cost-effective if four or more terminals were required (using asynchronous terminals such as the Teleray 3311). The use of a good PDP-11 cross-assembler on the DEC-10 was an essential component of these developments.

Also in 1976, a 714 emulator was implemented on an Interdata 6/16 minicomputer. The availability of software modules on the 6/16 to handle many of the data communications functions (e.g., terminal and line interface support) promised significantly to simplify this exercise. Such, however, did not prove to be the case, with many bugs and deficiencies being revealed in those modules before the emulator was finally installed at Murdoch University.

Some 20 or 30 installations of the various versions of the 714 and 734 emulators have now been made in Western Australia, on all five Cybers in Perth. The decision to follow this approach has been well-justified, as the 734 emulator has been adapted to provide a multi-drop capability. This has allowed installation at the one site, on the one line, of mixes of multiple card readers, line printers and VDUs. It has also proved invaluable to Health Computing Services, with their diverse needs in providing computing services to Perth's teaching hospitals. One of the adaptations pioneered by HCS has been the support of "site poll", which has dramatically improved response times on emulator VDUs.

### 3. CONVERSATIONAL REMOTE JOB ENTRY

Experience with the DEC-10 to Cyber link, described in 1. above, led the Centre to believe that the increasing pressure to provide improved interactive access to the Cyber could be largely satisfied by providing an adequate "edit and batch submit" facility. This belief was bolstered by similar developments being undertaken overseas and at Melbourne University. Accordingly, it was decided in 1978 to acquire a PDP-11/60 which would provide a good, cheap editing capability, and to link it to the Cyber using our 734 emulator software.

This was implemented in 1979, with the emulator running in a PDP-11/03, back-ending the 11/60. The batch-submit functions are implemented by jobs which run under the RSTS/E operating system. This makes them much easier to implement (they are written in BASIC), and use can be made of a suitable existing editor, such as SOS. A spooler program empties the queue of jobs being submitted to the Cyber, sending them as files to an asynchronous "terminal" which is the 11/03. Output being returned from the Cyber is held on disk by the CRJE pending action by the user. The user can attach to such files, examine them with the editor, save them on his own disk, purge them or have them printed at a nominated or default printer attached to the CRJE. Alternatively, he can have his job automatically printed at the central site (or on some RJE printer) using the Cyber ROUTE command, or have it automatically printed on a specific printer on the CRJE.

A bonus is the access so provided (for authorised users) to the other facilities of the RSTS/E operating system environment, such as the WORD-11 word processing software now installed on the 11/60. Many of the facilities for support of interactive terminals are much better under RSTS/E on the 11/60 than under NOS/BE (or even NOS!) on the Cyber. The CRJE is an important step in the direction of elimination of cards and card punches, particularly for students, while preserving many of the advantages of a rapid batch service. Instead of acquiring and maintaining card punches to support the increasing number of students making use of the Cyber, we can now substitute an equivalent number of VDUs, at many times smaller cost per unit, and with considerably greater flexibility.

### 4. PACKET SWITCHED NETWORK

As early as 1974, the Centre began investigating the applicability of packet-switched networks to handle the data communications needs of Centre users, and indeed, of most computer users in the public sector in Western Australia. There had, of course, been some spectacular disappointments in this area, which prompted us to tread very cautiously. Furthermore, there were significant political implications in any such "global" approach, with some quarters openly concerned lest a body to control all public sector computing ride in on the back of a general network.

Nevertheless, aspects of this approach are sufficiently attractive to warrant careful analysis. For example, it would only be by collaborating that most of the various public sector organisations could afford data communications to country towns in Western Australia. Accordingly, a report was prepared in 1977 calling for an in-depth study of the needs for such a network in Western Australia (Reid, 1977). In response to this call, a Western Australian government task force has collected data on traffic volumes, growth patterns, etc., in all public sector organisations in Western Australia. Discussions are continuing with Telecom to determine how soon a suitable service might be offered publicly; at present, it still looks as though 1982-83 will be the earliest that this might happen in Western Australia. Five years is not a very long time when developing facilities such as this, so a high degree of consultation is required.

At the same time as the above discussions were taking place at the political level, the Centre had been investigating the technology of packet-switched networks. Some less ambitious projects with limited objectives had been very successful, e.g., Merit in USA (Scott, 1978) — but even here it had taken a long time for use of the network to take off. Of those projects with broader objectives, only ARPANET had much written about it, and the magnitude of that exercise was well beyond the reach of our resources.

We were casting about for a strategy to provide the following functions:

- rationalise the diversity of communications links existing or envisaged among the equipment in the Centre or elsewhere;
- provide a degree of insulation for terminals from changes in hosts (i.e., limited "virtual terminal" capability);
- provide access by as large a population as possible to a wide range of facilities;

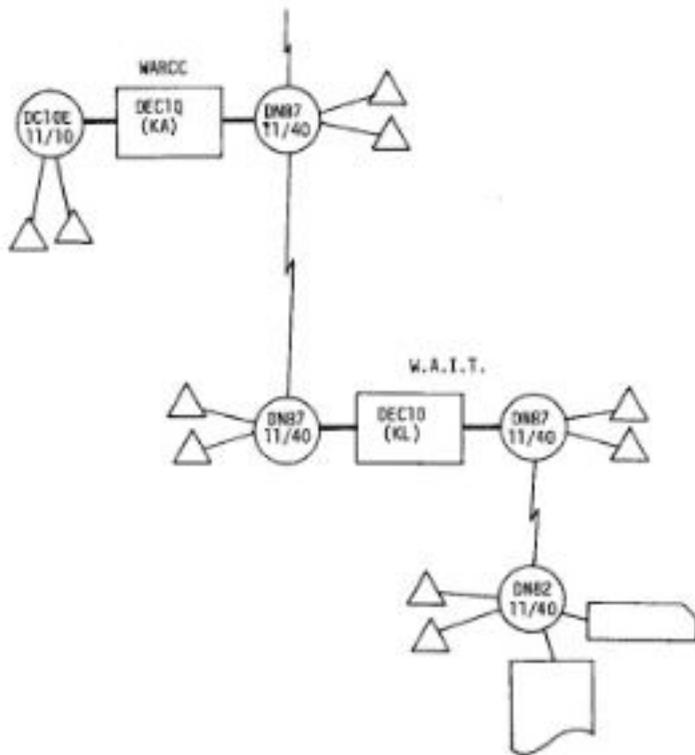


Figure 3. Network of DEC System-10s

- provide access to off-campus (and interstate and overseas) facilities;
- enable terminals on a State-wide basis to gain access to the Centre's and other facilities;
- provide a high degree of flexibility and adaptability in any communications offering;
- and not least, we wanted something that would work!

Overall, we needed a "transport mechanism" which would provide for terminal and file traffic between an array of suppliers (hosts, other networks, etc.) and consumers (terminals, other hosts, minis, etc.); and which would do this in a rational, consistent fashion (see Figure 1).

The offerings of the computer suppliers were canvassed, but little was available here. Control Data offered nothing; most other suppliers offered nothing; IBM had announced SNA, but that seemed to be ruled out on the grounds of extreme expense and dearth of documentation, so the connection of non-IBM hosts looked impossible. Only DEC's offering, DECNET, seemed promising.

Obtaining information about DECNET proved difficult. Nobody in Australia knew anything about it. Eventually, it proved possible to obtain a copy of the software, with very limited documentation, thanks to the efforts of the staff of the local DEC office. Indications were that this product would satisfy most of the above needs. Furthermore, it seemed possible to implement this software between the two DEC-10s at WAIT and at WARCC with almost no effort.

Surprisingly, this indeed proved true, and by spring 1977 a packet-switched, multi-host network was installed between WARCC and WAIT, using DN87 front-ends (upgrading the DC76s with the DECNET software), and a synchronous 4800 bps line (see Figure 3). More surpris-

ingly, almost no bugs were found in this code! This is believed to have been the first multi-host packet-switched network to be operational in Australia.

The next stage was to adapt this software to interface to the Centre's Cyber as well. The approach taken was to make the Cyber look like a DEC-10 to the network, and the network like a 714 cluster to the Cyber. The first part of this was achieved by taking the software which ran on the DEC10 to service network traffic, and to rewrite it to run on a PDP-11, calling it "NET11". Software to emulate 714 clusters on a PDP-11 already existed, but this was rewritten to achieve greater efficiency in PDP-11 CPU and memory, and was reduced in size to a few pages of code.

The three elements of this software were then interfaced and installed on a PDP-11 (designated a "CN87") in front of the Cyber's 2550 (see Figure 4). A full discussion of the development of this software (including how it was tested) can be found in Fernandez (1978).

This expanded network went into operation at the beginning of 1978. An important aspect of the development had been the principle that no changes should be made to the host operating system (in this case NOS/BE). DECNET employed a three-layer approach, and these layers and their interfaces were strictly defined and policed (DEC, 1976).

It had also been intended to connect a few PDP-11 hosts located in other educational institutions, but this proved more difficult than at first hoped. A discovery was made that DECNET came in two incompatible flavours - a version for DEC-10s (using ANF-10 software), and a version for minis which was DECNET proper. The latter did not have a DEC-10 interface (nor does it have yet), but was to become the main offering of DEC for data communications networks. The former, the version we had employed, was not going to be developed further by DEC.

Accordingly, in order to incorporate a PDP-11 into the network, we had to adopt the same approach as for the Cyber; i.e., we had to make a PDP-11 look like a DEC-10. This did not prove too troublesome, as we already

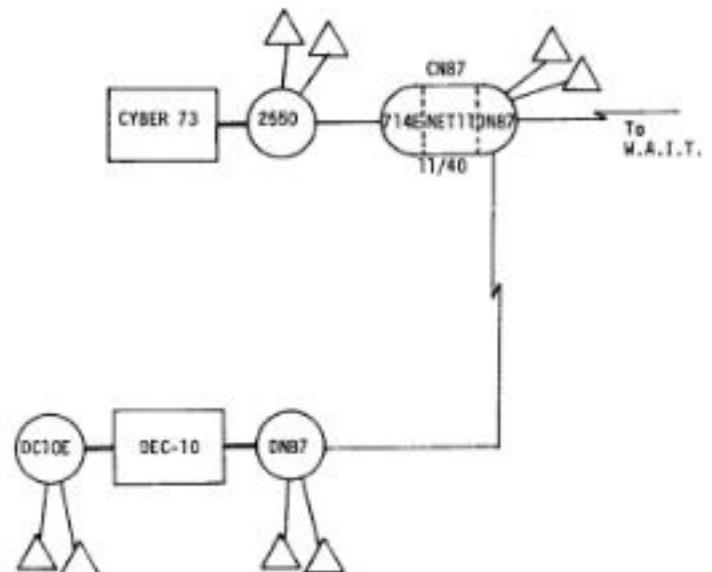


Figure 4. Installing a Cyber in the network

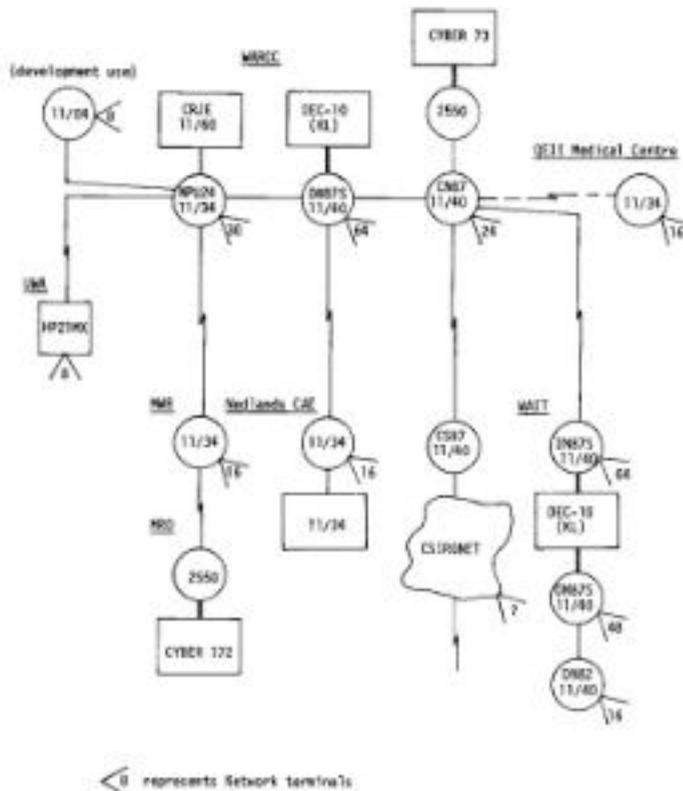


Figure 5. The WARCC network, 1980

had NET11, though the RSTS/E operating system did not have a remote terminal concentrator capability. Instead, use was made of its "pseudo-terminal" facility, and a program written to run under RSTS/E to handle network traffic. This facility was installed, also at the start of 1978, on the PDP-11/34 system at the Nedlands College of Advanced Education, less than a mile from WARCC, over a 2400 bps synchronous line.

In other developments, the CRJE was also connected to the network in the same way as the NCAE PDP-11/34; The Cyber 172 at Main Roads Department has also been connected to the network via a node located at the Metropolitan Water Board, and a further node to permit access to the network by terminals at the University's Medical School located at the Queen Elizabeth II Medical Centre, about one mile from WARCC, is on order. Finally, a PDP-11/40 has been used to provide a two-way gateway between this network and CSIRONET, which became operational towards the end of 1980 (see Figure 5).

It has not proved possible yet to connect the Interdata 8/32 at Murdoch University, because its operating system supports neither terminal concentrators nor pseudo-terminals. Discussions are continuing, to discover some other way to connect this facility in a simple way. Discussions are also being carried out with a few other organisations, which might further extend the network. In particular, ways of incorporating an IBM host into the network have been explored, and this no longer seems as formidable a task as thought at first.

## 5. FUTURE NETWORK DIRECTIONS

The above development of a packet-switched network has been carried out on a shoe-string budget, and

has been experimental in nature. The results achieved have been very encouraging, though many loose ends need to be tidied up. This approach has proved to be a viable framework within which to provide for an ever-increasing diversity of needs. At present, terminal switching is essentially the only facility provided (and a device such as a private automatic computer exchange [PACX] would be both more efficient and more economical for that function alone), but the following developments will fit well in the framework adopted.

### (a) File Transfer

File transfer between hosts will be an important requirement, for many reasons but primarily to allow use of different packages on different computers. Although magnetic tapes still represent the fastest data communications medium, the trend is decidedly away from them: for all but very large files they are much slower than use of a network; considerable incompatibilities still exist between tape files on different computers (even from the same supplier); it is an operator-intensive activity; it relies on use of mechanical devices; and in general is a labour-intensive activity (add up how much time is spent untangling tape transfer problems between computers!).

File transfer from minis to large computers will be (and already is) important to enable analysis by the mainframe, perhaps using specialised software packages, of data collected by the mini; to allow access to the number-crunching or data processing capability of the mainframe; to enable incorporation into a central data base of data collected at diverse local facilities or just to process regional data against a central data base; to make local results available to a wider population; to enable batch submission to take place from decentralised equipment; or otherwise to make accessible the specialised facilities provided on the larger computers.

File transfer from the mainframe to mini is needed to support cross-assembling and down-line-loading functions, to return results of mainframe processing to the originating mini, to support remote printing, to provide for rationalized support for graphics, with some processing being done on the mainframe, but high-speed interactive support provided at the mini, etc.

### (b) Connections to a wider variety of Equipment

The variety of equipment and services is continually increasing, and access by workers in educational and research institutions (in particular) is vital. In this category would be access to the wide variety of packages available on IBM equipment (there are currently almost no IBM computers in educational and research institutions throughout Australia). There is going to be a need to gain access to other specialised facilities, such as array processors, data base processors, information retrieval systems, etc. Australia as a nation cannot afford, for example, much more than one computer in the class of the Cyber 203, and if its researchers are not to be at a disadvantage compared with colleagues in the UK or USA, then they must be given access to such facilities via networks.

### (c) Connection to other Networks

Part of the above variety of services will be provided if rationalised links can be provided to existing national and overseas such as CSIRONET, Tymnet, Tele-

net, ARPANET, etc. This is best provided by means of gateways, which ultimately will be facilitated by widespread use of standards in the data communications area such as X25.

Furthermore, such links can foster a high degree of communication between researchers, nationally and internationally, and between researchers and government and industry; this is particularly relevant for Australia, with its small, widespread and isolated population. Much research thrives on consultation, collaboration and co-operation; the fuel crisis is making it too expensive to have much face-to-face contact, and Australia will be at a particular disadvantage. Data communications may provide a way of compensating for this, and ensuring that we do not fall behind or fail to attract and retain competent researchers.

#### (d) Electronic Mail

Already, experience overseas (e.g., in ARPANET) suggested that electronic mail is going to be one of the most important functions provided by networks (see, for example, Uhlig, Farber and Bair, 1979). Researchers, particularly, feel very isolated in Australia, and electronic mail holds out the following advantages over conventional communications media —

- easy, rapid transmission of hard copy;
- broadcasting of messages to groups of colleagues;
- avoids the frustration of the telephone; and
- avoids the delays and uncertainty of the mail systems.

#### 6. CONCLUSION

Considerable difficulties have yet to be overcome before we reap all the benefits of 5 above. It is clear that the present attempts at a network at WARCC will probably never provide all these benefits, and incur several frustrations for users. There are substantial overheads in the use of packet-switching, especially when dealing with a DEC-10 in full-duplex mode over the network. Furthermore, it is by no means clear that the costs of a network are justified for the present volume and style of traffic, compared with other mechanisms such as a PACX for local traffic, or the switched telephone network for off-site traffic.

On the other hand, the cost of data communications is dropping dramatically — perhaps not as fast as the cost of computer hardware, and perhaps not so fast in Australia as elsewhere because of the high degree of regulation. But the use of general purpose networks such as that pioneered at WARCC is here to stay. To oppose this trend would be like trying to save the Pony Express, which went bankrupt two years after Western Union introduced the telegraph to the West.

Only such a general-purpose network can hope to provide the full range of facilities needed, or provide the flexibility to adapt to changing demands and changing services. The launching of a nation-wide packet-switched service in December 1982 will be an important step for Australia. However, one can be forgiven for fearing that the cost may deter much *ad hoc* use, at least in the first instance, unless a clear vision of the benefits is retained. This is nowhere more true than among the various research institutions in Australia, which have to date been very slow to realise the importance of access to a national network. This is not so in USA where Peter Denning, ACM President, in reporting on a meeting between the

Council of Scientific Society Presidents and the office of the President of the USA, notes: "A step of high potential impact is support of national computer networks, which would permit exchanging documents, programs, and data among scientists; networks would also permit remote use of specialised equipment" (Denning, 1980).

Providing the raw communications channels, albeit packet-switched is, however, only part of the answer. Access to the range of facilities and services available on any national network needs to be "facilitated", especially if they are to be used by non-computer professionals. In the USA a body has been set up specifically to accomplish this (Heller, 1978). This may not be the pattern for Australia, but a real need will exist and will have to be addressed.

#### 7. ACKNOWLEDGEMENTS

The work described in this paper has been performed by only a handful of people, who have demonstrated a high degree of dedication and hard work to see these developments realised. Chief among these are Terry Gent, Bruce Kirkby, Joe Fernandez and Alan King, to whom WARCC is very grateful for their enthusiasm and effort. The author also wishes to thank them for the comments they have passed on this paper.

#### REFERENCES

- DENNING, P.J. (1980), "October 14, 1980", *Commun. ACM*, 23, 12, pp. 673-74.
- DIGITAL EQUIPMENT CORPORATION (1976), "DECNET Digital Network Architecture, General Description Manual", AA-H202A-TK.
- FERNANDEZ, J.J. (1978), "A Communications Network Linking DEC System 10s and a CDC Cyber", *Proc. 8th Aust. Comp. Conf.*, Canberra, pp. 485-500.
- HELLER, P.S. (1978), "The Edunet Story", *Edunet News*, No. 10, Winter 1978, p. 1 (contained in *Educom Bulletin*, 13, 4, Winter 1978).
- HERMAN-GIDDENS, G.S., WARREN, R.B., BARR, R.C., and SPACH, M.S. (1975), "BIOMAC: Block-Structured Programming using PDP-11 Assembler Language", *Software Practice and Experience*, 5, 4, pp. 359-74.
- MOORE, D.W.G., JARVIS, C.L., and NICHOLLS, I.G. (1966), "User Efficiency in a Time-Shared Environment", *Proc. 3rd Aust. Comp. Conf.*, Canberra, pp. 282-85.
- NICHOLLS, I.G. (1969), "On-Line Computing in a Small University", *Proc. 4th Aust. Comp. Conf.*, Adelaide, pp. 245-49.
- REID, T.A. (1977), "The Case for a Feasibility Study of a W.A. Regional Computing Network", *Report of the Technical Sub-Committee of the Network Advisory Committee*, W.A. Regional Computing Centre.
- SCOTT, R., MASSY, W., HUGHES, R., KURTZ, T., MCCREDIE, J., ROBINSON, R., and SPIES, R. (1978), "The Edunet Business Plan", *Educom*, 31 Oct., 1978, pp. 15-17.
- UHLIG, R.P., FARBER, D.J., and BAIR, J.H. (1979), *The Office of the Future*, North-Holland, pp. 23-45.

#### BIOGRAPHICAL NOTE

The author entered computing in 1961 at the Weapons Research Establishment in South Australia, and then worked for the Bureau of Statistics before joining the staff of the Computing Centre at the University of Western Australia in 1969. He became Director of that Centre (now the Western Australian Regional Computing Centre) in 1979. He has a BSc degree and the Dip Comp from the University, and spent three years lecturing in the Diploma in Computation program there. He was awarded the ACS Case Study Prize in 1978 for his paper, "The Trials and Tribulations of an On-Line Computer Project".