For Telecom Australia
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Trends in Telecommunications Technology and Techniques

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TRENDS IN TELECOMMUNICATIONS TECHNOLOGY AND TECHNIQUES

An Information Paper prepared by staff of the Research Laboratories, Telecom Australia

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FOREWORD

This paper provides a comprehensive review of approaching developments in telecommunications technology and techniques. It seeks to assist Telecom Australia's planning of its technical research, development and innovative activities directed at improvement or diversification of the services it provides to the people of Australia or the development and improved operation of its telecommunications network - as Telecom enters an era of change. This era will see a continuing convergence and growing interdependence of telecommunications and computer technologies. The products of these technologies will create demands for national telecommunications networks to support an increasingly diverse range of customer services. These same forces will change the traditional roles of established organisations providing these services, as more enterprises seek to participate in their marketing.

The paper has been prepared by the Research Department as one of its responsibilities in the annual cycle of events which yields Telecom's corporate 3-Year Programme of Research, Development and Innovation (RDI).

The primary emphasis of this paper is on possible technological futures in telecommunications and the resulting major technical issues which must be considered in Telecom's strategic thinking on future developments in customer services or network systems. The paper does not attempt to predict whether or when Telecom will introduce a technical innovation; it merely outlines possibilities foreseeable from available evidence of world advances in telecommunications technology and techniques.

In the next RDI programming cycle, the Headquarters Engineering Department will build on this paper to produce a sequel which appraises the technological possibilities in the light of customer and network demands, operating costs and efficiences, industrial relations, manufacturing and supply, and other considerations - to make more definite predictions about the nature and timing of innovations being considered by Telecom.

Apart from its primary purpose in the context of the RDI Programme, the paper has relevance to Telecom's strategic thinking for the future on other issues, such as manpower skills, recruitment and training, finance, marketing, its relationships with industry, etc. It is therefore a corporate information paper of more general application in other planning processes.

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4/12/1981

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1. INTRODUCTION.

1.1 Description and Purpose.

This paper has been prepared to provide a comprehensive overview of the major trends in telecommunications technology and techniques which could find future application in the telecommunications services provided by Telecom and in the development of the network over which Telecom provides these services to the people of Australia.

The paper is intended to provide one of the inputs to the regular processes by which Telecom corporately plans and programmes its activities which comprise research, development or design, using existing or new techniques and technologies, and which are related to possible or planned technical innovations in telecommunications services or network systems. These processes culminate in the annual preparation of the corporate 3 year Programme of Research, Development and Innovation (RDI). The formulation of this programme is guided by RDI Strategic Guidelines, which are prepared, and revised from time to time, to indicate management objectives for this type of innovative activity in the light of Telecom's charter, other corporate plans and a range of social, economic, technical and other environmental pressures.

The paper seeks to inform management about longer-term future possibilities, through advances in technology and techniques,for improving or diversifying customer services or for developing and operating the telecommunications network, and so to promote corporate discussion of these possibilities in the formulation of the RDI Strategic Guidelines and subsequent plans and programmes. The outcome of these discussions will be documented in more detail through RDI processes by the Engineering Department, in its subsequent preparation of a document entitled "Appraisal of Technological Innovations". The sequential preparation of the "Trends" and "Appraisal" documents is a cyclic procedure which was established in 1978 as a regular part of the RDI process. This edition of "Trends" marks the start of the second cycle.

This "Trends" paper gives primary emphasis to future technical issues which might arise from world advances in fundamental materials science and electronics technology. After surveying the trends in these fundamental areas, it highlights the technical aspects of likely resultant changes in telecommunications services or techniques which could become technically practicable in the Australian context. The next "Appraisal" paper will extend these considerations to encompass social, economic, network evolution, logistics and resource factors to outline, with more deliberation, those innovations which might be introduced by Telecom Australia in either its telecommunications service offerings or in its network, in a broad time scale compatible with community demands and the evolutionary Australian network environment.

1.2 Horizon and Datum of Overview.

The view outlined in this paper of future trends in telecommunications has a horizon extending a decade and more hence. The datum against which this horizon is based comprises the spectrum of services already provided by Telecom, those improved or new services planned for introduction in the near future, and the associated network developments in hand or planned to provide these services.

A brief overview of this datum is given in Appendix 1. It depicts an extensive Telecom network already embarked upon a change from established technology based on analogue telephone signal handling and electro-mechanical switching techniques to more recent technologies using all-electronic digital signal handling and stored program controlled switching techniques. It outlines changes being made to accommodate the requirements of its customers, particularly the business sector, for improved telephony and data transmission services made technically and economically possible by these new techniques. These in turn owe their realisation to recent rapid changes in electronics technology, particularly microelectronics.

It is particularly significant that microelectronics technology is relevant to the provision of both telecommunications and computer-based services and that the adoption of a new technology or technique in either service area often promotes the desirability and viability of further change in both areas.

1.3 Classification and Presentation of Material.

There are a number of ways of organising the material of this paper for presentation. However, the interactive nature of most classification groupings makes it difficult to classify the material in a clear sequence based on cause and effect, and some overlap must be tolerated between the major sub-divisions of the material.

The topics discussed in this paper have been grouped according to the following three main classifications:

- trends in fundamental telecommunications technology
- trends in telecommunications services
- trends in telecommunications techniques.

Chapter 2 of the paper provides a management overview of these trends and discusses some of their broader implications. Chapters 3, 4 and 5 of the paper give more detailed outlines of trends under each of the three classifications, in the order listed above. The material presented under each classification is sub-divided along the lines indicated in Figure 1.1.

The ultimate adoption of any change in technology or technique which results in the provision of a new or improved service must do so at a cost acceptable to the customer. Quite often, the introduction of a new service must wait for its economic viability on the maturation and adoption of a new telecommunications technology or technique. However, alternative patterns of cause and effect can occur. For example, the adoption of a new network technique for operational reasons can result in cost-effective opportunities to provide new or enhanced services to the customer. Alternatively, new materials, components or manufacturing technologies can find their expression in new developments in customer terminals, which create customer demands for new facilities. Together, customer and operational demands then dictate particular network solutions, often requiring the adoption of new telecommunications techniques in substantial parts of the existing networks or the creation of new overlay networks.

The pages which follow present a view of the major trends in technology, services and techniques of likely interest to Telecom Australia within the next decade or so, and of some of their principal interactions and potential implications in the longer term future.

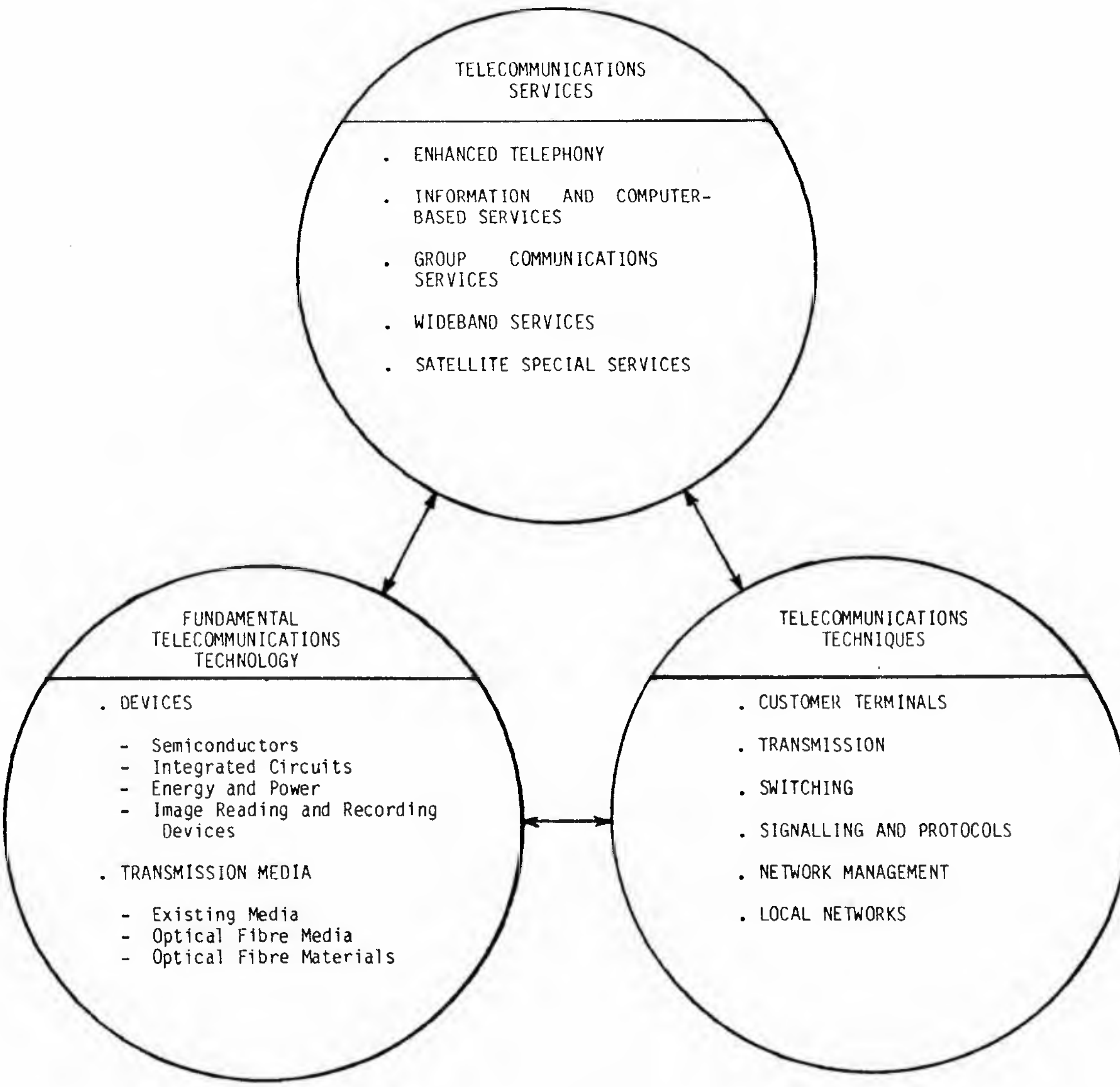


FIGURE 1.1 - CLASSIFICATION OF TRENDS IN TELECOMMUNICATIONS

2. OVERVIEW OF FUTURE TRENDS AND SOME IMPLICATIONS

2.1 Introduction

The future trends in telecommunications technology, services and techniques are treated in detail in Chapters 3, 4 and 5 respectively. A brief summary of these trends is given in this Chapter for the reader who desires a quick overview. Conclusions are then drawn from the trends to highlight some of the implications inherent in them.

2.2 Summary of Future Trends

2.2.1 Trends in Telecommunications Technology

(i) Device Technology

Rapid changes are taking place in various aspects of device technology, particularly relating to materials, device capability, power consumption and cost.

The emphasis on semiconductor techniques is increasing, with challenges to current memory and printing technology coming from wafer-scale integrated circuits (IC) and laser printers respectively. Memory capacity and speed are both being extended in new semiconductor devices without significant cost increases. Megabit capacity per IC device chip can now be realised and gigabit capacity is expected before the end of the decade. Laser printers can print up to 45 A4 pages per minute.

Many special purpose ICs are now being developed to perform specific functions, some of which include analogue as well as digital processes within the one chip. Some of these functions include line interfacing, digital switching, signal processing, and monitoring and testing.

The scale of integration is increasing, with progressively greater emphasis being placed on large scale integration (LSI) and very large scale integration (VLSI), particularly in processor and memory chips, resulting in greater processing power at decreasing cost. More than 100 000 devices per chip can be realised now, and the exponential growth in the number of devices incorporated on a single chip is expected to continue for at least another five years.

Gallium arsenide device technology is challenging silicon device technology in the high frequency/high bit rate fields. It is also becoming increasingly important in the conversion (both ways) between optical and electrical signals. A sixfold increase in speed can be obtained by using gallium arsenide, resulting in switching speeds of 17 picoseconds (10^{-12} seconds) compared to 100 picoseconds for silicon, while the upper frequency capability of 2 GHz for silicon has been extended to 70 GHz by the use of gallium arsenide.

The use of gallium arsenide together with other elements, particularly indium or aluminium, is enabling transmission at longer wavelengths than the 0.85 micrometre (μm) presently possible with silicon to be achieved over optical fibres, ranging through the 1.3 - 1.6 μm band and eventually to the 2 - 5 μm band.

The increasing emphasis on semiconductor technology and the increasing movement towards LSI and VLSI is helping to reduce power consumption and hence energy costs, and this trend will continue. The efficiency of direct solar cell conversion from solar to electrical energy will increase with the use of better silicon techniques and later through the use of other materials.

Solar-to-thermal conversion systems will play an increasing part in the air-conditioning of both offices and equipment rooms as they become cost-competitive with systems operated from commercially supplied electricity.

(ii) Transmission Technology

Metal cable technology is now almost fully matured, with little scope for further significant development or cost reduction. Graded index optical fibre cables are now maturing in development, but with considerable potential for both further development and cost reduction.

Currently, optical fibre cable systems which are economically competitive with systems based on metal cables are available on a production basis. These systems combine multi-mode fibres operating at 0.85 μm wavelength, silicon detectors and gallium arsenide emitters. For good quality systems, the bandwidth available over a 1 km path is 800 MHz, and path loss is just under 3 dB/km. Fibre losses can be reduced to about 0.5 dB/km at wavelengths of 1.3 or 1.55 μm and bandwidths of 2000 MHz can be obtained over 1 km at wavelengths in the vicinity of 1.3 μm, but this requires the use of different semiconductor materials for sources and detectors. These latter devices are expected to become commercially available in 3 to 6 years.

Single mode fibres are being developed and these should yield bandwidths at 1 km of about 100 GHz at a wavelength of 1.3 μm, with an attenuation of about 0.4 dB/km. Cables using such fibres should become available in the second half of the 1980s.

Further developments in optical fibres depend on the development of ultra-pure glass materials with low optical scattering and absorption. Experimental figures of 0.01 dB/km attenuation have been obtained at a wavelength of 4.6 μm, but considerable further development is required to realise economically viable systems operating at this wavelength.

2.2.2 Trends in Telecommunication Services

Interest is growing in various forms of service, including voice and non-voice. Non-voice services utilise voice bandwidth in some instances and are wideband in others. In many instances, particularly for services involving voice bandwidths, technological limitations are no longer relevant; the limiting considerations are customer acceptability, marketing, regulation issues, etc.

Services are currently defined in terms of customer requirements and also in terms of network capability. Telecommunications services are currently provided by a number of special purpose networks devoted to specific purposes, such as the public switched telephony network (PSTN), the digital data network (DDN) and the packet switched network (PSN), each of which is designed to suit a particular type of service. There is a strong move towards the "integrated services digital network (ISDN)" concept, in which the customer will see a single network interface for all services. Within the ISDN, network resources will be shared between services. It is expected that early evolutionary forms of ISDN will be established in the second half of this decade.

There is also a marked trend towards the extension of digital lines to customers' terminals and the use of intelligence in these terminals.

Major trends in various services are as follows:

(i) Telephony

The telephone will be equipped with a keypad, a display facility and internal intelligence, which will enable it to display dialled number or other data, provide repertory dialling, display call duration and cost information, etc. In combination with additional network capability, re-direction of calls, display of called number, message storage, use of synthetic voice announcements to assist users of advanced facilities, use of voice recognition for control purposes, etc., are all technically feasible.

The use of cellular radio techniques will permit enhancement of mobile and paging services, and developments in radio technology are leading towards two-way paging communication and rationalisation of paging and mobile services. Digital radio techniques are also being extended into the rural areas, enabling the provision of most of the facilities which will be available in the metropolitan areas.

(ii) Information-Based Services

The development of distributed data bases, small but powerful mini and microcomputers, and the availability of digital techniques on customers' lines will enable a whole new range of services and facilities to be provided, including computer services, data-base access, information retrieval, credit checking, message storage, electronic mail, etc.

The telematic services (videotex, teletex and facsimile) will be enhanced to provide faster service and additional facilities.

The introduction of keypads and displays on customer terminals, including telephones, will lend impetus to more diverse developments in information-based services.

(iii) Group Communications

Business is becoming more and more oriented to interaction between groups of persons. Group communications, or conferencing facilities, are reflecting this tendency. There is increasing use of group communications overseas, both audio-conferencing and video-conferencing, from both private and public facilities. The use of video conferencing is currently limited to interconnection of two locations at any one time, and some technical problems remain to be solved in order to provide simultaneous multi-point interconnection.

Audio-conferencing is well developed as a technique and is ripe for introduction as a network service. It is already provided on PABXs.

(iv) Wideband Services

These include high speed data services and various forms of TV communication, including cable television (CTV), Pay TV, etc. Research trends in service provision are towards the use of optical fibre distribution networks with central switching. A network approach using these techniques may prove technically feasible in the second half of the decade. Digital radio transmission at 30 or 40 GHz, or unguided infra-red transmission are other possibilities for wideband reticulation.

(v) Satellite Services

Special services might be provided by satellite which are difficult by other means. These include rapid trunk relief (which could be by means of a transponder operating at 70 Mbit/s), thin route telephony, enhancement of some special rural services (such as School-of-the-Air), disaster area relief, etc.

2.2.3 Trends in Telecommunications Techniques

(i) Terminal Techniques

Rapid developments are taking place in customer terminals, particularly those used for business purposes. This is arising from the merging and combination of services and technologies which have been traditionally separate. Digital techniques and microprocessors are being used to enable combinations of voice, data, text and image communications to be handled within common terminals. PABXs are already being developed with a capability to handle the various forms of communications used in modern business. Again, these utilise digital technology for both communications and control. Increasingly flexible and versatile terminals can be expected as manufacturers progressively acquire a broader base for products handling voice, data, text and image communications.

There is continuing development in digital speech coding techniques and the bit rate required to transmit speech is being progressively reduced. Currently, it appears practical, but expensive, to code speech at 4.8 kbit/s for transmission over data circuits. Semiconductor developments, volume production and coding improvements will all tend to reduce the costs of data-rate speech coding to an attractive cost.

Synthetic speech and voice recognition will be used to make terminals more user-friendly and to increase versatility without increase of complexity.

Encryption will progressively become more important for commercial security reasons. Techniques for its application in digital circuits are now available, and volume production will reduce the costs of the IC devices employing these techniques.

(ii) Network Techniques

Development is taking place on all aspects of network techniques, namely, for transmission, switching, signalling, network management, and the newly identified sector of importance, local networks.

These developments indicate an evolutionary progression towards the establishment of all-digital networks, with the extension of digital transmission and the imminent introduction of digital switching in the Telecom network. This digital evolution will form a foundation for the eventual introduction of an ISDN, probably in the 1990s.

Identifiable trends in transmission techniques include:

- the introduction of high capacity digital radio systems in the trunk network and medium capacity digital radio systems in the junction network

- the introduction of first generation (0.85 μm wavelength) optical fibre systems in the junction network and later application of subsequent generations of optical fibre systems in both the trunk and junction networks, and possibly in submarine cable applications

- the increasing use of satellites, with later generation systems employing time division multiple access (TDMA) techniques, digital transmission and regeneration, on-board switching and improved spot beam control

- the introduction of digital transmission in the existing local distribution network to support access to a multi-service offering

- the possibility of a replacement wideband distribution network.

The basic trend in switching is towards digital switching for a variety of applications, including:

- circuit switching for voice and data
- message switching
- packet switching for data
- wideband switching, both in large centralised systems and in customer terminals.

Control is becoming more distributed, functionally organised and modular as the cost of processing and storage decreases, with attendant improvements in overall system flexibility and reliability. The extra processing power will be progressively used for self-diagnostic, adaptive strategies in the face of faults and for network management.

Considerable development is taking place in signalling with the trend being towards the use of advanced data network techniques. Between exchanges, common channel (data link) techniques are being introduced, with increasing emphasis on a layered structure in which various functions associated with transport, error control and service "user" information are being segregated into individual, separate, functional layers. The CCITT Signalling System No 7, which embodies these features, will come into common usage late in the 1980s. In local networks, digital signalling techniques having a layered basis will be introduced concurrently with digital transmission on the link from the exchange to the customer's terminal, also probably late in the 1980s. The layered structure will enable a wide variety of services to be provided, thus paving the way for the introduction of the ISDN.

Network management is becoming more important as the networks grow in complexity, size and importance to customers. Some of the more important functions include the provision of:

- effective exchange and route control in situations of unforeseen network overload and failure

- a fast, flexible method for controlling, collecting and distributing operational and maintenance data.

The trend is clearly towards the use of data and computer techniques to assist in the performance of these functions. The rate of introduction of the techniques is controlled by other than technical considerations.

Local networks, in the sense of geographically compact networks serving a particular organisation or group of customers, are achieving increasing importance. These networks can carry a variety of services or combinations of services, including:

- voice
- data
- wideband (TV signals)
- ISDN.

They can utilise central or customer switching, such as in PABXs, etc, or highway-organised systems like those used in computer networks such as Ethernet, Wangnet, etc. These two approaches represent the traditional but different approaches of the telecommunications and computer industries. Both will be well represented in future digital local networks and both types will require interfaces with the public national digital networks.

2.3 Conclusions

There are three major areas in which future trends have profound significance for Telecom; these are in the areas of:

- device technology
- services
- networks.

These three areas are mutually interdependent and subject to external market and industry forces on the one hand and government policies in terms of regulation on the other. The former can be predicted with reasonable confidence. The outcome of the current Government Inquiry into Telecom will determine the latter.

2.3.1 Device Technology

There is considerable pressure in the world semiconductor industry for continued expansion, and a recent ASTEC survey indicates continued strong growth in Australian requirements through the next two decades. Two relevant on-shore initiatives have already been taken, namely, the establishment of a VLSI design facility in South Australia by the CSIRO and of a microwave technology centre at Queensland University. The establishment of a silicon wafer fabrication and circuit design facility in Canberra by NATSEMI (National Semiconductor) is under active consideration by the Government. All three initiatives will assist in providing local industrial capabilities which could be applied in the local production of telecommunications equipment.

While Telecom continues its practice of selecting its major telecommunications systems technologies from those developed overseas by the large international companies, there is little room for the Australian semiconductor facilities to play a dominant role in influencing trends in local manufacture of major telecommunications systems, mostly under licence. Nevertheless, these facilities will have a capability to play significant roles in the local development of specific key devices, the lack of which might restrict the development of locally designed sub-systems which would otherwise be viable. Examples include front end satellite receive amplifiers; electro-optic transducers in the longer wavelengths, etc.

Device technology in the microprocessor and memory fields has considerable momentum overseas and is unlikely to be a significant local activity. However, developments in these fields will have a significant effect on customer terminals and switching, control and signalling systems, and likewise on network control and management. Limiting constraints on what will be achieved will be other than technical.

The major options open to Telecom will derive from the identification of key devices which are required to enhance system performance or permit system development and from the sponsorship of developmental work to realise these devices. Even if the results are not directly applicable, the additional knowledge gained will contribute to product improvement and give Telecom expertise in key elements of future systems.

Important strategic issues for consideration by Telecom concern its approach to ensuring continued local production of major telecommunications systems and the use of locally made components, at least on a second-source basis.

2.3.2 Services

The further development of Australian telecommunications services depends quite critically on Government policy (regulation), market forces, offerings from private industry and Telecom initiatives. Technology itself does not constitute a restriction to further developments, but reductions (which are largely foreseeable) in the cost of some new technological solutions may be required to provide the economic viability necessary to the introduction of services utilising these solutions.

Overseas market surveys and field experience indicate that growth of new services in the domestic sector will be much slower than that in the business sector.

There are three major areas of interest in service development:

- telephony and derived services
- information-based services
- wideband services.

(i) Telephony and Derived Services

The basic telephony service will remain the most significant component of the total services provided in Australia for the foreseeable future. However, an enhanced telephony service will develop in the business sector, and audio-conferencing based on telephony will also develop as a generally available service.

In the enhanced service, the new facilities offered will be both exchange-based and terminal-based. Network-oriented facilities will include automatic transfer (follow-me), abbreviated dialling, interception, call charge recording, message store and forward, etc., and must be provided by additional intelligence in switching centres. Telephones will be equipped with intelligence, a keypad and possibly a display to enable additional terminal-based facilities to be supplied. These will include features such as automatic last number re-dial, repertory/abbreviated dialling, wake-up alarm, and displays of call cost information, time and calling line identification. The keypad and display will enable the telephone to be used as a simple terminal for some of the information-based services, particularly for credit checks and data-base access for simple transactions, etc. This will represent the first widespread instance of convergence between telecommunications and computer-based services. Small business systems are already available which provide some of these features.

(ii) Information-Based Services

Currently, Telecom's data transmission (DATEL) service is its major information-based service, in which data is carried either over the public switched telephone network (PSTN) or leased lines. Shortly, data will also be carried over the new Digital Data Network (DDN) and the Packet Switched Network (PSN/AUSTPAC). These two new networks will provide the equivalent of leased line services and switched data services respectively, with transmission speed and price improvements.

Other information-based services include the telematic services, namely, facsimile, teletex and videotex. These could be carried over the PSTN or the future PSN. There is an awakening business interest in these services both overseas and locally. Australian developments will depend heavily on Government policy and the outcome of its current Inquiry into Telecom.

Telematic services will probably be re-defined to take advantage of the additional capabilities offered by 64 kbit/s customer lines. A degree of service convergence will also simultaneously occur with this latter development. Terminals will become data, text and image-oriented, and the concept of separately identified services will fade and be replaced by concepts of information transfer and information retrieval.

The addition of digitally coded voice facilities to an information terminal connected to a digital network will enable terminals to be produced which will have a very wide range of application and which can provide communications on a modal basis, that is, by voice, data, text and image. These terminals will consist of a handset, keypad/keyboard and screen. A scanner and/or printer may also be provided.

(iii) Wideband Services

Wideband services, apart from data, are ill-defined at present in terms of international specifications. Pay TV, Cable TV, point-to-point TV links and video-conferencing are the services most likely to be required. Widespread acceptance of video-conferencing in the business community will probably depend on the availability of either domestic satellite channels or optical fibre cables at an economically viable cost, although earlier service possibilities may arise out of the development of coaxial cable CTV networks.

(iv) Future Service Offerings

The options available to Telecom are unclear due to uncertainty concerning Government policies. Assuming policies favouring Telecom's participation in the provision of new services, their introduction will be determined largely by marketing considerations and technical constraints or possibilities arising from network developments.

Enhanced telephony and information-based services could be provided via the PSTN and PSN at an early stage, using terminals now becoming available. Further service convergence will depend on the provision of an ISDN with digital access available to the customer.

Wideband service options will depend on regulation issues, developments in optical fibre technology and the availability of satellite channels.

2.3.3 Networks

There are three major aspects of networks, each of which is subject to quite different developmental influences and pressures. These are:

- the public main networks themselves, consisting of exchanges and inter-exchange circuits
- public network operation, control and maintenance
- local networks.

(i) The Main Networks

Currently, a transition is taking place in which analogue signal techniques are being supplanted by digital techniques. Examples of this are the evolution of the PSTN towards an integrated digital telephony network (IDTN) and the impending establishment of the digital data network, the packet switching network and the special services network. Each of these networks will be based on the application of digital techniques. The telephony application will be dominant for many years. Consequently, the relative proportion of the PSTN which is digitally based will be small for some time in relative terms, but it will quickly surpass the other networks, which will be totally digital from their inception.

The ability to extend digital lines to the customer's premises and the availability of multi-service digitally connected terminals will increase pressure on the IDTN to carry services other than telephony, thereby initiating the development of an ISDN in which network resources will be shared by a number of different services. At this future stage, the digital portion of the main public network will have to take on the characteristics of a network providing transparent digital connectivity and have a signalling system compatible with the establishment and supervision of circuits without unduly restricting the type of service to be carried. The signalling system will also have to be capable of carrying end-to-end service-related information, such as that relevant to the upper levels of the ISO/CCITT Reference Model of Open Systems Interconnection.

(ii) Public Network Operation, Control and Maintenance

The operation of Telecom's networks will become more complex as they grow, as the number of functions to be served increases and as their relative reserve capacity is reduced (ie. as the networks operate closer to their ultimate capacities). The decisions to be made in times of fault and/or overload will become more complex and more significant in their impact, while the time to make these decisions will decrease. The time is approaching when the ability to make meaningful decisions under these circumstances will be beyond human capability, thus requiring some form of automated, adaptive control. The technology for this is available; the limitations on its general use will be other than technical.

A future high level operational network will also need to maintain details of and automatically allocate network resources (e.g. transmission links, service numbers, etc.) in a more integrated way than is being done on a fragmented basis at present.

(iii) Local Networks

Local networks comprise the infra-structure which links the final switching point of the main network to the customer's terminal. They include the "customer's line" and any subsidiary conditioning equipment which may be required.

Local networks will probably be an area of great overall change, great opportunity and great pressures. Change will be service driven, industry driven and network driven, influenced by regulation, and subject to interface standards set by an external body, the Standards Association of Australia. Iteration between terminal manufacturers and local network providers could well be the greatest force leading to the development of modal communications, integrated terminals and service convergence.

The task of the future local network will be to extend digital transparency from the final switching point of an IDN (or ISDN) to the customer's terminal. It will have to convey all of the signalling information required for network set-up, supervision, etc., and in addition, the signalling (or protocol) information required to enable inter-terminal co-ordination.

The local network has been subject to the traditional telecommunications networking skills in the past, and these skills are still being applied, particularly in the case of private networks served by PABXs. However, the computer industry has also developed networking skills of a different type, which are optimised for information-based services. It is now active in developing local networks of a different type to those being developed by the telecommunications industry. For both technical and economic reasons, these networks cannot be sensibly ignored where information-based services are involved. Consequently, the local network scene will probably contain a diversity of approach in the future.

(iv) Future Network Options

The options available in the networks field will be influenced by:

- approaches towards network provision; how much diversification into specialised networks occurs and how much resource sharing between services is provided in the evolution towards an ISDN;

- approaches towards local networks, for both narrowband and wideband services. Serious moves towards the development of an ISDN will require a clear approach towards service definition, followed by a clear approach towards protocols and customer access to the main networks via a local network originated either by the telecommunications industry or by the computer industry.

Service regulation in the early stages will be a relatively simple matter upon which to pronounce. As convergence progresses and the distinction between services becomes blurred, it will be less easy to make pronouncements, and consequently, additional opportunities will arise for both Telecom and its future competitors. From this viewpoint, some options are going to become easier, while others will become more difficult to exercise.

3. TRENDS IN FUNDAMENTAL TELECOMMUNICATIONS TECHNOLOGY

3.1 Introduction

Network customers of the future will increasingly demand a basic telecommunications service which offers a number of optional communication modes (e.g. data, voice, image) and a number of different access modes (e.g. simultaneous, alternate, uni- or bi-directional). To cater for such a future, the progressive deployment of advances in both device and media technologies will be necessary to enable the following broad requirements to be met:

- enhancement of some existing services
- introduction of new services demanded by customers
- improved utilisation of telecommunications networks.

Advances in device technologies will be achieved through advances in materials science and technology, together with continuing refinements in manufacturing processes. Driving forces directing new device developments will include:

- the need for efficient use of available bandwidth for both guided and free space transmission
- the continuing need for reduction in the unit cost of circuit functions
- the need for efficient use of energy, e.g. on a per circuit function basis
- the need for flexibility in network and terminal control in a geographical, modular and functional sense.

Considerations of materials science and technology will also continue to dominate the changing scene in transmission media. High purity glass technology and associated manufacturing processes will increasingly challenge established metal based technology. Advances in wideband optical fibre cables together with advances in opto-electronic devices will complement many of the advances expected in other more general areas of device technologies and manufacture.

The synergy of all these developments will permit a continuing reduction of per circuit costs of high capacity trunk systems and, in the distribution network, architectures offering a flexibility and capacity hitherto beyond the realm of economic feasibility. This chapter therefore sets the scene for the following chapters by addressing significant advances in fundamental technology. The trends described are linked with materials and manufacturing process technologies and with the continuing drive to broaden device and circuit application areas.

3.2 Telecommunications Device Technology

3.2.1 Introduction

Historically, advances in telecommunications device technologies have made possible later developments in telecommunications transmission and switching systems, and as these developments have found wide ranging application, the original device technologies have greatly influenced network evolution. In addition, advances and refinements in production processes have made practical and economic equipment designs only feasible with contemporary technology. For example, in terms of circuit design, all-electronic telephones and switchblocks have been feasible for a number of years. However, they only became a practical proposition with the development of large scale integrated (LSI) circuits in the mid to late 1970s.

This pattern of development is expected to continue, but with some noticeable new trends. For example, the rate of development and change will increase, with more functional capability being provided in future systems and an increasing pervasion of intelligence throughout the network.

The main features of foreseeable trends in telecommunications device technologies over the next 10-15 years are outlined under the headings following.

3.2.2 Semiconductor Technology

Since the development of the first integrated circuits in 1963, silicon has remained the most commonly used semiconductor material, being both abundant and cheap and requiring relatively simple refining and crystal growth technology. With the subsequent refinements required by circuit designers, demands on crystal perfection and range and control of electronic properties have increased considerably. Silicon has been able to meet many of the demands made of it, and its continued dominance as a general semiconductor circuit material is assured in the foreseeable future. Indeed, its application extends into the microwave, optical, high current, high voltage and high power discrete device domains as well as in "silicon chip" integrated circuits.

In the quest for better circuit performance, increasingly sophisticated fabrication process technologies are being adopted. Techniques such as molecular beam epitaxy, ion implantation and electron beam lithography are giving device fabricators better control over dimensions and yielding devices with increasingly high operational speeds and packing densities. Coupled with essentially defect-free silicon crystal growth techniques and microscopically planar-surfaced wafer preparation, these technologies are making possible the production of very large scale integrated (VLSI) circuits with commercially viable yields. During the 1980s, these developments will have significant technical and economic benefits in computing and telecommunications.

Researchers are also looking to the gallium arsenide family of compound semiconductors as materials with which to build circuits and devices that operate at higher speeds than are possible with silicon at present. Though its technology is more difficult, gallium arsenide has significant performance advantages over silicon because of its fundamental material properties. Specifically, gallium arsenide devices are less temperature sensitive, have higher gain, use less power, and have higher speeds of operation when compared with silicon devices in the same configurations. Although its device fabrication technology is not as simple as that of silicon because it does not form as highly stable an oxide as silicon, the performance advantages of gallium arsenide will be increasingly utilised in microwave and high speed logic integrated circuits for satellite, microwave radio and computer systems.

In addition to its high frequency capabilities, gallium arsenide and its related semiconductor compounds exhibit a number of phenomenological properties not shared with silicon. The most significant of these for telecommunications in the short term is its ability to convert electrical signals to optical signals for optical communications. Already, directly modulated semiconductor lasers operating at wavelengths compatible with low loss fibres have been demonstrated in system applications. The future will see an increase in optical integrated circuits with electrically analogous components working in the optical domain and a progressive integration of photonic and electronic functions on single chips of these materials at the electrical network interface.

While silicon and gallium arsenide based semiconductor technologies have been developed to a high degree of sophistication, new technologies in other semiconductor and superconductor materials are being researched for a diverse range of applications. Of these, the cadmium sulphide family of semiconductor compounds is of interest for solar-to-electrical energy conversion and the next decade should see significant developments in this area of application. In the very high speed switching area, the development of the superconducting Josephson junction is becoming of increasing interest, particularly for computer applications. Switching speeds of 1 picosecond (10^{-12} seconds) have already been achieved in such devices, compared with 17 ps in gallium arsenide and 100 ps in silicon devices.

In future, new phenomena and advances in materials and device fabrication technologies will be exploited in what is a rapidly changing and rapidly adaptable field of microelectronics.

(i) Optical Devices

The development of low loss optical fibres over the last decade has been coupled with the development of compatible, reliable semiconductor laser sources. Lasers emitting at the currently used wavelength of 0.85 micrometre (μm) are complex structures based on mixed compounds of gallium and aluminium arsenides. Reliable lasers with estimated lifetimes beyond 20 000 hours and coupled powers of 2 mW, which are adequate for many envisaged applications, are now available from a number of manufacturers at a cost of approximately $250. As current system trials give way to applications in the network, the increased market volume for laser sources should lead to a significant reduction in cost.

The next generation of optical fibre systems, which are expected to operate at wavelengths of 1.3 - 1.6 μm will have the advantages of larger bandwidths and longer repeater spacings than the current shorter wavelength systems. For these longer wavelengths, sources based on mixed compounds of indium, gallium, arsenic and phosphorous are becoming available, though the initial costs are high ($3000-$5000).

Silicon detectors for the 0.85 μm wavelength have been very successful. However, for the longer wavelengths (1.3 - 1.6 μm), detectors based on indium gallium arsenide in an integrated detector/amplifier circuit are expected to satisfy receiver needs.

In the longer term, the 2-5 μm region holds the promise of very long, unrepeatered systems. Although sources and detectors at these longer wavelengths are available, the intensive development needed to demonstrate their viability for long-haul communications will depend on parallel developments being made in optical fibres at these wavelengths.

Signal processing in optical communications systems is at present performed essentially at baseband in the electrical domain. Current trends in optical component research indicate that many electrical functions have optical analogies and can be performed at optical frequencies. Some optical components are being integrated in the same chip as the laser diode and are already finding application in specialised items of equipment. Increasingly, optical integrated circuits will allow signal processing in the optical domain and should make such devices as optical system repeaters simpler in the future. Single chip integration of photonic and electronic devices and functions at the electrical network interface could also benefit present day communication systems both technically and economically. Some simple integrated devices have been demonstrated in laboratories, but this technology is as yet in its infancy.

(ii) Microwave Technology

The trends in microwave technology are toward improved performance, better reliability, increased efficiency and lower cost. These goals are progressively being realised with the growing monopoly of solid state device integration at higher frequencies. Under the strong impetus of increasing microwave radio, satellite telephony and satellite direct broadcasting applications, significant gains are currently being made in the areas of design and mass production techniques for both digital and analogue microwave systems.

In microwave technology, gallium arsenide is achieving the prominence silicon has gained at frequencies below about 2 GHz. Of gallium arsenide devices, the most significant to emerge recently is the metal-semiconductor field-effect transistor (MESFET). This device offers both low noise and medium power handling capabilities and is undergoing intensive development by a number of the major microwave equipment manufacturers. While the emphasis in microwave circuit technology to date has been to use such discrete devices in wave-guide or, more recently, in hybrid microstrip transmission line configurations, future microwave circuits will be increasingly monolithically integrated (including active and passive components, both lumped and distributed) on modular gallium arsenide chips. The element-to-element interfaces, which cause major problems in discrete component circuits, become virtually transparent in monolithic circuits. Monolithic approaches are particularly exciting since they may lead to new types of components unimagined in other circuit technologies. It is now possible to conceive an entire sub-system with gigabit speed digital processing, digital-to-analogue conversion, microwave amplification and perhaps acoustic wave oscillator stabilisation all integrated on a single chip.

Future developments in microwave technology are expected to concentrate on improving device performance and cost in circuit functions such as mixing, switching, filtering, modulation, frequency generation and amplification. MESFETs, both low noise and high power, will be increasingly used in new generation equipment. Already, MESFETs capable of replacing thermionic travelling wave amplifiers up to 40 GHz are being demonstrated, while frequencies of application in low noise amplifier configurations have been extended to 70 GHz. Future developments will also address design philosophies that make mass-produced microwave integrated circuits insensitive to component fabrication tolerances to avoid the common microwave problem of individual circuit adjustment in situ.

3.2.3 Integrated Circuit Technology

Integrated circuit (IC) technology is a major underlying contributor to trends in telecommunications technology. Future advances are anticipated in the scale of integration and in the use of ICs to provide both special purpose devices and distributed intelligence at network nodes.

(i) Integrated Circuit Device Scaling : LSI & VLSI

The past decade has seen very rapid improvements in integrated circuit fabrication process technologies, enabling both chip areas to be increased and more transistor devices, and hence more circuit functions, to be packed into a given chip area. These large scale and very large scale integration (LSI and VLSI) technologies have yielded increasingly complex and powerful integrated circuits. These improvements are a direct consequence of various process technology developments, including improved device structures and device definition; improvements in circuit design enabling simpler functional module realisation and improved applications orientation; and greater use of computer-aided design approaches for certain types of circuit function.

Five years ago saw the availability of circuits with 5000 devices per chip; today, more than 100 000 devices can be found in one package. This growth trend has been exponential and should continue so for at least the next five years. The most important consequences of LSI/VLSI realisations associated with greater functional density per chip are:

- improved performance per function
- more powerful real-time control capabilities
- lower overall cost per circuit function
- intelligent logic associated with a diverse range of non-digital circuit functions - a particularly useful combination in telecommunications applications.

The limiting factors on continued exponential growth in the scale of silicon integrated circuits in the coming decade include:

- the imminent approach of some fundamental device physical limits
- the difficulty of providing a multiplicity of external package connections to small semiconductor chips
- the need to dispose of increased levels of heat dissipated from small areas
- as the major difficulty, the realisation of suitable applications which fully use the potential to achieve entire sub-systems on a

chip (i.e. sub-system applications that would be sufficiently ubiquitous to warrant mass production).

These matters are now receiving considerable attention and further advances can be anticipated in the next few years.

The consequences of accelerating growth in device scale for telecommunications developments include:

- the design of telecommunications equipment systems and sub-systems may be carried out at the semiconductor chip level; the benefits lie in performance, cost, power consumption and space requirements;

- the development of equipment based on specialised, custom-designed, complex integrated circuits produced in-house by telecommunications manufacturers will become common; this may introduce component second sourcing and system maintenance complications for equipment users.

(ii) Special Purpose Telecommunications Devices

During the sixties and seventies, the semiconductor industry was strongly aligned to the needs of the computer, consumer and industrial control markets. Most recently, and continuing into the next decade, semiconductor device manufacturers are concentrating effort towards the development of specialised ICs for application in telecommunications systems. The estimated share of the world semiconductor device market devoted to telecommunications in 1985 is fifteen per cent, worth approximately US $7 billion in that year.

This trend towards an increasing range of specialised telecommunications devices may be attributed to:

- anticipated growth in the demand for telecommunications services

- subsequent marketing interest shown by major semiconductor houses

- increases in circuit complexity permitted by LSI/VLSI technology

- the ability of complex semiconductor circuits to meet stringent performance specifications imposed in many telecommunications environments.

In particular, this field of application has called upon IC applications specialists to identify complex sub-systems for silicon integration. The trend has been in two major directions:

- the development of specialised digital circuits for switching, data protocols, etc

- the evolution of new design and fabrication methods which achieve combined analogue and digital functions in one circuit.

There is a large body of circuitry in the latter category which simplifies system design for digital switching and transmission systems, line interfacing, and signal processing in general. The ability to include digital monitoring and testing facilities for remote, automated maintenance within individual sub-systems should become evident within the next few years.

Aside from improved performance and maintenance aspects, two likely major consequences of the telecommunications IC thrust are:

- a progressive reduction in equipment lifetimes, not through lower reliability levels but more as a result of:
  - a lack of long-term device back-up, as a consequence of rapid change;
  - a high rate of technology turnover, as a result of lower priced, higher performance and capacity devices appearing every couple of years.
- the likely proliferation of customer systems with various degrees of sophistication made available at relatively low cost, providing circumstances where the telecommunications user may wish to have the freedom to choose a system - at his own expense.

(iii) Memory Devices

Over the past decade, integrated semiconductor memory circuits have provided a direct measure of the state of semiconductor technology achievement at any particular time. Sixty-four thousand bit memory chips are now commercially available in metal oxide semiconductor (MOS) technology, and capacities of several million bits have been achieved in laboratory developments.

The significance of memory device developments to telecommunications systems has become apparent in the past decade, when the availability of large capacity memories, either magnetic or semiconductor, has provided extensive system control flexibility through stored program control (SPC) methods. Combined with microprocessor and state machine logic techniques, the semiconductor memory has enabled the increasing adoption of remote processing, more flexible implementation of intelligent terminals, and lower cost control-processor development.

Steady improvement in VLSI semiconductor memory technology is anticipated over the coming decade with major developments providing reductions in access time and power dissipation. These developments will enhance the potential for application of memory circuits in telecommunications.

In the field of mass storage, semiconductor wafer-scale ICs are expected to overtake the role previously assumed for magnetic bubble memories. Already, laboratory developments have yielded several million bits of memory in one device. Storage capacities of more than one thousand million bits are anticipated in multi-layer wafer-scale semiconductor memory devices within a decade. The realisation of these capacities will push semiconductor materials processing techniques to their limit and could require the use of new memory circuit configurations to bypass a percentage of faulty memory elements which will have to be tolerated in production devices.

Further developments in the memory device field indicate the future feasibility of remote electrical erasure and reprogramming of moderately sized memories, and the emergence of non-volatile semiconductor random access memory (RAM) circuits. Special purpose signal processing applications will be satisfied by charge-coupled device technology, although such memories will be limited in capacity.

(iv) Processing Intelligence and Logical Control

Digital signal processing, the microprocessor phenomenon and the power of the computer are well known to telecommunications. Extensive, low-cost memory capacities, combined with specialised minicomputers for control, have introduced the stored program controlled (SPC) switching era. Microprocessor developments have led not only to distributed control techniques in switching systems but also to intelligent terminals for the customer and a whole range of versatile testing and monitoring equipments.

The coming decade will see further developments in computer-based technology, particularly in the following respects:

- a continuing decrease in the cost of computing power and control intelligence

- a blurring of the traditional distinctions between micro, mini and main-frame computers. Single and multi-chip micro-computers are now reaching former minicomputer capabilities (thirty-two bit words; terra-byte addressing capability; built-in operating systems; high-level language capabilities). Minicomputers with storage capabilities of several megabytes are attaining the speeds and processing power of main-frame computers of the seventies. Advanced main-frame computers are specialising in multi-task, high capacity data processing applications.

- a general increase in the overall processing capacity of intelligent machines at all levels.

The impact of these developments will continue to be seen in developing data switching systems, in distributed control as a common system design philosophy, and in more intelligent terminals and business systems.

Innovations in processor architectures are rather infrequent. Most of the development trends in this field are associated with device technology advances. For example, it is envisaged that main-frame computer systems with cycle times of the order of five nanoseconds and one hundred times the computing power of current, large systems could be achieved with Josephson cryogenic device technology. Advances in the application of high level programming languages (e.g. PASCAL, ADA) to the lower complexity micro-scale processors will continue to reduce the cost of widespread intelligent control in all types of telecommunications equipment.

An additional aspect of logical control technology is the advent of economical custom-designed VLSI device and logic array technologies. These are only beginning to impact on systems technology, but they should greatly improve functional performance capabilities, reduce cost per function, and increase levels of proprietary and system secrecy in the next decade. The proliferation of general purpose mass-produced transistor-transistor logic (TTL) chips currently seen in control equipment will be replaced by fewer, improved performance, custom-made logic circuits. In many cases, these techniques will be applied as a lower cost, higher performance alternative to microprocessor-based control systems, the great advantage lying in replacing the costly software functions with efficient, "hard-wired" circuitry.

3.2.4 Energy and Power Considerations

The anticipated energy crisis will increasingly require telecommunications network administrators to incorporate new forms of energy supply. Notable among these is solar energy. Designers of integrated circuits will look to low power designs to overcome energy supply problems and heat dissipation problems in large scale circuits.

(i) Low Power Device Technology

In a number of complex integrated circuit applications fields, there is strong justification for minimising the power consumption per circuit function. This is particularly so in the telecommunications field, considering:

- continuing increases in energy costs
- the considerable cost of air conditioning and temperature control equipment for major systems installations
- the recently proven viability of alternative power sources, their use being feasible only for equipment systems having low dissipation levels
- the increasing degree of technological sophistication of remote, unattended equipment requiring independent, low capacity power supplies
- the need to minimise the power consumption of multi-facility customer terminal equipment powered by exchange battery via telephone lines.

Various recent developments in device technology are contributing to the continuing reduction in IC power dissipation. These include fabrication process technology improvements leading to smaller, more efficient device scaling and various circuit design innovations which provide greatly reduced dissipation per function. The design methods, including switched capacitor and charge parcelling analogue circuits, are most suited to metal oxide semiconductor (MOS) technologies, particularly complementary MOS (CMOS).

Most specialist telecommunications circuits are being implemented in low-power CMOS technology, a trend which is expected to continue. It is predicted that by 1985, about 60% of all ICs used in telecommunications equipment will be implemented in MOS technology, at least 40% of which will involve low-power CMOS.

(ii) Energy Conversion

Since 1970, the rate of oil discovery has not kept pace with the rate of consumption, heralding a foreseeable end to abundant cheap supplies of oil-based fuels. Over the next two decades, further dramatic changes in cost and availability can be anticipated for the reason of both declining supply and perhaps political instability in major oil producing countries. The impact of this scenario on Australia will be ameliorated in the short to medium term because of the availability of indigenous fossil fuel supplies. Mobile transport fuels will undoubtedly have the more immediate impact and this will affect the operation of Telecom's large vehicle fleet. While conservation measures and alternative fuel sources such as Compressed Natural Gas (CNG), Liquified Petroleum Gas (LPG) and supplemental organically generated alcohol fuels will alleviate the immediacy of the problem, new energy technologies being developed, such as electrical or hydrogen powered vehicles, will need to be adapted to satisfy Telecom's long term needs.

As part of the global R&D energy effort, the development of photovoltaic solar cells has accelerated and the US Department of Energy (DOE) is confident that photovoltaic energy will be cost competitive with thermally generated electricity within the decade. With increasing application in remote installations in thin route trunk repeaters, and in satellite and digital radio concentrator system (DRCS) terminal equipment where solar power is already cost competitive, Telecom will benefit in the short term from developments in solar photovoltaics. Solar cells have been traditionally made from expensive single crystal silicon as a spin-off from space power applications. They are giving way to cheaper polycrystalline silicon cells and cells made from other materials for terrestrial applications. Among the other preferred materials, gallium arsenide looks promising for special applications (e.g. in concentrators), while the greatest hope for distributed solar power lies with some of the more abundant cadmium sulphide family of compound semiconductors. The concept of integrated rooftop applications envisaged for the latter materials awaits the technical solution of current lifetime problems. Recent breakthroughs in semiconductor-electrolyte cells also hold promise of low cost photovoltaic generation. Whichever of a number of embryonic materials and processing technologies now under development achieve prominence in the future, cost, longevity and reliability will be the controlling parameters determining their adoption for distributed applications.

In low grade heat applications such as heating and cooling of buildings, solar-thermal conversion is becoming cost competitive with grid-supplied electrical conversion over most of Australia, though it is not as yet comparable with the cost of direct combustion of fossil fuels. In the next decade, solar-thermal technology will become established and will find increasing application in the air-conditioning systems of exchange and office buildings. Concentrated solar-to-thermal-to-electrical conversion is currently possible with overall efficiencies of 40% (four times higher than that of photovoltaics) and holds promise for the more energy intensive industries.

Energy storage remains a difficulty. As cells become cheaper, electrical storage will be essential only for over-night demand. While battery storage is likely to remain expensive, it may continue to provide storage for low energy density applications. Alternative storage techniques based on rotating masses in motor/generator sets or hydrogen/fuel cell systems are being developed for centralised or energy intensive applications. Storage technology development will rely heavily on materials development to overcome some of the current difficulties.

3.2.5 Image Reading and Record Devices

With increased availability of higher speed data channels, significant improvements are foreseen in image and record transducers to provide a range of telecommunications services involving high speed paper-to-paper information or stored data transfer.

Current trends in image reading transducers indicate that semiconductor devices will be predominant in the foreseeable future. Already, linear image devices with up to 2048 elements (1728 elements for facsimile) are in use. These operate compatible with mechanical systems which move the paper or scan the lines in the direction orthogonal to the linear image device. Available devices could handle 300 A4 pages per minute. Semiconductor image arrays have been developed for television cameras, and some are claimed to be of high quality. For facsimile, the number of elements required (1728 x 1100) is large and arrays of this size have not been realised experimentally as yet. However, with continuing development in semiconductor technologies, and particularly of charge coupled devices based on low defect silicon, a large semiconductor image array is a realistic expectation for the future.

Record output device development does not exhibit any definite trends at present. In the area of non-impact printers, thermal, ink-jet and dielectric technologies are expected to be able to cope with the requirements of distributed data processing, word processing and facsimile applications at rates up to 20 A4 pages per minute over 64 kbit/s transmission paths. Laser printers, though more costly, are beginning to appear and can print up to 45 A4 pages per minute. Most current effort is being directed at two-level monochrome printing mechanisms, leaving half-tone and colour printing as problems for the future.

3.3 Transmission Media Technology

3.3.1 Introduction

Advances in transmission media technology over the next decade will be dominated by developments in optical fibre technology. No substantial changes in metal pair cable production processes are foreseen other than some refinements, e.g. increasing line speeds for extrusion. Coaxial cable technology is fully matured. Some advances are foreseen in the stabilisation of insulating materials but these will not contribute to changes in established metal cable technology. Current metal waveguides are considered to be uneconomic for network use and significant developments in design or production processes are not foreseen to alter this status. Consequently, optical fibre technology is considered exclusively in this section.

3.3.2 Graded Index Fibres

Over the last three years, optical fibres and fibre systems have advanced even faster than expected. Graded index multi-mode optical fibre cables can now be produced routinely and at moderate cost, with transmission bandwidths of 800 MHz at 1 km and losses just under 3 dB/km. These figures apply at a wavelength of 0.85 (μm) in the near-infra-red region of the electromagnetic spectrum, where readily available optical sources based on gallium arsenide material and detectors based on silicon operate efficiently. These first generation systems of 8, 34 and 140 Mbit/s capacities are readily available from several manufacturers and are installed routinely overseas.

Present telecommunications-grade fibres are based on high purity compound glasses or silica materials. High purity silica exhibits very low losses at slightly longer wavelengths than those commonly used at present. Silica fibres can achieve losses in the vicinity of 0.5 dB/km at wavelengths of 1.3 μm or 1.55 μm. Furthermore, material dispersion in silica reaches a minimum value at wavelengths in the vicinity of 1.3 μm, so that much higher optical fibre bandwidths can be achieved simultaneously with this low loss. Fibre transmission bandwidths of 2000 MHz at 1 km on a production basis have been reported. These advances offer even longer repeater spacings than those realisable with first generation systems, and spacings of up to 40 km at 140 Mbit/s are possible. However, optical sources and detectors at this wavelength are still in the early stages of development. It is anticipated that optical fibre transmission systems operating at this longer wavelength will become commercially available in about 3 - 6 years.

It is expected that graded index optical fibre costs will continue to decline, particularly for the low loss and high bandwidth grades. Recent manufacturing developments, such as the vapour-phase axial deposition (VAD) technique for fibre preform manufacture, have enabled longer production lengths to be made and also minimise the need for manual intervention. The bandwidth of VAD fibre is now comparable with that of fibres produced by the conventional modified chemical vapour deposition (MCVD) process, with production costs potentially much lower.

Testing of optical fibres at the manufacturing and cabling stages is presently a time-consuming and costly factor in the production process. Automated test equipment now becoming available will contribute to the decrease in fibre production costs.

The multi-mode nature of optical signal propagation in graded index fibres limits the bandwidth that can be achieved. Higher bandwidths are obtainable at a substantial cost penalty by close control of the refractive index grading profile but production yields of very high bandwidth fibres are poor. There appears to be little prospect for improvement in this area and graded index fibres are expected to remain limited to approximately 140 Mbit/s capacities if transmission distances more than a few kilometres are required.

3.3.3 Single-Mode Fibres

Another type of fibre is receiving attention for higher capacity systems. This is the single-mode fibre. Its small core diameter and refractive index difference allows propagation of only one optical mode and hence it does not suffer the bandwidth limitation of the graded index multi-mode fibre.

Recent reports on uncabled single-drum lengths of single-mode fibre cite attenuations of 0.2 dB/km at a wavelength of 1.55 μm and 0.4 dB/km at 1.3 μm. The corresponding bandwidths were 40 MHz for a 100 km link at 1.55 μm,or 800 MHz for a 50 km link at 1.3 μm. If these are extrapolated back to 1 km to compare with the bandwidths of graded index multi-mode fibres, the respective equivalent bandwidths are 5 GHz at 1 km (1.55 μm) and 100 GHz at 1 km (1.3 μm). These measurements were made with laser diodes whose spectral widths are wider than usual; consequently, even wider bandwidths than those reported could be obtained.

Cabling and jointing operations will not significantly increase the cited losses, which are very close to the intrinsic losses in silica. It is evident that single-mode systems operating at these longer wavelengths will most likely find application as digital links in the trunk network. Some overseas authorities are planning or conducting trials of submarine cables using single-mode fibres, which take advantage of these low loss and high bandwidth properties. In terms of device and fibre developments, single-mode systems will probably be available in the second half of this decade.

3.3.4 Other Optical Fibre Materials

The fundamental limit to attenuation in optical fibres is that set by Rayleigh scattering, and the attenuation due to this mechanism decreases rapidly with increasing wavelength. However, there is no advantage in moving beyond about 1.6 μm in wavelength if the fibres are to be made from silica or other oxide-based glasses, because material absorption causes increases in attenuation. Worldwide research is currently directed towards finding other glasses which combine the properties of low optical absorption at longer wavelengths (2 to 5 μm) with mechanical and environmental stability, and which can be manufactured to the required purity and drawn into fibres. Some recently discovered glass materials based on the fluorozirconates or fluorohafnates of gadolinium and ytterbium offer potential attenuations of less than 0.01 dB/km at a wavelength of 4.6 μm. However, it remains to be seen whether such exotic materials can be processed to yield cabled optical fibres with appropriate transmission properties at reasonable cost. In this regard, it is sobering to recall the scepticism with which predictions of inexpensive silica-based fibres with attenuations of 10 dB/km were greeted only a decade ago.

4. TRENDS IN TELECOMMUNICATIONS SERVICES

4.1 Introduction

Interest is growing in both new non-voice services and the enhancement of facilities currently provided to customers. The constraints imposed by slow call set-up and restricted bandwidth make the present telephone network increasingly unsuitable for the provision of advanced services. Some of these disadvantages can be and are being overcome by the introduction of new service-dedicated networks. The alternative is to apply emerging technology to the established public network such that a greatly increased range of user requirements can be satisfied. Digital technology is recognized as having the potential of providing a single network capable of carrying virtually all services. Many telecommunications administrations have accepted the concept of an integrated services digital network (ISDN) and are planning for its gradual implementation. It is also under study in the CCITT.

4.1.1 Aspects of Integration

An important distinction must be drawn between two basic aspects of integration. The first involves service integration as seen by the customer at his interface to the network. He sees a common interface for all his services utilising a unified set of control procedures. He is unconcerned whether his data, voice and other services are actually carried on common plant. The second aspect places emphasis on the network provider and the use of common equipment to switch and transmit all services, i.e. network integration. When considering the provision of future telecommunications services, an amalgam of both approaches must be adopted.

4.1.2 Classification of Services

There are many ways of classifying services. Traditionally, this classification has been based on technological parameters which facilitate the planning and provisioning of services over new or established plant. In this regard, parameters such as transmission bandwidth (or bit rate in digital systems), the type of signal (e.g. speech or data) which determines the limits of performance requirements, and also the traffic characteristics (in particular, its network dispersion) are important. Many of the new services mentioned in this chapter will, in all likelihood, affect network traffic characteristics. Consequently, the type of switching technique which is most cost effective will also need consideration.

In this paper, services are categorised broadly by bandwidth, namely "voice" bandwidth (or narrowband) services in Sections 4.2 and 4.3, and "wideband" services in Section 4.5. Further, Sections 4.2 and 4.3 can be regarded substantially as voice and non-voice services respectively. In an all-digital network,the distinction between voice and non-voice services will disappear and these services will all be considered as digital streams of various bit rates. The only difference between the services will be the end-to-end performance requirements (e.g. bit error rate, delay, throughput).

Planning for telecommunications services has generally considered solely point-to-point (switched or leased) communications. Section 4.4 considers trends and aspects of multi-user group communications. Finally, Section 4.6 considers satellite special services.

4.1.3 Service Requirements

The definition of future service requirements will become very important, especially when considering the integration of services. Some future services offer the possibility of being implemented either at customer terminals or centrally within the network. Careful thought therefore needs to be given to the network characteristics of each service. For integrated services, CCITT Study Group XVIII is considering both path criteria (which include general network features such as customer access and routing and performance requirements) and "intelligence" requirements in the definition of service-related network features.

Potential service offerings can only be defined after consideration of both user needs and potential network capability. However, advances in communications technologies have resulted in service offerings changing from being technology-limited to being marketability-limited.

4.2 Enhanced Telephony

4.2.1 Introduction

Enhanced telephony services are readily identifiable as those services which provide additional facilities to the basic telephone service and may be either terminal or network supported. In the short term, only a minority of new telephone services are expected to include enhancements to the basic service.

There is a range of technically feasible means of supporting enhanced telephony facilities, but it is likely that factors such as regulation, marketing and tariff structures will be important in determining the technical approach adopted.

Two main technology-oriented trends are evident. The first is the application of digital techniques to customer equipment and subscriber lines, and the second is a widening both in the range of terminals and the facilities they provide.

4.2.2 Telephone Terminals

Over the next 10 years, telephone terminals will be increasingly characterised by features such as keypads, displays, digital voice coding in the terminal, and most importantly, intelligence. Once digital techniques become cost effective for a particular type of terminal, the incremental cost of additional facilities is relatively low because of the inbuilt intelligence. Consequently, many terminal supported features such as last number re-dial, repertory dialling, call duration and cost information display, time, alarm, calculator, etc. will become available.

In the longer term, terminals could also support various voice message services such as personal recorded announcements, incoming message storage and voice reminder messages. Synthetic speech output from the terminal could provide voice guidance in the use of various facilities. Speech recognition capabilities could provide convenient terminal input by the user to support enhanced facilities. The development of a wide range of terminals is anticipated and the market for sophisticated terminals will develop in the business sector, where human and efficiency factors will justify the costs involved. With increasing facilities and complexity, terminals will become more and more complicated to use. "User friendly" terminals would provide the user with simple guidance for the use of each facility (e.g. by synthetic voice).

4.2.3 Centralised Facilities

There is a limit to the range of facilities which can be supported solely on a terminal basis. Facilities such as centralised reception services, automatic transfer and "follow me", call waiting indication, call queuing, individual call records, calling line identification, call charge recording, conference calling and voice store and forward facilities all require network information and control. These facilities may be provided by a small business system (SBS), PABX, public telecommunications network, or a combination of these. For example, with its development of the 1A Voice Storage System, in conjunction with electronic switching, the Bell System is offering a centralised voice store and forward service with both call answering and advanced calling capabilities. The call answering service is essentially a centralised telephone answering machine which gives either a standard greeting or a personal message. The service may be turned on or off as required by the user. The advanced calling service enables users to store spoken messages for forwarding by the system to a user-specified destination at a user-specified time. User requests for information are input via voice frequency (VF) tones from the telephone keypad.

This centralised service has the advantage of being able to answer calls while the customer is busy on another call. This would not be possible on a terminal-based system. Also, this centralised service makes more efficient use of resources such as memory and has an overriding control on message forwarding and therefore on traffic dispersion and common control equipment utilisation.

4.2.4 Rural Services

The provision of enhanced telephony services to remote locations will be facilitated by the utilisation of new transmission and switching techniques. These techniques include digital radio concentrator systems (DRCS), small remote digital switching systems and domestic satellite systems. The DRCS will be deployed in rural areas for voice services where this solution is economic. As small remote exchanges become economic and are deployed in rural areas, the radio concentrator solution can be extended. Future customer demand may require the DRCS to support a multi-service offering and thus require that the local concentrator network be interfaced to a national network developing along the lines of the ISDN concept.

For the rural area, the continued use of high frequency (HF) radio services should be regarded as an interim solution, especially in the light of satellite capability, although developments in equipment for the HF band are continuing, with the incorporation of microprocessor control and automation leading to a better quality of service.

4.2.5 Mobile Services

Mobile communications in the telecommunications network currently range from simple paging systems to the public automatic mobile telephony service (PAMTS). Current trends in mobile radio services include the development of high density cellular networks supporting both voice and low speed data services. The introduction of PAMTS in the Telecom network may develop along these lines. The technology for this development already exists and future trends will therefore depend on customer demand. An additional trend may see the introduction of a more elegant paging service, even extended to a 2-way capability by equipment miniaturisation and a closer interaction between the mobile telephony and paging networks to provide a more integrated approach to the provision of mobile services.

A long term possibility may be the development of portable "handbag" type units offering a range of services and calling for vastly significant changes to present system concepts. Another long term possibility is the use of satellite techniques (requiring high power spot beams in non-shared frequency channels) to provide Australia-wide mobile services.

For all the above applications using radio systems, radio frequency spectrum availability is the final limitation and spectrally efficient transmission techniques including suitable modulation methods will be required.

4.3 Information and Computer-Based Services

4.3.1 Introduction

The current era has been described as the "information revolution", and it follows closely upon, and is also a natural consequence of, the computer revolution. This is evident in the Telecom network by the growth in data traffic, which has led to plans for the introduction of a digital data service (DDS) and a packet switched data service (AUSTPAC). This trend is expected to continue, and it will place increasing onus on network operators to provide more diverse and improved data transmission services.

Information or data transfer may be carried out between customer terminals (which might simply be intelligent customer terminals with storage facilities, or nodes in a computer network); between the customer and the network operator, to a public access database (such as supplied by videotex or "electronic" directory services); or between the customer and a private computing facility or data store. Information retrieval services will be influenced by both data transmission rates and advances in customer terminal techniques. In particular, the use of VF keypads for information input in conjunction with synthetic speech output from the information source, as well as the integration of full keyboards and visual displays in the customer terminal, will have signficant impact on these services.

This section considers data transmission services, telematic services, message store and forward and other computer-based services. Telematic services are considered as a group because of the current thrust within the CCITT for the integration of these services using a common protocol which in turn is leading to the possibility of their integration within a terminal. Message store and forward services might be considered to be enhancements to information transmission services.

4.3.2 Data Transmission Services

A likely general perspective for data transmission in the Telecom network for the next decade is as follows:

- The DDS and AUSTPAC networks will operate on a wide scale and will cater for the great majority of leased data services and all packet switched data services respectively.

- The present Datel network will decline and will serve only those customers requiring a circuit switched service over the public telephone network.

- A specialised circuit switched data network may not develop; any required circuit switched service will continue to be provided on the switched Datel network until some form of ISDN develops.

This perspective is based on two main observations, namely, that data services will develop independently of the minor refinements anticipated in modem technology, and that, from an operations point of view, the need to distinguish data traffic from other communications traffic will diminish as the decade progresses. This latter comment is a consequence of the anticipated progressive sharing of network facilities by all digital traffic. It also suggests that the basic divisions that exist in telecommunications services are not confined to data types, e.g. the difference between real-time and non-real-time services, where delay and fidelity contribute differently to the degree of customer satisfaction.

Influences which may affect data transmission over the next decade include:

- the possibility of de-regulation of telecommunication services

- the use of satellite working

- additional processing power in network nodes and customer terminals.

The first influence may contribute to the establishment of private networks and, to a lesser extent, to the changing mix of telecommunications technology in Australia. The remaining two are directly concerned with the deployment of new technology which will be used to the advantage of both network administrators and customers. For example, for satellite working, the prospect of switched spot beams and developments in inexpensive earth stations will give a degree of flexibility to data transmission, and the prospect of new launch technology may significantly reduce overall system costs. On the other hand, developments in device technolgy and signal processing power will add sophistication to networks and terminals which will allow enhancements in services.

4.3.3 Telematic Services

The French PTT coined the term "TELEMATIQUE" to describe their programme of development of a family of co-ordinated telecommunication products and services, each of which is capable of meeting a market need in its own right. The key elements of the French programme have been stated to include the use of advanced technology and modular design, coherent research, overall compatibility and a total commitment to making the services available to the mass market. To date, this programme consists of four distinct product groups, namely:

- VIDEOTEX: TELETEX

- ELECTRONIC DIRECTORY

- MASS-FAX

- TELEWRITER

The term "TELEMATICS" has since been accepted by the CCITT to cover all text and graphics transmission services such as facsimile, videotex, teletex (super telex) and telewriting, and individual standards have been recommended by the CCITT for each of these services.

Most national systems do not yet conform fully with these recommendations, having been developed prior to their publication, but it is anticipated that, in the next few years, they will all move towards full compatibility. In addition, the CCITT is working towards compatibility between the different telematic services to allow interworking, for example, between teletex and facsimile, or videotex and teletex.

On another front, the development of service integration, fully supported by developing standards within the CCITT, is likely to be another factor which will increase interest in compatibility of telematics terminals. The future availability of a 64 kbit/s channel to the customer will greatly increase the transmission speed of future telematic services. An A4 size document could be transmitted by facsimile in 3 seconds, or a text-only business letter could be transmitted by teletex in 0.5 seconds. Videotex will be able to transmit detailed, photographic quality video pictures in as little as 5 seconds.

As the degree of service integration and the use of integrated telematic terminals increases, the traffic in the expanding digital network may gradually change its nature. Telematic messages tend to have different frequency and duration characteristics from telephone conversations, and this may put new and greater demands on common equipment dimensioned on the basis of telephony traffic. In addition, the centralised nature of many telematic services such as videotex would change the dispersion of traffic on the network to such an extent that some parts of the network may also need to be re-dimensioned.

4.3.4 Message Store and Forward Services

Computer-based text store and forward services, also known as electronic mail, are currently being marketed by the computer timeshare services industry (e.g. TYMNET - ONTYME II), and have resulted from the capability of networking computers. The user accesses the message service via a simple procedure. The system allows simple message creation and editing, handles message distribution (to one or more recipients), filing and retrieval, and also indicates whenever there are messages awaiting attention (at log-on).

Such a service is relatively simple to implement for small groups. However, for large populations (e.g. 100 000 users), problems in handling large databases arise which require sophisticated software techniques applied to the areas of distributed databases to yield reliable, responsive and low cost communication.

A logical extension of the above service is the addition of data storage and retrieval facilities, which enable privately stored data to be sent as part of a message. This type of service provides the user with extra database management flexibility.

An integrated store and forward service would include text and speech and also facsimile, as well as database access capabilities. The common control procedures for text and facsimile which are currently under study by the CCITT will allow integration of those facilities within the user terminal. This is seen as more desirable than integration at the network level.

Store and forward services can take advantage of off-peak tariff rates and could affect network traffic dispersion. For the next two decades, individual store and forward services will arise. These services need not be network-based but could be incorporated into large PABXs by the addition of processing power, or into terminals by providing inbuilt storage for memory-to-memory transfers.

4.3.5 Other Computer-Based Services

The expected major growth areas in computer-based services will be to support information transfer and text processing. The use of information retrieval services, including videotex, is expected to increase and current research in various administrations is aimed at interconnection of retrieval services. Hence, future developments of nationally provided videotex services will be expected to provide gateways to other services. This technique is already implemented on the Prestel-derived Bildschirmtext service provided in West Germany. Such services may be nationally or internationally based and be purely retrieval-oriented or provide computational facilities not available on the host videotex service.

The longer holding times inherent in these types of telematic services will need consideration when dimensioning local networks. A relieving factor will be the increasing power available in terminal equipment which will allow bulk transfer of information or control programs to the terminal, with ensuing stand-alone operation. This trend is already demonstrated in teletex services, whereby stand-alone operation is the norm, and relatively brief connection via the switched network is used to carry out memory-to-memory transfer of information. If overseas trends are followed, communicating word processing will form the major applications growth area in Australia.

Much of this growth will occur in the business sector where it can be expected that the current trend to distributed intelligence networking will continue. The Australian computing milieu lags that of the USA by 2 to 3 years. This will decrease, but we can expect to see a growth of over 30% per annum in local networks (i.e. those with nodes located within 20 km of the major host) based on mini/microcomputers during the period 1983 to 1990 and beyond. The use of larger main-frames to support networks is expected to grow more slowly; one estimate is of the order of 15% per annum. (Note: the figures above refer to the USA).

An unknown factor is the expected emergence of "hobbyist networks" which may occur in the mid to late 1980s. These networks are a projected outgrowth of the home computer revolution and are expected to be made up of an indefinite number of participants and will utilise the public network. They may utilise local data packet assembler/disassembler (PAD) facilities or existing voiceband services via acoustic or hard-wired modems. Growth rate is very hard to estimate although the concept is reported to have taken hold in the USA.

The emergence of local area networks will have an effect on the requirements of the commercial sector. These intra-site networks operate at effective bit rates of over 5 Mbit/s and support many non-homogeneous terminal connections. Some of the expected network growth will be absorbed by these networks. However, a significant proportion of these networks will interconnect via the public data network using X.25 or similiar protocols to support outlying nodes or sub-networks, creating a demand push for high speed data transmission capability in the public local and trunk networks.

Point of sale and credit validation transactions may be expected to increase over the next 5 years at rates determined mainly by the availability of "inexpensive transmission". These services will undoubtedly be reliant on the packet switched network and will be characterised by a large number of call connections and relatively short holding times. A similiar growth rate may be expected in electronic funds transfer and order processing services. The former will require encryption of the data stream for security and the provision of such facilities will need to be considered. Continuation of current trends in VLSI component technology will result in the inclusion of such facilities in the terminal.

If two communicating terminals employ data encryption, then each terminal must be supplied with a common encryption key to enable each party to receive, decipher and encipher all messages between the terminals. To enable secure communications between different companies, an intermediary might be used. Telecom could provide such a service via a key distribution centre, where random session keys are generated and transmitted to each of the communicating parties. The users need never be aware of the actual key and thus security is maintained.

4.4 Group Communication Services

4.4.1 Introduction

Historically, the development of public telecommunications networks has been based on and shaped by the need to establish speech links between pairs of arbitrarily located individuals. On the other hand, it is a characteristic feature of modern business and social activity that it is based on co-ordination of and co-operation between groups of people. Group communication or teleconference services, which establish simultaneous links between and among groups of people, appear in principle to be a major potential service area. Table 4.1, which gives a classification of group communication services on seven dimensions, illustrates the range and diversity of these services.

To date, a variety of special purpose systems and networks have been built and a number of individual terminal equipment designs have been developed. There are several designs of small group, speech-only meeting room systems available for use in switched telephone networks and there currently exist a few commercially available conference bridges. Most of the latter are basic speech bridging modules and very few have been developed to the stage where they have full network and user interfaces. There is intensive development activity in this area in the USA and significant products can be expected to emerge in the next five years. How useful these developments will be in the Australian network is largely unknown. The French have introduced a "speech plus" (refer Table 4.1) conference network which includes both public and private terminals; the British have their well known Confravision service, which appears to be spreading gradually into Europe. In North America, the providers of satellite and cable television (CTV) systems are currently very active in the advocacy and marketing of TV conferencing.

Generally, there is little community awareness of the range of services which could be made available, of how such services might be applied, or of how choices should be made between alternative services. This renders orthodox market research difficult and the results somewhat unreliable. Such research needs at least to be combined with demonstrations and exploratory user trials of likely services and systems.

TABLE 4.1 : CLASSIFICATION OF GROUP COMMUNICATION SERVICES

Number of Locations	Variability of Locations	Participants per Location	Mode(s) of Communication		Access/ Availability	Terminal Type	Primary Service Basis
two only	fixed	single	(4) speech only	"Audio Conferencing"	private	full studio	network
multiple	arbitrarily variable	small group (6-10 max)	(5) speech plus		public	meeting room/ minimal studio	terminal
	mobile	(2) large group	(6) live video	"TV Conferencing"	(10) mixed	normal office or home	hybrid
	(1) mixed	(3) mixed	(7) live video plus				
			(8) mixed asymmetric				
			(9) computer				

NOTES

(1) mixed location services are those which cater for both fixed and variable or mobile sites, e.g. individual telephones linked into a conference between fixed sites.

(2) e.g. as in convention halls, lecture theatres etc.

(3) e.g. a combination of small groups and individuals linked through a telephone conference bridge.

(4) e.g. normal telephone conferences.

(5) two sub-divisions:

(a) speech plus auxiliary modes e.g. fax, Slow Scan TV, and

(b) speech plus auxiliary cues e.g. speaker identification, request to talk, who's present, etc.

(6) live video conferencing will always incorporate speech links and may include some form of video-based graphics.

(7) video plus conferencing, e.g. video with auxilliary fax, video with data base access, etc.

(8) (a) mixed mode systems e.g. a video conference linked speech only to other participants.

(b) asymmetric systems e.g. one-way video, both-way speech.

(9) computer conferencing is usually implemented as a non-real-time service or facility.

(10) e.g. private TV conference studio linked to public Confravision terminal.

4.4.2 Technical Standards and Protocols

Group communication services currently operate over existing networks and conform to prevailing network technical standards, but few international standards or service protocols specific to these services exist. An important strategic question is to determine, for the various classes of service, what levels of standards and protocols need to be defined. The appropriate levels of standardisation may themselves differ from service to service, and as the dominant classes of service are as yet uncertain, international standardisation is likely to progress relatively slowly. In the longer term, ISDN concepts are most likely to form the basis for standardisation.

4.4.3 TV Conferencing

TV conferencing obviously makes major demands on network capacity, both on long haul links and in local distribution. The impossibility of meeting these demands economically has to date prevented any significant provision of TV conferencing in Australia, despite a number of specific service requests. In the next 5-10 years, commercial development of TV coding techniques, the increasing penetration of PCM digital transmission and optical fibre cable technology will significantly ameliorate these difficulties, though the economic viability of TV conference services may remain uncertain during that time. The advent of CTV services and digital microwave radio and satellite transmission systems would introduce some new possibilities into network planning for TV conferencing and these require exploration.

Multi-location TV conferencing presents a number of intractable problems in terminal design, network planning and operations. Some demand is likely for both public and private fixed-site systems, but if overseas trends are followed, there will also be requests for service to specific events, such as conferences and conventions, on an occasional or ad hoc basis. Links to overseas events of this nature are also likely to be requested. In some cases, asymmetric systems will be requested, e.g. TV from a central location, with audio return links from a number of satellite locations. Plainly, systems of this nature present unusual requirements on network flexibility and management, particularly if they are required on an ad hoc basis.

4.4.4 Audio Conferencing

In contrast to TV conferencing, audio conferencing makes no remarkable demands on channel capacity and is likely to provide only a small component of total network telephony and data traffic. There is already a small established demand for multi-location audio conferencing, which is presently met by operator-assisted connections established by means of centralised bridging facilities. Such conference bridges constitute a network facility which could utilise new technology to both reduce costs and improve performance. Significant expansion of capacity in this area may be required in the next 2-10 years. Bridges and other techniques for multi-location working for "speech plus" conferencing will be required within 5-10 years. Techniques and technological solutions for distributing bridging functions between public and private, network and terminal, manual and automatic systems will be important factors in determining future strategic outcomes in this area.

4.5 Wideband Services

4.5.1 Introduction

Traditionally, wideband services have been provided on an ad hoc point-to-point basis. Services included high speed data and video channels. Overseas, the distribution of TV channels over coaxial cable represented an early provision of broadcast service over a cable network with a switching function at the customer's premises. Current CTV systems using special coaxial cable have developed overseas to become sophisticated broadband tree networks, with a portion of system capacity available for upstream use. The initial application of this upstream capacity is expected to be for data services, polling, telemetering, etc.

A current research trend in wideband service provision is the establishment of experimental wideband distribution star networks using optical fibre cables, with switching capacity centrally located. It is difficult to predict when this trend will lead to more widespread and real application since its economic viability will depend upon further technology developments and demand drives from a significant community sector. Some commentators predict that suitable technology will be available by the mid-1980s. However, little comment is offered regarding the size of the anticipated demand or the cost of the technology.

Considering the business sector as a prime mover for wideband service demand, it is possible that a network approach to the general provision of wideband services (in the sense of the following definition) should be considered for the second half of the 1980s.

Wideband services can also be provided over limited distances by digital radio transmission systems operating in the higher frequency bands, e.g. at 30 and 40 GHz, and later at 60 GHz. Infra red transmission techniques might also be used.

4.5.2 Definition of "Wideband Services"

It is difficult to come to a precise definition of a wideband service. Currently, the CCITT is considering various forms of access to a network developed along the lines of the ISDN concept. Among these is a transparent group of n x 64 kbit/s channels, where n is not yet defined. However, a broad definition that may be of initial use is one which admits to the need for new distribution cable provision.

A number of wideband service types already exist, e.g. CTV, PAY TV, stereo broadcast, videophone, etc. There are prospects of others, e.g. fast facsimile, further developments in video services and developments in interactive services. Various lists could be made of all these service types.

Interim solutions for the provision of these services could require the adoption of various transmission modes, e.g. coaxial cable tree networks for CTV, radio broadcast at UHF for PAY TV, etc. However, as noted above, the dominant and long term trend is the provision of a wideband distribution network solution to cater for all wideband services (and possibly some of the narrow-band services as well).

For such a solution, it is necessary to categorise service types according to network rather than customer-perceived parameters, e.g. bandwidth required and sensitivity to common impairments. In this regard, international standardisation of service requirements is not well advanced.

4.5.3 Wideband Services Distribution Networks

In considering a distribution network approach for wideband service provision, many factors must be considered. Some of these are:

- the appropriate network architecture (network architecture generally refers to the way in which the various network functions, eg. signalling systems, switching, multiplexing, etc. combine to provide the network capability)
- the type of access (e.g. one-way or two-way)
- the type of switching
- the possible interworking with other networks, e.g. the IDN and later, the ISDN concept
- the provision for gradual network evolution.

Some of the above factors are considered in greater detail in the next chapter of this paper.

A number of public network administrations are conducting field experiments of wideband distribution networks. These experiments include optical fibre cables and central switching. Currently, the costs of establishing the networks are high and their application is not yet seen as economic. The main purposes of the experiments are:

- examination of the prospects for visual and computer information transmission and optical transmission technology from performance and cost viewpoints
- evaluation of wideband services required by potential subscribers to determine the social and market implications of improved TV and telephony services, and particularly of interactive and security services for homes
- investigation of the feasibility of such systems and determination of the direction of future research and development in the field of switched integrated video, telephony and data distribution
- exposure to practical experience in the design, construction, operation and maintenance of wideband services transmission networks based on optical fibre technology.

4.6 Satellite Special Services

4.6.1 Introduction

Satellite special services are defined as those which cannot be expediently provided by other means. The provision of such services will be possible with the advent of the Australian National Satellite Communication System, and technical and economic trends in these services will be tied to those of satellite transmission in general. One particular feature of relevance to the Australian environment is that the provision of services by satellite is distance-independent.

4.6.2 Foreseeable Satellite Services

The following list briefly outlines foreseeable satellite services. A broad definition of "service" has been assumed to enable the list to specify services in terms of broad application areas, which are as follows:

- Trunk relief: As bearers available for immediate relief in the terrestrial trunk network, it is likely that the capacity of a single transponder will in the future support a 70 Mbit/s stream. This could provide contingency for bulk data transmission.

- Thin route telephony: A national beam associated with a pool of dynamically assigned RF carriers could provide a rural subscriber service and may be appropriate in situations where the DRCS would not be economic.

- Enhancement of services currently supported on HF radio: The availability of mobile communications and school-of-the-air type services is currently influenced by ionospheric effects on HF radio, and this could be improved by use of a satellite.

- Disaster area relief: In disaster areas, where existing communications terminals are rendered inoperable, portable satellite earth stations can be flown in to give immediate service restoration.

- Australia-wide mobile services: Towards the end of the 1980s, advances in high power satellite technology could open up the possibility of providing Australia-wide mobile services using non-shared frequencies.

5. TRENDS IN TELECOMMUNICATIONS TECHNIQUES

5.1 Introduction

Earlier chapters have depicted the possible emergence of a variety of new services, made feasible by advances in fundamental semiconductor and computer technology. These services will impose new requirements on future telecommunications networks, which will be met by the adoption of new or improved telecommunications techniques, whose cost-effective adoption also relies on the use of the same advances in fundamental technology which give rise to new service options.

This chapter discusses the major trends in telecommunications techniques which will allow future services to be effectively provided and/or supported in a unified way.

The most visible trend in telecommunications techniques is towards a unified approach to the provision of services (whether speech, data, text, facsimile, image, video, etc.), to achieve cost effectiveness from the viewpoint of both the network users and the network operators. Service integration will in turn necessitate an integration of network techniques, and the progressive integration of services and techniques is basic to the development of the integrated services digital network (ISDN) concept, which envisages a unified telecommunications network architecture providing a wide range of services.

5.1.1 Classification of Telecommunications Techniques

In general, telecommunications techniques may be conveniently grouped into two basic categories, namely:

- Customer terminal techniques
- Network techniques.

However, it is sometimes difficult to distinguish between these two categories in some applications, such as local networks which are designed to support communications over a limited geographical area.

Some trends in customer terminals and associated techniques have already been mentioned in Chapter 4. This chapter highlights recent developments regarding the integration of services in new customer terminal equipment such as the "multi-service work-station". Such developments, together with progress in local network techniques, will enable the automation of office information systems. Advances in speech processing (synthesis, coding and recognition) and data encryption techniques are also mentioned, together with some comments on packetised voice techniques.

5.1.2 Classification of Network Techniques

In telecommunications, a number of network techniques are used in the transfer of "information", with the latter term used in its broadest sense to include sound, data, facsimile, video, telemetry, etc. Major emerging techniques are discussed under the following headings:

- Transmission, including network synchronisation
- Switching
- Signalling and protocols
- Network management

- Local networks.

For the purposes of this chapter, a telecommunications network is considered to be composed, as illustrated in Figure 5.1, of three basic types of networks, namely:

- private local networks, each generally providing communications services over a limited area (e.g. a building, an industrial site) and possibly having access to other private networks or to public networks
- public local networks, each generally providing services over limited areas (up to about 10 km radius) and having access to public main networks
- public main (national and international) networks, which in turn consist of junction and trunk network components.

Fundamental techniques such as transmission, switching, signalling, protocols and network management are applicable to all three types of network.

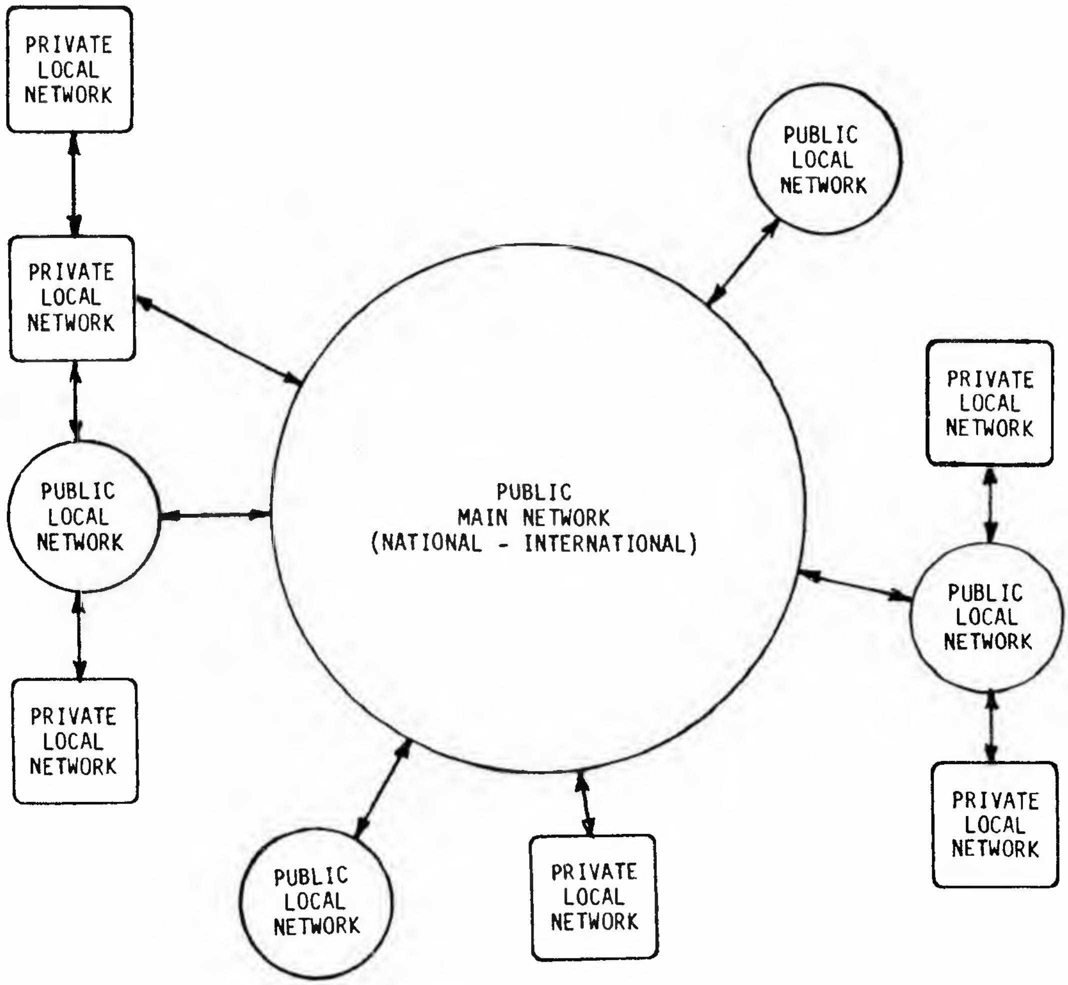


FIGURE 5.1 - GENERAL STRUCTURE OF A TELECOMMUNICATIONS NETWORK

Major trends in transmission techniques include:

- the introduction of high-capacity and medium-capacity digital radio systems in the trunk and junction networks respectively

- the introduction of optical fibre systems in the junction network

- increasing use of digital techniques in satellite communications

- multi-service distribution in local networks

- the introduction of a separate synchronisation network to provide accurate timing for digital systems.

The basic trend in switching techniques is towards digital switching with distributed control in order to cope with the increasing range of services having diverse characteristics and requirements. Other objectives in switching systems design (hardware and software) are to provide more flexibility, more expandability and better maintainability. These trends and objectives are currently being achieved for circuit and packet switching hardware, but to a much lesser extent for software. Since software development consumes up to 85% of total system development costs, the imbalance in research effort will need to be addressed in the next decade. Switching for wideband services (e.g. full-motion video) requires further advances in device technology and system design techniques.

In order to ensure that effective information interchange between communicating parties (people or equipment) is achieved, sets of rules and procedures must be adopted. These are commonly known as signalling procedures or protocols. Major developments in this field are:

- the CCITT Common Channel Signalling System No. 7 for controlling and supervising connections for digital telephony and circuit-switched data, including the transfer of information relating to network management, operations and maintenance

- the ISO/CCITT Reference Model of Open Systems Interconnection, which provides a common framework for the development of international protocol standards to allow different information processing systems to interwork. These systems include computers, data terminals, and associated devices.

Trends in management techniques for circuit-switched networks are covered in the discussion of Common Channel Signalling System No. 7, which has this capability designed into it. The trends in management techniques for packet switched networks flow from the processing intelligence built into such networks.

Local networks are designed mainly to support a range of services over a limited area. Traditionally, they are oriented towards telephony. In recent years, new technologies and techniques have allowed the characteristic of limited coverage to be exploited. High bit rate non-voice services can now be provided over metallic pair cable and coaxial cable, and optical fibres will predictably find application in this area. Types of these networks already in existence or being developed include:

- "Intelligent" digital PABXs
- Local data networks

- Cable TV networks
- ISDN local networks.

However, a great deal of standardisation effort is required to ensure that future networks yield maximum benefit.

5.2 Customer Terminals and Associated Techniques

5.2.1 Introduction

The application of microelectronics technology to customer terminals has already yielded a diversity of types of telephone and data terminal equipment, offering increasingly more facilities as the cost of the technology has decreased and customer awareness and demand has increased. The salient trend in terminal design is the incorporation of "intelligence" provided by microprocessors, to increase facilities available to the user or to decentralise signal processing to the terminals. The automation and integration of office communications systems for a range of services (e.g. speech, data, text) is a particularly fertile area for development.

5.2.2 Telephones

Telephones and telephone attachments provide a potentially large market opportunity for the application of microelectronics devices. Already, analogue telephone instruments incorporating a wide variety of enhanced facilities, either built-in or as compatible attachments, are being marketed, and this trend can be expected to be sustained by cost reductions and growing demand, particularly among business customers. Digital telephone sets, incorporating similar facilities, are technically feasible and used in some PABXs. Their ultimate adoption in public switched network applications is assured as the network passes through successive phases of digitalisation leading to the ISDN concept in the early 1990s.

5.2.3 Integrated Business Systems

A major application area for intelligent communications terminals is the business sector, where both technology and customer demand will result in more sophisticated multi-service work-stations supporting a range of integrated communications services, providing the user with facilities to communicate, produce, manipulate, process, store and retrieve "information" within an organisation. In this context, the term "information" includes voice, data, text, image/video, etc. Foreseeably, over limited geographical areas (e.g. up to 10 km distance), communication between work-stations will be provided by local networks, with or without access to public local or main networks.

Multi-service work-stations with access to information processing systems will provide a basis for the introduction of integrated business systems for office automation, in the drive to increase the productivity and effectiveness of staff. Aids such as efficient information communication/distribution (e.g. electronic mail), information storage and retrieval (e.g. database), information processing (e.g. application program packages) will become basic provisions in an automated office environment.

Although the integration of automated business systems is attracting a great deal of interest, little standardisation is taking place. The establishment of standards is vital to maximise benefits to users in relation to the interconnection of products from different manufacturers and the expandability of an adopted system and network. The efforts of standardisation bodies such as the CCITT and ISO on the formulation of a Reference Model of Open Systems Interconnection (see Section 5.5) and the current work of the Institute of Electrical and Electronics Engineers (IEEE) on local data networks will be of assistance for the orderly study and development of automated business information systems. Future considerations of potential providers of such systems must therefore include the three basic components of office automation, namely:

- office equipment
- computers
- telecommunications.

5.2.4 Signal Processing Techniques

In addition to microprocessor control techniques used in intelligent terminals, a number of new, more complex signal processing techniques are becoming technically and economically possible in terminals through microelectronics. The following briefly describes some of the trends associated with speech processing and data encryption.

(i) Speech Synthesis

Speech synthesis techniques may be classified as one of two types. The first type is the "phonemic" technique, which constructs synthetic speech from its basic sounds using a knowledge of these sounds and rules for their concatenation. The second type is the "compiled speech" technique, which contains a store of encoded words which are systematically concatenated to form synthesised messages. The former technique yields an infinite number of synthesised messages, but of rather poor speech quality; the latter technique supports only a finite vocabulary, and, although individual words are of fair quality when concatenated, the overall message may be of poor quality. Thus for overall quality, the objective with this latter type of technique is to pack as large a vocabulary as possible into a given memory.

A viable alternative of the latter technique, especially in the light of decreasing costs of memory, is to use a speech coding technique which results in better quality synthesis but needs more storage. A suitable algorithm is also required for the computer-controlled concatenation.

Current technology has produced single chip synthesisers of both types. Improvements in the quality of phonemic synthesisers are hampered by the inadequacies of the current speech production model and alternatives are under investigation. Efforts to increase the flexibility of "compiled speech" synthesisers are also in hand and the release of this technology is imminent, but there will be an attendant loss of speech output quality.

Automated voice response systems used in applications or services using synthesised speech for the output of information (such as directory assistance) will adopt the alternative compiled speech synthesising technique whenever quality is of paramount importance. This approach will become more attractive as the quality of the encoded speech is attainable at lower bit rates.

(ii) Speech Coding

The quality of reproduction of digitally encoded speech has been categorised into four broad classes denoted as "commentary", "toll", "communications" and "synthetic". Toll quality is described as being comparable to that of an analogue speech signal of telephone bandwidth (200 - 3400 Hz) with a signal-to-noise ratio greater than 30 dB and harmonic distortion less than 2 - 3%. Current techniques can achieve telephone toll quality at coding rates of 16 kbit/s and above. At bit rates exceeding 64 kbit/s, it is possible to achieve higher, commentary quality performance.

Below about 4.8 kbit/s, the reproduced signal has a synthetic or unnatural quality resulting in substantially degraded speaker recognition, and coder performance is speaker-dependent. Between 4.8 and 16 kbit/s, communications quality coders exist which provide highly intelligible reconstructed speech signals with some noticeable distortions and quality reductions.

Coding techniques can be classified as two differing types. The first is referred to as "waveform coding", which attempts to represent, via some suitable code, the speech signal waveform. The second, referred to as "source coding", exploits the physical properties of speech production and hearing. Consequently, coding schemes employing the latter technique and optimised for speech will not be as effective when used for data signals.

With the adoption of 64 kbit/s PCM as a digital transmission standard by the CCITT, integrated circuit manufacturers were quick to respond. However, the uncertainty of future directions in speech coding techniques has caused IC component design and production to lag significantly behind the developments of coding techniques. This has resulted in Bell Laboratories and NEC producing general purpose signal processing ICs for speech coding. It is expected that the components industry will follow within the next 4 - 5 years. The current emphases are to reduce the bit rate required to achieve toll quality speech and to improve source coding techniques. It is expected that for telephony-based applications, 16 kbit/s will be the maximum bit rate required for digitally encoded speech.

(iii) Speech Recognition

Advances in speech recognition techniques over the last decade have been relatively slow and this will continue over the next decade. The best results that have been achieved so far are the speaker-independent recognition of spoken digits over the telephone. This has been applied to an information service which supplies the caller with a synthetic speech announcement of the current status of specific monetary funds, keyed by two spoken digits. Some systems exist for the retrieval of information or the control of machines by voice input, but they are generally capable of recognising a limited number of users and commands.

Most speech recognition algorithms are computationally intensive and not readily amenable to large scale integration techniques. Nonetheless, integration is being attempted by at least one manufacturer, at the cost of recognition performance. Extension of current recognition techniques to continuous speech is under widespread investigation, but this task is significantly more difficult than the recognition of isolated words.

(iv) Data Encryption

In 1977, the US National Bureau of Standards endorsed an encryption algorithm known as the Data Encryption Standard, and subsequently, encryption was recognised as a necessary technique for the secure transmission of data through public networks. Encryption hardware, both at the microchip and system level, is now being produced by a number of manufacturers and is finding its way into a wide range of data terminals (e.g. automated banking terminals).

5.2.5 Packetised Speech

Another development related to speech is the coding and conveyance of speech over a packet switched network. As this "packetised voice" is transmitted and switched on a block or packet basis, special procedures or protocols are required to ensure that low, constant network transit delay and adequate fidelity are achieved. (Note that for data communication protocols, the requirements are generally toward error-free delivery, as data can tolerate some transit delay which may be variable).

Although investigations are being carried out with packetised voice on networks such as the US Department of Defence network ARPANET, this form of voice communication still requires extensive investigation (technical and economic) before it can be viably applied in public packet switched networks which cater for a variety of services such as data, text and facsimile.

5.3 Transmission Techniques

5.3.1 Introduction

As in other countries, the Australian public telephone network will evolve towards an integrated digital telephony network (IDTN) as digital transmission is integrated with digital switching. As the digital telephony network grows, other non-telephony services will be integrated into an integrated services digital network (ISDN). Some of these services are yet unspecified. Against this scenario, identifiable trends in transmission are as follows:

- the introduction of high capacity digital radio systems in the trunk network and medium capacity digital radio systems in the junction network

- the introduction of first generation (0.85 μm wavelength) optical fibre systems in the junction network and later application of subsequent generations of optical fibre systems in both the trunk and junction networks, and possibly in submarine cable applications

- the increasing use of satellites, with later generation systems employing time division multiple access (TDMA) techniques, digital transmission and regeneration, on-board switching and improved spot beam control

- the introduction of digital transmission in the existing local distribution network to support access to a multi-service offering

- the possibility of a wideband distribution network.

In examining these trends, two main observations can be made, as follows:

- Optical fibre systems and satellites present unspecified limits for innovation. Digital radio will see more refinements to its well established technology base. The potential for further increasing the capacity of pair cable is limited. Coaxial cable technology may begin to be superseded by optical fibre technology in the latter half of the decade.

- Of the trends listed above, the last one will prove the most challenging, and depending on the size of the demand for wideband services, it has the greatest ingredient for change in the long term, as optical fibre technology will take a leading role in determining the provision of wideband services in the longer term.

5.3.2 Radio Transmission Systems

The major developments are outlined under the headings following:

(i) Digital Radio in the Trunk Network

High capacity digital radio systems (DRS) at 140 Mbit/s (operating initially in the 6.7 GHz band, with possible extension to other presently analogue bands at 4 GHz, 6.1 GHz and 11 GHz) and 34 Mbit/s (in the 2 GHz band) will find overbuild application in the trunk network. An initially rapid deployment of these systems may be tempered in the longer term by later generation optical fibre systems. The technology of high capacity DRS will mature with the development of spectrally conserving modulation techniques, with higher sophistication and cross-polar discrimination restoration combined to make most efficient use of the limited radio frequency (RF) spectrum resource. Higher than 16-level modulation schemes are being researched to further improve spectrum utilisation. More sophisticated adaptive equalisation techniques are evolving to combat the unwanted effects of frequency selective fading. Microprocessors will be used increasingly in radio equipment for more intelligent signal processing. Developments leading to economic 34 Mbit/s encoders for PAL TV signals will allow 4 TV programmes to be transmitted on a single RF bearer, leading to vastly improved trunking of TV programmes.

In the context of an IDTN, single sideband amplitude modulated (SSBAM) systems are seen to have limited prospects.

Costs for high capacity digital radio equipment have not yet stabilised. Volume production could yield cost reductions, but high capacity systems do not traditionally represent a volume market.

(ii) Digital Radio in the Junction Network

Medium capacity 34 Mbit/s systems operating in the 13, 15 and 18 GHz bands will find application for route relief. The technological refinements anticipated for high capacity trunk applications may have only a slight impact on these systems, where rainfall attenuation is the major impediment. High capacity 11 GHz systems may also be used, e.g. as tail systems.

In this network sector, the distances involved rule out the use of the millimetre wave and infra-red bands, due to increased atmospheric absorption. Unlike high capacity DRS, equipment cost trends have largely stabilised.

(iii) Radio for Local Distribution

For general local distribution, radio transmission is not appropriate. However, for some short distance (less than 10 km) point-to-point, wideband applications, a radio solution will be possible in the 30 and 40 GHz bands, sufficiently distant from the 18 GHz band proposed for junction applications. Further, the band at 60 GHz is sufficiently localised by severe atmospheric absorption to attract special attention, e.g. for private point-to-point services (less than 2 km) or on a cellular basis to enable frequency re-use applications. For these systems, equipment is reasonably small and lightweight, thus facilitating installation and neighbourhood acceptance. The technologies associated with these applications will continue to mature over the next decade. Refinements may include the application of production processes to achieve component integration (e.g. antenna with RF components), with potential cost reductions. These systems have typical capacities of 16 Mbit/s, with future possibilities of 34 Mbit/s.

In addition to the above, infra-red systems are easily installed and offer short distance localised operation, e.g. over 1 km between city blocks. Current systems offer capacities of a few Mbit/s or a single video channel. Increases in capacity and range can be expected to follow advances in optical fibre related technologies yielding increased stability and life-times of laser diodes. Cost reductions in equipment are likely when volume production is appropriate.

(iv) Radio Frequency Spectrum Management

With trends towards the use of the higher bands and the development of the range and capabilities of radio services, there will be a continuing need to develop philosophies for spectrum management to avoid haphazard developments and to enable successful sharing of this limited resource by various services.

5.3.3 Optical Fibre Systems

Trends in optical fibre systems are discussed under the headings following:

(i) Optical Fibre Systems in the Trunk Network

Optical fibre systems should ultimately find application in the trunk network, possibly during the late 1980s. Their prospects, however, will depend upon developments in high capacity digital radio systems and on perceived needs for trunk system diversification. High capacity single-mode fibre systems operating at long wavelengths (1.3 or 1.5 μm) are likely, where the wide bandwidths and low losses can be used to advantage, e.g. for system capacities of 140 Mbit/s and

565 Mbit/s, with repeater spacings of typically 40 to 50 km. With improvements in opto-electronic device reliability, submarine optical fibre cables could also find application as a part of the digital trunk network. In this application, lower system capacities may be used to permit increased repeater spacings or increased system margins.

(ii) Optical Fibre Systems in the Junction Network

Optical fibre systems operating at 34 Mbit/s and 140 Mbit/s are now finding application over longer distance routes in junction networks. As optical fibre cables and opto-electronic device costs continue to decrease, fibre systems will become more competitive for shorter junction routes.

The introduction of longer wavelength (e.g. 1.3 μm) systems is anticipated in the late 1980s for longer, high capacity routes or where longer repeater spacings are required. However, it is not expected that first generation systems operating at the shorter wavelengths would be upgraded by installing longer wavelength equipment as a matter of course, except in unusual circumstances. If an optical fibre is to carry a high capacity system (e.g. 140 Mbit/s), its design must take account of the wavelength to be used. One viable strategy would be to install short wavelength systems at 34 Mbit/s in the short term on optical fibres designed to offer high bandwidths at the longer wavelength. When extra capacity is ultimately needed, higher capacity, long wavelength systems could then be installed on the fibre and the advantages of long wavelength operation obtained.

(iii) Optical Fibre Systems for Local Distribution

Present and foreseeable low bandwidth/bit rate services are unlikely to provide an application for optical fibres in local distribution networks in the next decade or so. A range of available optical fibre systems could find application for point-to-point wideband services (e.g. point-to-point video). Where high voltage isolation is required (as in an electrical substation) or where high electrical noise environments occur (as in railway communications), optical fibres are attractive even for low bandwidth services.

5.3.4 Digital Satellite Systems

Over the next 10 - 15 years, the use of satellites is seen as expanding. Regenerative satellites employing on-board switched spot beams and time division multiple access (TDMA) techniques will represent the trend beyond the early 1990s, with increased use of the higher bands (20 - 40 GHz) and the attendant increased bandwidths available (3 GHz). These advances will allow more flexibility in satellite system configuration.

While satellite lifetimes are to some degree a matter of economic compromise, they are expected to be extended beyond ten years. Improvements in equipment design are expected to lead to increased transponder equivalent radiated power and smaller earth terminals for the same signal quality.

Major earth stations have nearly bottomed in cost. This is true for 4/6 GHz systems but not necessarily for 12/14 GHz earth stations such as may be used in the Australian National Satellite Communication System (ANSCS). The same can be said for intermediate size earth stations, where the major cost reduction factor will be due to quantity purchase.

Since remote telephony, small earth stations are now in an early stage of production, there will be considerable scope for cost reduction. Again, quantities and advancing technology will indicate the trend. Earth station hardware based on frequency division multiple access (FDMA) techniques has nearly bottomed in cost, while there is scope for cost reduction in digital and TDMA hardware.

The satellite costs, neglecting launch costs, have not nearly bottomed. A fixed design should see future reductions in cost due to larger numbers and increased experience, but not at the rate occurring 5 years ago.

The largest potential cost reduction of a satellite system is in the launch costs. Recent success with the NASA space shuttle indicates that future communication satellites might be launched at decreased cost in this manner.

Considering only technical aspects and not economic or other factors, satellite communication systems can provide all of the services that can be provided by a terrestrial radio system. However, because communications is independent of the distance between communication points (provided that both terminal points are within the antenna coverage of the satellite), satellites have some advantages over other wideband media. This fact could be exploited in a number of applications such as long distance trunk telephony, thin route telephony, mobile communications, data communications, television and sound broadcasting, and special services such as CTV and school-of-the-air services. Temporary overload or disaster area relief services are particularly suited to satellite systems because of the ease and rapidity of installation of transportable earth stations. For broadcast transmission, developments in source encoders will allow the economic use of a single transponder by two 34 Mbit/s colour TV signals. Increased use of satellites for TV relay purposes will also free terrestrial links at 4 GHz and allow the development of other terrestrial systems in this band.

5.3.5 Multi-Service Distribution in the Local Network

(i) General

The appropriate evolution of a digital local distribution network over the next 10 to 15 years is of major concern to the operators of public telecommunication networks. The major factors determining this evolution include:

- technological developments in transmission systems
- the level of demand for various services, especially wideband services which could be broadcast or switched
- non-technical factors, e.g. de-regulation.

If there is little demand for wideband services, 144 kbit/s transmission on symmetric pair cable will suffice, with wideband requirements being provided by special point-to-point bearers.

However, if there is a high demand for wideband services, two possibilities arise:

- a coaxial cable distribution network
- an optical fibre distribution network.

In the following, all three possibilities are discussed.

(ii) Symmetric Pair Cable Distribution Network

This solution will apply new transmission techniques to already in-place mature transmission bearer technology.

Full duplex digital transmission on pair cable at 80 kbit/s over distances up to 4 km represents the current state of systems under development; 64 kbit/s over 5.5 km has been achieved. Competing transmission techniques are burst separation, frequency separation and echo cancellation. No one method has emerged as the optimum, although the frequency separation technique is the least favoured.

The next ten years will see these techniques refined to the point where one or more will be available for network use. However, it is unlikely that such techniques will permit transmission of 144 kbit/s for distances much above 4 km. For this higher speed, other strategies involving remote concentrators or multiplexers and/or regenerators can be used to achieve suitable transmission distances.

(iii) Coaxial Cable Distribution Network

This solution deploys a mature cable technology and applies established transmission techniques. It is already widely used in cable television (CTV) distribution and local area data networks. A tree network structure is employed to provide a single (or possibly two) broadband bearer past each customer's premises. This network:

- can provide broadcast (downstream) wideband services
- cannot provide switching of wideband messages unique to each customer (the tree does not provide a dedicated wideband transmission path for each customer)
- can provide a switched narrowband service to each customer, e.g. at 144 kbit/s.

To provide a switched narrowband service, a virtual star network can be formed from the physical tree and a portion of the total capacity is allocated to each customer. This allocation may be achieved through frequency separation, time separation or spread spectrum techniques.

A broadband coaxial cable network provides a good bearer for digital signals and should give a high transmission performance. It provides bandpass transmission channels which necessitate the use of digital data modems (a mature technology). Initial studies indicate that the cost of providing both TV and telecommunications services on this type of network may be comparable to that of separately providing the TV service on a CTV network and other telecommunications services on a symmetric pair cable network.

(iv) Optical Fibre Distribution Network

This solution deploys a new and evolving transmission technology and uses established transmission techniques. A network using optical fibre technology will have a star structure, with wideband switching facilities located centrally. The star structure overcomes the present limitations of optical sources (due to non-linearity of power output) which prevent more than about four video channels being transmitted on one fibre using analogue techniques. Digital techniques are currently too expensive for distribution application. The star structure avoids the use of the presently available tap couplers which have excessive losses. Future advances in tap coupler and optical source technology are not expected to alter the preference for a star network. The main advantages of a physical star network using optical fibre transmission are as follows:

- A physically separate wideband communication path is assigned to each customer, enhancing the security of information.

- The number and types of services available can be increased by expanding the switching capacity at the central point.

- In many circumstances, line repeaters can be avoided.

- The use of a large and expensive fibre volume and/or expensive very high capacity fibre types can be avoided.

Assuming a sufficient service demand, the major technology advances that will greatly increase the prospects of this solution will be refinements in manufacturing processes together with volume demand to permit a reduction in the costs of fibre cable and optical sources. These trends may not be evident till the late 1980s.

Other advances that will enhance the applicability of this solution include:

- wavelength division multiplexing (WDM), permitting up to about three video channels to share one fibre

- frequency division multiplexing (FDM) with WDM, to increase the fibre capacity further

- bi-directional couplers, allowing duplex operation on one fibre.

Either digital or analogue techniques can be used in the distribution area. This choice is an important one as far as the application of optical fibres in this area is concerned. In the long term, digital techniques are preferred, but they are costly to implement at present.

5.3.6 Network Synchronisation

For an IDN supporting only telephony traffic, adequate network timing can be provided by good quality crystal clocks operating plesiochronously. However, other traffic such as digital data requires more accurate network timing. Consequently, as the network evolves toward the ISDN concept, accurate network synchronisation is necessary, and to provide this facility, a separate synchronisation network must be developed.

A national synchronisation network which is separate from the traffic network will evolve as an integral part of the digital network. The precise form of the synchronisation network will emerge about the middle of the 1980s. International requirements for digital network timing will be finalised during this decade, with international working remaining plesiochronous. The technology to implement a national synchronisation network is available and significant developments are unlikely. The scale of production of synchronisation hardware will remain low and costs will not decline.

5.4 Switching Techniques

5.4.1 Introduction

The basic trend in switching techniques is toward digital switching. As the ISDN evolves and telecommunications services become more diverse, various switching techniques are available to support them. These include:

- circuit switching
- packet switching
- message switching
- hybrid circuit/packet switching.

Recent trends in the design of hardware for SPC switching systems (for digital telephony, data and other non-voice services) suggest that advances in VLSI device tehnology will continue to be applied to yield new systems which are more flexible, more expandable and more easily maintained. However, although about 85% of the cost of developing a new SPC switching system is for software development, current trends suggest that future improvements in techniques for software development will be slow, unless increased research effort is devoted to software engineering.

For wideband services (e.g. video and stereo music) requiring large bandwidths or bit rates (e.g. 20 kHz - 10 MHz or 1 - 100 Mbit/s), the design of large-scale centralised network switches awaits further advances in semiconductor devices and system design techniques.

5.4.2 Digital Switching

This section outlines some of the important trends and approaches adopted in switch design for telephony and circuit-switched data. The salient features evolve from the application of distributed control techniques. These allow the switch to have more functional modularity (and therefore flexibility and expandability), self-diagnosis and fault tolerance, thus presenting flexibility for planning future network configurations.

Similar hardware and software techniques are used in the design of packet switching systems. Additional aspects specifically related to public packet-switching networks are dealt with in the next section.

(i) Hardware Design Trends

(a) Distributed Switching and Control

The development of inexpensive processing power in the form of microprocessors and other VLSI components has enabled the advantages associated with distributed processing to be pursued in switching equipment, namely, increased throughput, flexibility and fault tolerance. The trend in switching equipment is towards digital switching, with distributed processors providing switchblock control and other related exchange functions, while the switchblock itself also has a distributed architecture. This modularity and flexibility of architecture allows the switch size to be increased by simply adding extra switch and processor modules.

This flexibility may also be enhanced by the provision of inter-processor communication via the switchblock channels (which may carry data or voice traffic), eliminating the need for separate communication channels. A single exchange type should result, which can satisfy the requirements of the range of exchange sizes from small (e.g. local exchanges) to very large (e.g. trunk exchanges) with a high degree of fault tolerance.

Distribution of control, however, may introduce problems in unexpected interaction of control or diagnostic systems, and an optimised approach might not become apparent until the mid-1980s

(b) Functional Modularity

The trend towards modular building blocks in both the switching and control sub-systems of new generation switching systems is expected to continue, since modularised design facilitates modification and expansion and provides flexibility of configuration. Modularity also provides the advantage of easy incorporation of new technology.

(c) Self-Diagnosis

Distributed control provides sufficient intelligence for some sub-systems to perform self-diagnostic functions. Each of these intelligent sub-systems can monitor its own performance (and that of others around it) and inform higher level control of any fault which occurs. This type of diagnosis is necessary in a highly complex system not only to contain maintenance costs, but more importantly, to facilitate fast fault detection and recovery, thus enhancing the reliability of the overall system.

An extension of this concept enables fault-diagnostic information to be sent to a remotely-located control centre for further processing and subsequent corrective action, as discussed in Section 5.6.

(d) Fault Tolerance

Cost reductions in VLSI technology have now enabled circuit redundancy to be built into systems to increase their fault tolerance. This trend is particularly noticeable in switching systems, where a high grade of service necessitates a high degree of fault tolerance. With distributed switchblocks providing highly decentralised systems, an exchange may be designed so that any system fault will affect only a very small part of the exchange.

(e) Switchblock Architecture

LSI/VLSI semiconductor technology has provided, and will continue to provide, a variety of digital switchblock functions in integrated circuit devices. Future switching systems will use these devices to provide continuing cost reductions and performance improvements.

LSI and VLSI technology will also play a key role in the development of new switchblock structures. The trend in device development is toward distributed switching elements and these in combination with distributed control suggest a wide range of new switchblock configurations. The economics and technical advantages inherent in this trend will lend to the development of universal digital switching ICs, with switchblock structures having the features:

- maximum modularity
- time and space switching capability at each stage
- flexible structures which are economic over a wide range of exchange sizes
- decentralised switching capability.

Decentralisation of switchblock control functions will continue to take advantage of low cost microprocessors and memory devices. However, where switching elements are realised in IC form, there is considerable scope for including control elements within the switch itself. Such a trend would simplify switchblock design and reduce software overheads.

Overall, the trend is toward simplification of the switchblock structure at the expense of greater complexity in the switching elements.

(ii) Software Design Trends

Although the past decade has seen considerable progress, software development is still characterised by large teams of people working with inadequate tools on the translation of requirements specifications into working code. Presently, software represents about 85% of total system development cost and this is causing effort to be applied to improving software tools and techniques. However, current gains have mainly been due to a formalisation of the design and development process, together with a very rigorous approach to its management. A number of methodologies have been used, all having some degree of success. For example, the application of the finite state machine approach to design has had dramatic effect where it is applicable, but in a telephone switching system, this applies to only a small percentage of the total software.

Errors in requirements specifications or their translation into design are responsible for 70% of all faults in operating systems. New or modified techniques to improve all phases of the processes are under large scale investigation and a wide variety of methods to handle parts of the total problem or, more ambitiously, to automate the whole process are now appearing.

Automation projects aim to generate program code directly from requirements specifications. However, no simple methodology has yet appeared for system partitioning and this causes difficulties.

Currently, advances are being made in the standardisation of System Description Languages (SDL) and High Level (Programming) Languages (HLL), e.g. the CCITT SDL, HLL CHILL and the U.S. Department of Defence ADA. These will lead to enhanced maintainability. In their machine readable form, SDLs can be automatically tested for correct syntax, completeness, redundancy and consistency, while HLLs allow for more extensive and sophisticated compile time checks and are designed to allow concurrent execution, with suitability for both centralised and distributed systems.

The influence of these languages over the next five years could determine future trends in both software and hardware. For example, the development of ADA has already stimulated the development of the Intel 432, a "micro-mainframe" microcomputer which executes ADA directly. With these developments taking place, telecommunications administrations will require increasing software expertise to understand and evaluate the technology, as maintenance costs will vary considerably from system to system.

Computer networking with intelligent terminals is now providing an attractive answer to information processing problems. However, these networks pose problems for the software engineer due to the incompatibility of software from different manufacturers. Work on CCITT and ISO standards will help to provide a solution, but it is already obvious that data switching systems will have to be versatile and adaptable because of the options available within the standards.

5.4.3 Packet Switching

The experience gained with the development of the early public packet switched data networks has revealed that the availability of flexible "intelligence" is an important factor in optimising the cost/performance ratio of switching systems. Flexible intelligence allows problems, such as the wide range of service characteristics (e.g. bit rates, signalling procedures or protocols) of data terminals and different traffic requirements, to be dealt with effectively.

Design trends in packet switching will continue to use microprocessor and memory component technology to achieve modular approaches to:

- the functional design of distributed systems
- the distribution of processing capacity, allowing systems to expand with growth in service demand and traffic
- fault prevention and diagnosis and system architecture, for improved reliability and grade of service.

These trends will be assisted by the development of microprocessor-based units for performing specialised functions (e.g. management of a particular communication protocol). In turn, these will allow a large variety of multi-processor configurations to be used for achieving cost-effective solutions to complex functions associated with packet switching networks.

Another important trend in public packet switching networks is the application of hierarchical switching levels to network structure designs, as in telephone networks. Large capacity switches are used in a high-connectivity hierarchical architecture to establish connections with a reduced number of transits. Such a switch makes use of multi-processor structures with fast parallel interconnection buses. This approach lends itself to more flexible expansion of switching capacity. It also allows functions to be effectively shared among the different processing units, thereby further increasing total efficiency because of hardware specialisation.

Public packet switching data networks have also given importance to the functions associated with network supervision and management. This aspect is covered in Section 5.6.

This section has only considered packet switching for data and other related services such as telematics. Packetised voice is still at an experimental stage on some non-public packet networks.

5.4.4 Wideband Switching

Switching techniques for services operating at bit rates of up to 64 kbit/s or small multiples of 64 kbit/s have been considered in the previous two sections. These services may be regarded as "narrowband". Wideband services using higher bit rates or wider bandwidths require that special consideration be given to the design of wideband switches.

(i) Switching Approaches

Two basic approaches can be used to switch wideband services:

- Customer switching, performed at the customer premises, and
- Central switching, performed within the network.

(a) Customer Switching

This approach extracts or selects the required service from those made available at the customer's premises from the service-providing centre. It is applicable to "downstream" transmission only of services, which include TV and sound programmes.

Since customer switching requires the availability of a number of services at the customer's premises, considerably more transmission capacity is required to the customer's premises than would be the case if centralised switching were used. Techniques used to convey the services to the customer include:

- different transmission media (i.e. space division multiplexing (SDM))
- different frequency bands (i.e. frequency-division multiplexing (FDM))
- different time slots (i.e. time-division multiplexing (TDM))
- different wavelength bands (i.e. wavelength-division multiplexing (WDM)).

Customer switching is reasonably well developed in CTV and PAY TV applications. Its implementation does not follow any particular approach at this stage. In the long term, however, it may be desirable to ensure proper interworking between customer switching equipment and a future public switched wideband network. This could be achieved by the specification and subsequent application of standardised functional interfaces.

Although customer switching adequately services present CTV applications for TV and sound programme distribution, it does not have the flexibility of centralised switching.

(b) Central Switching

This approach implies that switches centrally located in the wideband network route only a selection of services to each customer upon request. Circuit switching is suitable for both upstream and downstream transmission between the customer and the service-providing centre and for two-way simultaneous (i.e. full duplex) transmission between any two or more customers. Central switching allows multiplexing methods to be used to transmit a number of wideband signals simultaneously between switching nodes, in addition to those between terminal nodes and customers premises. Central switching thus offers greater flexibility than customer switching in the large-scale distribution of wideband services.

Centralised switching can provide a single service or a number of services simultaneously to a customer location. The customer can then separate the various services by using customer switching in the terminal equipment.

(ii) <u>Wideband Switching Techniques</u>

The techniques used to provide centralised switching can be conveniently classified as electrical or optical, according to whether electrical or optical waveforms are switched.

Electrical switching techniques are similar to those presently used in telephone switching. They can use either electro-mechanical or solid state component technologies. Recently developed solid state devices promise switching rates of up to 10 GHz.

Optical switching techniques include:

- purely optical techniques (e.g. using Hall effect devices)
- opto-mechanical techniques, using movable fibres and movable beam steering devices (e.g. mirrors)
- opto-electronic techniques, in which switching is performed by photo-diode detectors or receptors, i.e. using optical techniques within the switch, but converting to electrical transmission at the switch boundary. (Optical transmission is also applicable.)

Of the above three techniques, optical and opto-electronic switching appear to be the more promising as they can satisfy the majority of requirements associated with wideband switching. These requirements are discussed in the following section. Opto-mechanical devices are expected to be only of passing interest while other techniques mature.

(iii) Wideband Switching Technologies

The considerable advances of recent years in the design and implementation of monolithic high speed switching devices can be expected to continue, with greater emphasis being directed toward gallium arsenide device technology, which appears suited to LSI/VLSI implementation. New technologies, relating to Josephson junction and opto-electronic devices, are the subject of major research activity in a number of computer/telecommunications manufacturing organisations and in the longer term, these technologies offer the prospect of picosecond and sub-picosecond switching speeds.

It is expected that switching devices suitable for network applications will be available in the mid-1980s and commercial systems in the late 1980s. Any of the optical, electrical and opto-electronic techniques mentioned previously may find application.

(iv) Considerations for a Wideband Switch

Because of the more stringent quality requirements of wideband services (e.g. linearity, low distortion, etc.), a wideband switch should have the following performance characteristics:

- low insertion loss
- low distortion
- low mutual interference or crosstalk with other switched channels
- low susceptibility to impulse noise.

Furthermore, because of the nature of wideband services, the switch should be flexible and adaptable to an arbitrary mix of one-way and two-way simultaneous transmissions. It should also be dimensioned to cope with long-duration wideband connections (e.g. for TV programmes).

Consideration must also be given to whether analogue or digital switching is used. With digital switching, little problem seems to be encountered with either digital or analogue transmission, analogue-to-digital and digital-to-analogue conversion being used in the latter case. With analogue switching however, care must be taken regarding the modulation technique associated with the wideband signal to be switched. For example, frequency modulation (FM) tends to be more tolerant to crosstalk and distortion than baseband and vestigial sideband (VSB) modulation.

Generally, wideband switching tends to imply circuit switching. Store-and-forward switching techniques (message or packet) could also be used. However, the large bandwidth or bit rate requirements of wideband services preclude the use of these techniques at this stage, as very large memory capacities would be needed to store the transmitted information.

Other approaches for the interchange of high (and low) bit rate information over a limited geographical area are available and these are discussed in Section 5.7.

5.5 Signalling and Protocol Techniques

5.5.1 Introduction

In telephone switching, "signalling" refers to the exchange of information (other than by speech) specifically concerned with the establishment, supervision and release of connections. In data switching, "signalling" also includes the exchange of data transfer control information associated with the actual information (data) transfer phase. This phase is analogous to the conversation phase in telephony.

With the advent of packet switching in the late 1960s, the procedures associated with signalling became synonymous with "protocol", which refers to a set of rules and procedures which allow effective information interchange between communicating parties.

Major trends in signalling and protocol techniques include:

- the introduction of the CCITT Common Channel Signalling System (CCSS) No. 7 for digital telephony, circuit-switched data and network management information

- the use of layered architecture for the study and design of protocols for data communications. This layered approach is being formulated by both the ISO and CCITT and it is also being applied to the investigation of signalling procedures for telephony and other non-voice services in an ISDN environment.

5.5.2 Common Channel Signalling System No. 7

The recent development of electronic stored program controlled (SPC) exchanges has provided a manyfold increase in the inbuilt capacity for processing control information in the exchange and for allowing the introduction of new exchange-based facilities. The limitations of the signalling system now determine the amount of information available and the facilities which might be provided. The multi-frequency code (MFC) signalling system, which suited the slower and reduced capabilities for processing control information in electro-mechanical exchanges, was extended to provide STD and ISD facilities, but it has limitations in that further facilities must require any additional control signalling to take place before or after a connection is established and at a slow rate.

Common channel signalling techniques can supply an SPC exchange with much more information for processing in the provision of new or enhanced facilities. In a common channel signalling system (CCSS), control signals for a number of speech connections are collected and passed between exchanges on separate, dedicated signalling channels. These channels are available for signalling at all times, not just during call set-up or release. The speech circuit is only required during the actual conversation phase and thus has a reduced holding time.

An inherent limitation of MFC signalling was that all signalling had to be associated with a call set-up attempt. CCSS brings about another dimension in signalling since signalling messages can be sent between exchanges for any purposes. It becomes possible to perform dynamic network management, for example, by changing routing tables in adjacent areas to avoid congested exchanges or trunks. Centralised data banks also become possible, which can be interrogated by exchanges to determine current routing requirements (which may vary with time of day) for special numbers. Facilities like these permit assignment of personal telephone numbers, calls for which are routed to locations specified by the holder and which can be changed at any time by the holder.

The complexities of these common channel signalling systems and the international nature of telecommunications are such that it is not economic or feasible for any single telecommunication administration to develop these systems simply for national use. These systems are therefore developed by the CCITT, and two such systems have been developed.

The first system, CCSS No. 6, was recommended by CCITT in 1972 and has been introduced into service in North America and internationally, particularly in the Pacific area including Australia. It was mainly designed for analogue circuits and caters only for telephony services. With the introduction of digital networks and hence availability of high data transfer rates (64 kbit/s), the No. 6 protocol was considered inefficient and a more modern system was recommended by the CCITT in 1980. The development of the new system, CCSS No. 7, is still continuing. To date, it provides signalling facilities for telephony and circuit-switched data services. It is an open-ended system in that its layered and modular structure gives it the ability to cater for new services, even yet to be defined, without affecting the operation of existing modules. Other advantages include lower processing overheads and more powerful management facilities to ensure reliable transfer of signalling information. Further details on layered protocol architecture may be found in the next two sections. The No. 7 system will be introduced in Japan late in 1981 and in several other European countries by the mid-1980s. It is expected to become the dominant worldwide signalling system by the end of the century and will form the basis for providing inter-exchange signalling and other needs in the development of the ISDN concept.

5.5.3 Layered Protocol Architecture

One of the fundamental problems in data communications is the interconnection and interworking of heterogeneous information processing systems from different manufacturers. These systems include computers, data terminals and associated devices. With the advent of experimental packet switching data networks in the late 1960s, the International Organisation for Standardisation (ISO) recognised the urgent need to standardise the rules associated with such interconnections, and in 1977, it commenced formulating the so-called "Reference Model of Open Systems Interconnection". The model serves two basic purposes:

- to provide a common basis for the co-ordination of standards development for the purpose of interconnection, and

- to allow existing standards to be placed into perspective within the model.

The model has been adopted by the CCITT as a basis for the study of its own "Reference Model for Public Data Networks".

With this model, an information processing system is represented by a conceptual structure of seven independent but interworking functional layers (or levels). Figure 5.2 illustrates the interconnection of two systems, namely, System A and System B, via a physical communication medium

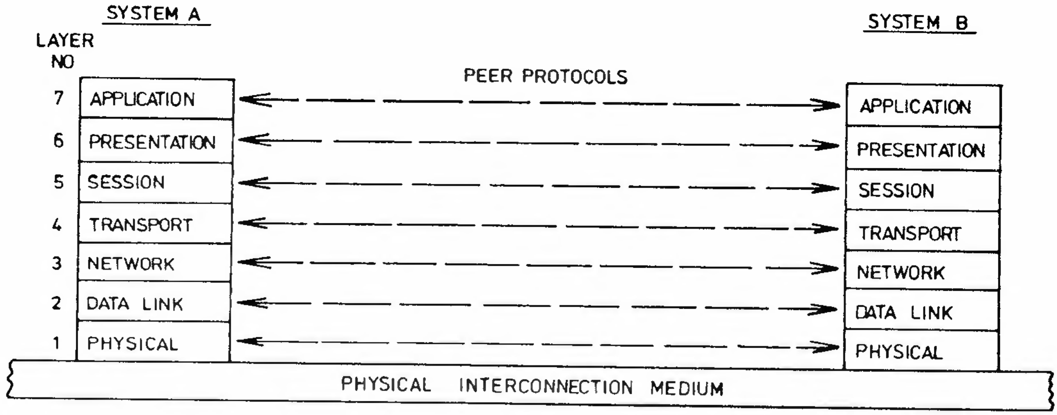


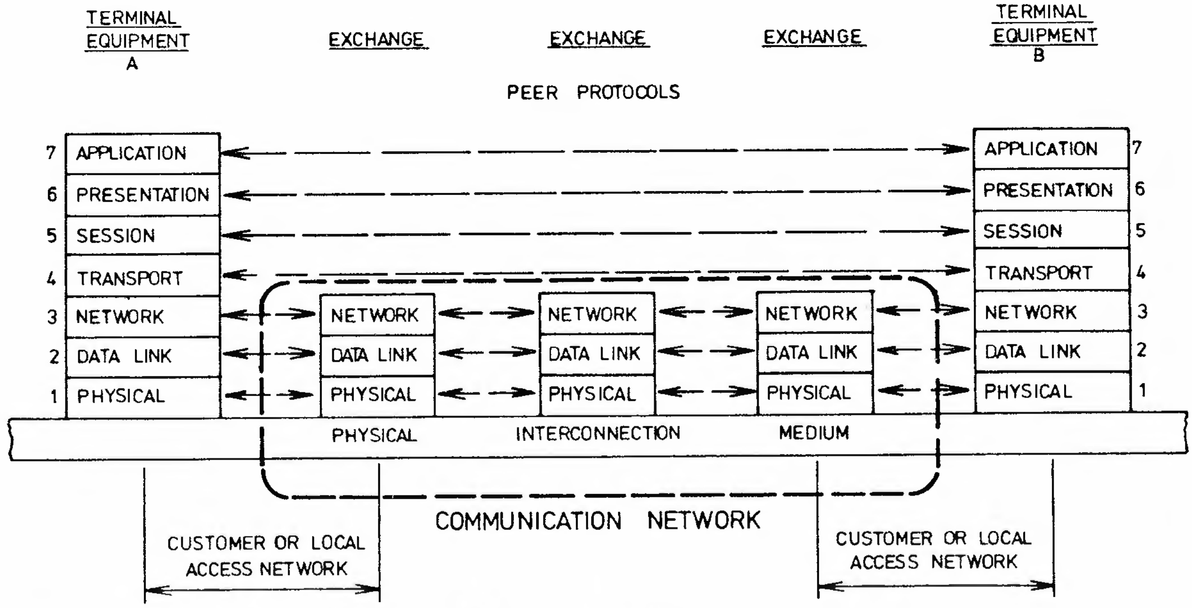
FIGURE 5.2 : THE ISO/CCITT REFERENCE MODEL LAYERED ARCHITECTURE

such as a metallic cable pair, an optical fibre or radio system. With the exception of the highest layer (Application Layer, Layer 7), each functional layer provides a number of services to support the layer above it. The upper three layers (Application, Presentation and Session) deal mainly with information processing activities, while the lower four layers (Transport, Network, Data Link and Physical) are mainly concerned with communication activities. Appendix 2 gives a brief description of the basic functions and services associated with each of the seven layers. Although information flow takes place between source and sink entities or functional units residing in the Application Layers of the communicating systems via the respective lower layers and the physical interconnection medium, the two systems communicate according to a set of rules and procedures associated with each pair of corresponding entities within each of the layers. These procedures are known as peer or layer protocols. Strictly speaking, the term "protocol" refers to the communication procedures between peer (or equivalent) entities. Loosely used, it refers to interchange procedures which may involve several peer protocols.

Figure 5.3 illustrates the interconnection of two layered systems via a switched network (e.g. circuit, packet) encompassing switching nodes. The latter can be generally represented by three lower layers (namely, Network, Data Link and Physical) although the source and destination nodes may also include the end-to-end functions performed by the Transport layer.

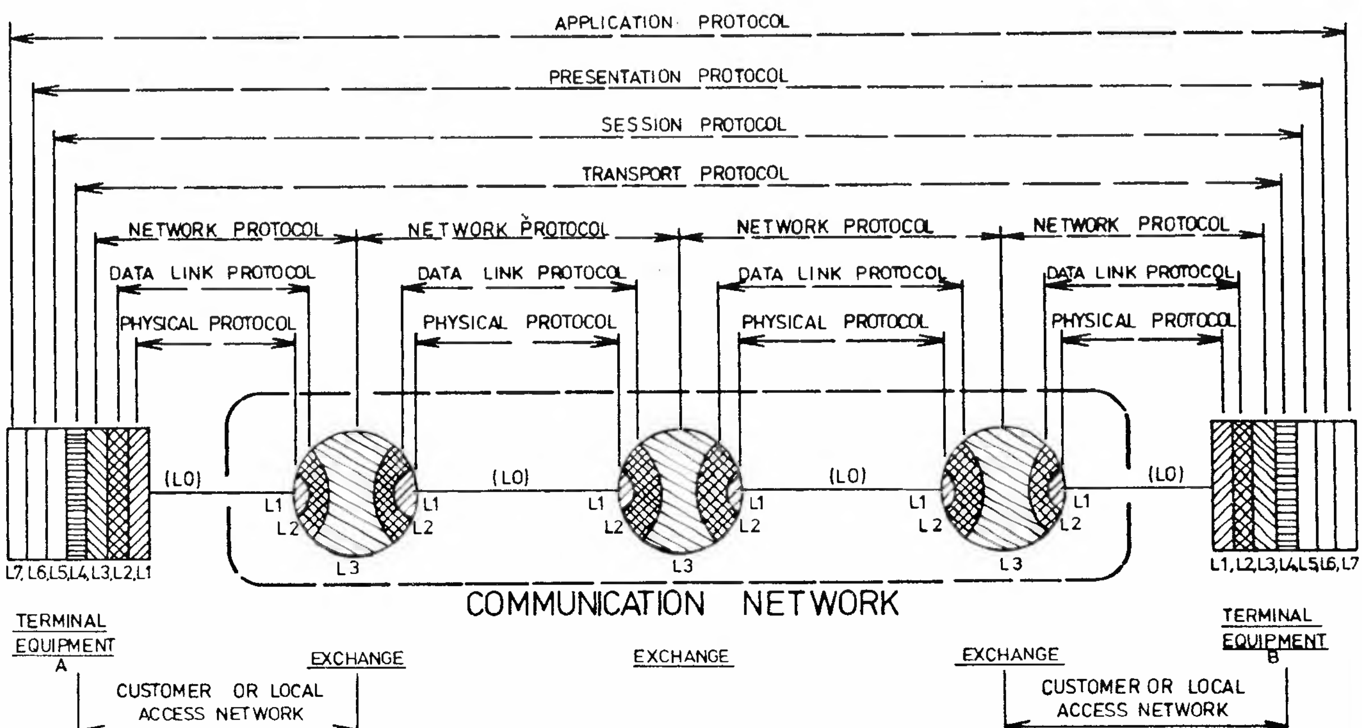
5.5.4 Applications of Layered Protocol Architecture

Although the ISO/CCITT Reference Model was initially formulated for data communications, it is proving useful for other types of communications. A partial layered protocol architecture was applied to the formulation of the Common Channel Signalling System No. 7. The Reference Model is also being applied to the study of signalling protocols associated with local data networks and customer access to a future multi-service ISDN.



NOTE: THE FUNCTIONS OF LAYERS 2 & 3 (DATA LINK & NETWORK) VARY ACCORDING TO THE SWITCHING TECHNIQUES (eg. CIRCUIT, PACKET SWITCHING) USED IN THE COMMUNICATION NETWORK.

FIGURE 5.3(a): LAYERED ARCHITECTURE OF A SWITCHED COMMUNICATION NETWORK (REPRESENTATION "a")



LEGEND: L7: APPLICATION LAYER; L6: PRESENTATION LAYER
L5: SESSION LAYER; L4: TRANSPORT LAYER
L3: NETWORK LAYER; L2: DATA LINK LAYER
L1: PHYSICAL LAYER; (LO): PHYSICAL INTERCONNECTION MEDIUM

NOTE: THE FUNCTIONS OF LAYERS 2 & 3 (DATA LINK & NETWORK) VARY ACCORDING TO THE SWITCHING TECHNIQUES (EG. CIRCUIT, PACKET SWITCHING) USED IN THE COMMUNICATION NETWORK

FIGURE 5.3(b): LAYERED ARCHITECTURE OF A SWITCHED COMMUNICATION NETWORK (REPRESENTATION "b")

5.6 Network Management

5.6.1 Introduction

The efficient operation of a modern telecommunications network not only requires adequate plant to carry traffic loads but also appropriate management techniques, including:

- effective network control functions for controlling traffic problems associated with unforeseen network overloads and failures

- a flexible method for the control and distribution of network operational and maintenance data required for preserving the integrity of the network, dimensioning the network and charging the customers, etc.

Network management techniques must also evolve with changing telecommunications technology.

5.6.2 Circuit Switching Networks

In circuit-switched telephone networks, network management capabilities have been enriched by the introduction of stored program control techniques and, more recently, common channel signalling systems.

The current approach to telephone network management is to provide an economic balance between automatic and manual control capabilities. Advances have been made in manual network control and real-time network surveillance capabilities, primarily by the introduction of computer-based systems which support the operation of centralised Network Management Centres (NMC).

The evolution towards an SPC network will allow more emphasis on improved, automated network control. For example, common channel signalling will permit rapid transfer of network control messages to source exchanges (e.g. transfer of "Hard-To-Reach" area code for controlling focussed congestion by restricting traffic destined for the concerned area). It also allows automatic "Out-of-chain" re-routing of calls away from congested, conventional hierarchical routes to predetermined routes with spare capacity. The CCSS network can also carry other than signalling messages, such as operational and maintenance data, and this will enhance real-time network surveillance and remote data acquisition by NMCs.

The current trend in the organisation of network management systems follows a hierarchical approach : each NMC supervises a well-defined area; a group of NMCs supports a Regional Operation Centre (ROC); and finally, all ROCs support a National Operation Centre (NOC), so that managers at the NOC have a national overview of important network management information and control responses within minutes of their occurrence.

5.6.3 Packet Switching Networks

By their inherent distributive processing nature, these networks have readily allowed sophisticated network control functions (such as congestion control, routing control and flow control) to be fully distributed within the networks.

Hierarchical structures are popular for organising the control and distribution of network operational and maintenance data. For example, one administration has adopted a three-level (local, regional and national) organisation as in the circuit-switched network above. Another proposes to use a two-level (primary and secondary) hierarchical structure, in which a lower-level Secondary Control Centre (SCC) is responsible for the supervision of a specific area served by a Packet Switching Exchange (PSE), while the Primary Control Centre (PCC) supervises the whole network (PSEs and trunks). The SCCs and PCC communicate with each other via the packet-switched network itself, thus forming a special "Closed User Group". In general, such hierarchical structures provide the flexibility characteristics necessary for smooth evolution in step with service and network growth.

It is common to have the lower level control centres performing mostly on-line data processing while the higher level centres mostly perform off-line data processing. However, the control capabilities of these centres tend to vary between different networks. Some allow the control centres to change the routing tables of the PSEs following detection of faults or overloads, while others have centres which can provide users with support tools such as a standard protocol tester, fault simulator, simulated traffic generator and performance monitor.

The evolution of telecommunications networks towards an ISDN will pose further challenge for network designers and planners to provide more flexible and effective network management strategies.

5.7 Local Networks

5.7.1 Introduction

In telecommunications, a local network can be regarded as that part of the total network which supports services within a limited area (e.g. within a company's premises or within a local exchange area). It can be a public local network, providing public facilities and operated by a national telecommunications administration, or a private local network providing private communications facilities. A private local network may or may not have access to one or more other (public or private) local networks or to the public main network - as depicted in Figure 5.1.

This section discusses the main trends in techniques for the provision of services in local networks. Because of their relatively small area of coverage (e.g. up to 10 km), the techniques used are in some cases different from those for main networks, in particular, for signalling procedures or protocols. The following topics are considered:

- digital PABXs
- local data networks
- cable TV-based networks
- ISDN local networks.

5.7.2 Digital PABXs

Traditionally, private local networks cater mainly for telephony and are served by analogue PABXs providing circuit-switched intra-corporate voice communications with access to the public switched telephone network and possibly to other public non-voice networks such as telex. The following developments are now being included in more recently designed digital PABXs:

- time division switching
- stored program control, allowing a wide range of new facilities
- switching matrices with large bandwidth or bit rates (e.g. about 200 kbit/s)
- distributed control and switching architecture.

PABXs are developing towards multi-service circuit switching systems which can support up to 250 kbit/s over twisted cable pairs using baseband modems. Further improvements in bit rates could result from the use of 2 Mbit/s switching techniques. These developments will require access interfaces to different types of public networks (e.g. packet switching network) and private networks (e.g. local data networks based on bus and ring architecture).

5.7.3 Local Data Networks

Recent years have seen the emergence, through microelectronics technology, of new data communications techniques for the interconnection of increasingly "intelligent" terminals over limited distances. These terminals range from microprocessor-based office automation systems (such as data terminals, communicating word processors) to large host computers.

Private local data (or computer) networks are more commonly known as "local area networks", and their number is growing rapidly due to the decreasing cost of computer equipment and the consequent increased automation of information gathering and information processing. Local area networks also allow expensive resources to be shared and provide new facilities for users to intercommunicate.

Typically, local area networks cater for an area of about 1 km span, offer data rates of up to several megabits per second and cater for several hundred attachments. Various types of transmission media are used, ranging from pair cable to coaxial cable to optical fibre. The longer term future should see a predominance of optical fibre.

Local area networks aimed at data processing and office automation can be broadly classified into two main types, namely, "broadcast topology" and "ring topology".

A typical example of a broadcast topology local area network is the Xerox Corporation's "Ethernet". Broadcast local area networks work on a contention basis, each user listening to the communication channel, transmitting information when the channel is found free and using re-transmission after a variable delay to resolve message collision. A significant recent event has been the formation of a consortium between Xerox, Intel and Digital Equipment Corporation (DEC) to develop Ethernet as a commercial product.

A typical example of a ring topology local area network is that developed at Cambridge University and known as the "Cambridge ring". These networks use a closed ring communication line and transmit information using small packets which circulate around the ring. The UK Science Research Council recently awarded a contract to Logica VTS to produce hardware for the Cambridge ring.

To date, local area networks have been primarily used "in-house", without connection to public networks. They generally use low level protocols and are tailored to specific uses. However, as these networks become more established, users will wish to communicate via public networks with users or equipment attached to public networks or to other private networks. Considerable effort is being devoted towards the development of protocols to allow such interconnection and it can be expected that the desire to interconnect private networks and public networks will impose new requirements on public networks, particularly in the areas of addressing, sub-addressing, facility provision and traffic handling capacity.

Another significant area of research concerns the use of private local area networks to carry voice traffic. Since a prime objective of these networks is office automation, users will see advantage in their use for voice communication as well as data, and predictably, this capability will be required between private local area networks via public networks. This will impact significantly upon the public network provider as, currently, public data network access protocols are designed to cater for data information, not coded voice information.

To date, little effort has been devoted to the development of international standards for local area networks although it is apparent that telecommunication network operators should take some interest in this topic in the future. It is anticipated that the next five years will see the production of local area network hardware in chip form and the development of high level interconnect protocols and with this, a significant increase in their use.

5.7.4 Cable TV-Based Networks

One approach to the provision of future telecommunication services is to incorporate these into CTV networks where such networks exist. Frequency division multiplexing (FDM) of the TV signals with digital signals carrying different types of traffic can be readily achieved on the TV cable using present data modem technology. Both circuit switching and packet switching techniques can be used on various frequency-separated passband data channels for different types of applications.

Cable TV-based local networks are commonly known as "broadband local area networks" and local data networks as "baseband local area networks". Both types of networks are presently supported by metallic coaxial cables, but optical fibres could find increasing application in networks of these types in the longer term.

5.7.5 ISDN Local Networks

One of the most actively debated topics within the CCITT is the approach to the provision of customer access to the public multi-service ISDN concept. Opinions differ as to whether this concept should be based on gradual evolution of the telephony-based IDN or by addition of a new and basically separated network. One dominant topic requiring urgent study for a successful ISDN introduction is the development of a flexible customer access arrangement in the ISDN environment. Flexibility is of fundamental importance, as it must allow for a wide range of diverse services (present and future) having different requirements and characteristics to be progressively integrated. The ISDN customer access topic involves consideration of a number of inter-related matters, including the following:

- customer services and facilities
- customer access types
- customer terminal equipment
- signalling procedures or protocols
- functional interfaces
- transmission techniques
- quality of service
- traffic characteristics.

The present CCITT study of ISDN local networks includes a wide range of services (with bit rates up to about 140 Mbit/s to cover moving picture or video applications) which might be supported by a variety of switching techniques (e.g. circuit or packet switching) in a national ISDN (long-haul) network. ISDN-type services have already been discussed in Chapter 4 and telecommunication techniques which may be used to support these have been described in this chapter. These techniques, and particularly those described in this section, will be the subject of ongoing study and development for ISDN local networks.

5.7.6 Future Interworking Considerations

It is expected that the future will require that the various types of public and private local network (PABX, data/computer, CTV, ISDN-based) should interwork and that access should be provided to different public national networks whether they are voice, data, video or ISDN-oriented. This interworking will be a major issue which requires urgent consideration by public network operators, as traffic between geographically-separated local networks will impose a new set of service requirements on the national networks.

DATUM FOR DISCUSSION OF FUTURE TRENDS

1. INTRODUCTION

In looking to the longer term future, it is useful to have an overview of the present state of, and Telecom Australia's accepted shorter term plans for, telecommunications services and network development. This appendix is intended to provide such an overview under the headings following.

2. CUSTOMER TELEPHONE SYSTEMS

Telecom provides a range of standard telephone instruments, whose technology incorporates carbon transmitters and rotary or keypad dials. In the main, decadic pulsed direct current signalling is used between telephone and exchange, and voice signals are analogue. Field trials of a new solid state replacement for the carbon transmitter are in progress. New telephones employing voice frequency tone dialling are being introduced at a rate to match the modernisation of the local crossbar exchange network to ARE 11 status.

Telecom also provides a range of small business telephone systems, automatic call distribution (ACD) systems and private automatic branch exchanges (PABX) systems. It also grants permits to private enterprise to provide and connect approved business telephone systems, ACDs and PABXs to the public network. Recent versions of these latter types of system incorporate modern technology; for example, small business systems incorporate microprocessors to provide a range of enhanced facilities; some PABXs incorporate stored program control (SPC) and digital/electronic switching.

Other Telecom-approved attachments are also provided by private enterprise, for example, message recorders, automatic/repertory dialling machines, etc. These also use recent technology.

3. TELEPHONE SWITCHING SYSTEMS

The majority of Australian exchanges use the electro-mechanical technology of either earlier Strowger 2000 type step-by-step systems or L.M. Ericsson crossbar systems. The major trunk exchanges utilise ITT stored program controlled (SPC) 10C systems.

Subscriber trunk dialling (STD) facilities are available to over 90% of telephone users and call charging is based on a unit fee/multi-metering approach using tariff scales determined by call charging zones and time of day.

Fundamental studies commenced in 1977 have yielded a number of significant decisions to:

- phase out step-by-step equipment by about 1995;
- modernise existing crossbar local exchanges to ARE 11 status by substituting electronic control, using the ANA 30 sub-system;

- adopt L.M. Ericsson's AXE system as the new local equipment standard.

Considerable progress has already been made with the crossbar modernisation programme. The first AXE exchanges will be put into service in late 1982. They will employ stored program control (SPC) and will initially use analogue (electro-mechanical) switching techniques in their subscriber switching stages and digital (electronic) switching techniques in their group switching stages. Initially, the 4-wire digital group switches will interface with analogue transmission systems, but by mid-1983, AXE group switches will also be provided to interface directly with digital PCM 30 transmission equipment using the T6 signalling system. These later AXE exchanges will also be able to perform some tandem exchange switching functions. By 1985, approximately 250 000 lines of AXE equipment will have been installed in the metropolitan networks.

Remote subscriber switching (RSS) systems are also planned for introduction into the network early in 1983. Initially, microprocessor controlled analogue systems will be used, but digital systems will also be required to provide facilities to work over analogue FDM 12-channel or digital PCM 30-channel multiplex equipment.

The above plans, coupled with plans for the further introduction of digital systems in the junction and trunk transmission networks are consistent with the 1980 policy decision to move towards integrated digital networks (IDN) for telephony services, initially as urban networks and later as a national network. To facilitate the extension of the IDN into the trunk network, consideration is being given to the introduction of a new digital trunk transit switching system simultaneously with the introduction of digital trunk transmission systems.

Although network studies are still in progress, it is expected that the combination of digital switching and transmission will be used to meet the majority of trunk network growth in the latter part of the 1980s. Current planning studies suggest that the IDN will be established between capital cities by about 1987 and that, by 1990, 60% of all new circuits for voice trunk traffic will be on the IDN.

In the rural and remote areas, it is planned to provide automatic telephony services to most subscribers by about 1990. The introduction of a digital radio concentrator system (DRCS) in late 1984 is planned to provide improved telephone, telex and data services for people in the more distant rural and remote areas of Australia. Up to about 12 000 services will be provided by this means by about 1990.

An extension of the capacity of the existing automatic telephone paging services to a maximum of 100 000 customers is planned for Melbourne and Sydney in mid-1982, and the new systems will provide enhanced options of home, regional or multi-regional service. In addition, a public automatic mobile telephone service (PAMTS) will be introduced in Melbourne and Sydney in late 1981. Initially, provision will be made in each city for up to 1000 customers, extensible later to 4000 customers, using zoned transmission and stored programme control to connect customers to the national network.

A new call charging technique for recording charge details of STD trunk calls is also to be introduced as an optional vertical service for a limited number of calls in metropolitan areas from 1984. Known as STD Call

Charge Record (STD/CCR), the service will be initially provided at ARF, ARE and AXE exchanges by using the STD/CCR facilities of the 10C trunk exchanges and the calling line identification (CLI) facilities of terminal exchanges. With the later introduction of digital trunk tandem exchanges, more extensive STD/CCR service options will be provided in metropolitan areas. STD/CCR services will also be provided from 1986 in country areas by the provision of charging facilities at minor switching centres.

4. DATA TRANSMISSION SERVICES

Telecom Australia provides a range of simplex or duplex data transmission services over the existing analogue-telephony-oriented network. These are grouped under the title Datel Services. Switched Network (DXL) Datel Services are provided at data transmission speeds up to 4800 bit/s over switched voiceband circuits: and Private Line (DPL) Datel Services operating at speeds up to 48 kbit/s are provided over dedicated point-to-point lines leased to customers. Telecom-provided or approved data modem equipment is used as an interface between the customer's computer equipment and the Telecom public telecommunications network.

The rapid growth in data traffic in the metropolitan and inter-capital city networks has led to plans for the introduction by Telecom of a Digital Data Service (DDS) and a Packet-Switched Data Service (called "AUSTPAC") in late 1982. Both services will be implemented as special new digital transmission network overlays on the existing network.

The DDS will use dedicated digital transmission links provided in the metropolitan and inter-capital networks and will provide nationwide service by about 1986. The basic set of services offered will be synchronous full-duplex leased services operating at 2400, 4800 and 9600 bit/s and at 48 kbit/s. A major new feature will be the facility to multiplex services using time division multiplexing (TDM) techniques into 48 kbit/s streams. A trial digital data network will be established to link Sydney, Melbourne and Canberra late in 1981. The subsequent introduction of a public inter-capital service linking all capital cities is planned for late 1982, with the extension of the service to about 100 metropolitan and provincial centres by 1985.

Initially, the AUSTPAC Service will be implemented as a new high-speed digital network linking packet switching exchanges in Melbourne and Sydney. It will provide a universal, intelligent store-and-forward network for switched data communications, providing facilities such as error protection, interworking between terminals operating at different data transmission rates, and connection facilities for X.25 packet, X.28 asynchronous and some types of synchronous mode terminals operating at a variety of data speeds up to 9600 bit/s. The AUSTPAC Service will have interconnection facilities with the existing Datel Service.

The initial AUSTPAC network will offer customers in all States a high efficiency, low cost means of enabling computers and terminals to communicate with each other and will facilitate the introduction of new services, such as electronic mail and electronic funds transfer. It is expected that, by 1984, the network will have expanded to six switching nodes.

5. TRANSMISSION NETWORK

The Telecom transmission network has evolved primarily as a vehicle for the transmission of analogue telephony signals. The transmission systems in use in the local, rural, junction and trunk components of the network mostly use analogue techniques, although since 1977, pulse code modulation (PCM) 30-channel digital transmission systems have found increasing application in the inter-exchange junction network. More recent versions of these PCM-30 systems will be introduced in 1983/84. The new systems use a T6 digital line signalling scheme which is more suited to interworking with AXE exchanges than the present T5 signalling scheme. By 1985, about 1100 PCM systems will have been installed in the metropolitan networks. These PCM systems will support both digitally-based voice and data services in the metropolitan networks.

The establishment of the digital data service (DDS) and the AUSTPAC service in late 1982 will provide the earliest demands for digital transmission facilities in the inter-capital trunk network. Data-above-Voice (DAV) techniques will be used initially on some existing radio bearers to provide inter-capital trunk transmission links operating at 2048 kbit/s for these new data networks. Data-in-Voice (DIV) techniques are also under evaluation for this purpose. DIV systems utilising 3 supergroup bands and thereby allowing the use of 2048 kbit/s data modems seem likely to be introduced about 1983/84, mainly on intra-State coaxial cable routes to provide for the DDS. Data-on-Radio (DOR) systems, which derive 8 Mbit/s capacity from an analogue bearer, will also be of interest in this time frame.

The increased use of digital trunk transmission systems in lieu of existing FM/FDM coaxial cable and microwave radio systems is predictable, as digital switching systems proliferate for telephony and the traffic demands of data transmission services increase. A number of studies and field trials are under way and these are expected to provide a basis for planning the national transition to a digital transmission network in the near future. These studies include:

- field trials of optical fibre transmission systems culminating about 1982 in:
  - a trial over 24 km (with two optical repeaters) of a 34 Mbit/s system (having a capacity of 480 PCM-encoded voice circuits and typical of a metropolitan junction network application) between the Spring Hill and Strathpine exchanges in Brisbane;
  - a similar trial over 36 km (with four repeaters) of a 34 Mbit/s system between the Exhibition and Dandenong exchanges in Melbourne;
  - a trial over 13 km (with one repeater) of a 140 Mbit/s system (having a capacity of 1920 PCM-encoded voice circuits and typical of a trial of a 140 Mbit/s digital radio trunk transmission system) between the Maidstone radio terminal and the Exhibition Exchange in Melbourne.
- field trials of high capacity 140 Mbit/s microwave radio trunk transmission systems commencing in 1982:
  - over a 300 km multi-hop overland path between Melbourne and Albury, which will later be joined with the last of the optical

fibre system trials mentioned above;

  - over a 30 km single-hop path over water from Port Pirie to Whyalla in South Australia.

- digital network synchronisation techniques, culminating in 1982 in a digital network synchronisation field trial which will yield design data for a National Synchronisation Network.

It is expected that the first 140 Mbit/s digital radio transmission systems operating in the 6.7 GHz band will be installed on the Sydney to Melbourne route in 1983, and on the Melbourne to Adelaide and Sydney to Brisbane routes in 1984.

It is also expected that optical fibre transmission systems will find economic application in some metropolitan inter-exchange routes from 1984/85 and from 1983/84 as tails for 140 Mbit/s digital trunk radio systems. Optical fibre systems of predominant interest in the Australian scene are 34 and 140 Mbit/s systems, with typical maximum repeater spacings of about 9 km and 11 km respectively.

The Australian National Satellite Communications System is also expected to be operational in 1985 and Telecom Australia will be one of the multiplicity of users of the system. Telecom will use the satellite to provide remote area telephone services to outback Australia and temporary trunk line transmission facilities. The extent of such use rests on economic and technical studies to compare satellite and terrestrial options.

6. TELEMATIC SERVICES

Telex, Teletex, Facsimile and Videotex Services fall within this group of services.

Telecom has an established national 50 bit/s Telex service providing communications between teleprinters via L.M. Ericsson electro-mechanical crossbar switching systems. The introduction of SAGEM teleprinters in 1980 as the Telecom standard terminal equipment item was a significant step forward towards modern technology. The planned introduction of L.M. Ericsson stored program controlled (SPC) AXB20 telex switching systems to provide future network capacity and enhanced facilities will also advance the technology of the telex network into the electronic era.

Telecom does not presently provide public facsimile services, but it allows the connection of privately supplied, approved types of facsimile equipment to be connected via switched or leased lines in the national network to provide private facsimile services.

Needless to say, advances in services related to the retrieval and/or transmission of information recorded on paper or in computer files are of interest to Telecom. Not only will they be derived from advances in digital and/or computer technology, but they also promise to be an area of business growth and diversity.

7. OTHER SERVICES

Other services provided by Telecom include the Public Telegram Service, which is in decline; radio and television programme transmission services;

a limited studio-to-studio video conferencing service between Melbourne and Sydney; and operator-connected telephone conferencing services.

Although not extensive when compared with telephone and data transmission services, advances made possible or economic by new technology in this general sphere of "wideband" services are of research interest to Telecom. They are also the subject of Government and other interest, in that the present Government Inquiry into Cable Television is relevant, as also are final detailed decisions regarding the planned multiple-user Australian National Communications Satellite System.

THE ISO/CCITT REFERENCE MODEL OF OPEN SYSTEMS INTERCONNECTION

This Appendix more completely describes the functions and services of the seven layers of the Reference Model illustrated in Figures 5.2 and 5.3 (Chapter 5). The following description commences at the highest layer, which is the Application Layer.

Application Layer (Layer 7)

This layer performs application/system activities to provide/support the information processing function. It contains the control function associated with transferring data between end-users (e.g. human operator, user application program). In addition, it contains the ultimate sources and destinations for the data exchanged.

Examples of Application Layer services are:

- time-shared computing
- remote job entry
- data entry
- file transfer
- electronic mail
- electronic funds transfer
- terminal and (human) operator services
- facsimile
- videotex
- teletex
- network management
- electronic directory.

Presentation Layer (Layer 6)

This layer provides services to the Application Layer in the interpretation of the data exchanged and the necessary transformation of this data in a manner appropriate to the communicating parties.

Examples of Presentation Layer services are:

- code translation
- data element translation
- data compaction/expansion
- data encryption/decryption
- command translation (as in virtual terminals)
- data structure (as in file transfer).

Session Layer (Layer 5)

This layer provides services to the Presentation Layer in the co-ordination of interactions between communicating parties. These services are classified under two categories:

- session administration services, dealing with the establishment and termination of the logical connection

- session dialogue services, dealing with the transfer of data over the established connection.

Examples of Session Layer services are:

- session connection establishment/termination
- dialogue control (one-way, two-way alternate, two-way simultaneous)
- flow control of session data transfer
- signalling of non-recoverable errors
- setting priorities
- dialogue recovery following failure of the transport service which supports the data transfer.

<u>Transport Layer (Layer 4)</u>

The purpose of this layer is to provide a universal transport service in association with the services provided by the lower three layers. It provides transparent transfer of data between session entities. The Transport Layer relieves the higher layers of any concern with the detailed way in which reliable and cost-effective data transfer requested by the higher layer(s) is achieved. It is required to optimise the use of available communication services to provide the end-to-end performance required for each connection between session entities at a minimum cost. The Transport Layer can be viewed as enhancing the quality of the network service (e.g. reliability by means of error recovery procedures, re-establishment of virtual circuits after failure, etc.). The Transport Layer may also provide for the extension of a connection, offering the same service across more than one network.

Examples of Transport Layer services are:

- transport connection establishment/termination
- quality of service selection
- class of service selection
- flow control
- sequence control
- segmentation/combining
- delivery notification
- signalling of non-recoverable errors.

<u>Network Layer (Layer 3)</u>

This layer provides the functional and procedural means to exchange data between two transport entities over network connections. It provides these functional units with independence from routing and switching considerations associated with the establishment, maintenance and termination of a given network connection.

Examples of Network Layer services are:

- routing and switching
- network connection establishment/termination
- full-duplex normal data path
- full-duplex expedited data path
- flow control
- multiplexed data path
- transparency of data path
- finite but unbounded network data unit size

- sequence control
- path purging procedures
- signalling of non-recoverable errors
- provision of quality of service requirements.

Data Link Layer (Layer 2)

The purpose of this layer is to provide functional and procedural means to establish, maintain and release data links between network entities.

Examples of Data Link Layer services are:

- link initialisation
- data unit framing or delineation
- link management (establishment, supervision, release)
- error control
- sequence control
- flow control
- transparency of data path
- abnormal-condition recovery
- signalling of non-recoverable errors
- support of multiple data links.

Physical Layer (Layer 1)

This layer provides the mechanical, electrical, functional and procedural characteristics to establish, maintain and release physical connections (e.g. data circuits) between data link entities within communicating equipments/systems. These equipments include customer terminal equipment (such as Data Terminal Equipment) and network equipment (such as a Data Switching Exchange or Inter-Networking Data Switching Exchange).

Examples of Physical Layer services are:

- point-to-point connections
- multi-point (centralised or distributed) connections.

GLOSSARY OF TERMS

Algorithm: A set of steps to be taken to effect a desired calculation or computer processing operation, often expressed as one or more mathematical rules which are applied successively to a table of input data to yield a table of corresponding results.

Analogue Signals: Electrical signals which are continuous over a time interval and which are characterised by the part of the frequency spectrum over which they range, e.g. the audio-frequency range from 50 to 4000 Hz for telephony signals. Sets of analogue signals are multiplexed over a wider frequency range (bandwidth) by frequency division multiplexing (FDM) techniques to permit a single transmission link to carry signals from a number of separate telephony channels.

Asynchronous (Digital) Transmission: A technique of aligning transmitter and receiver for transmission of digital signals, whereby the transmission of a character or message (comprising a number of bits) is preceded by a "start" signal to prepare the receiver to accept the transmitted character or message, and is followed by a "stop" signal to reset the receiver in preparation for reception of any subsequent "start" signal.

Attenuation: The degree to which a signal becomes weaker as it progresses along a (lossy) transmission path.

Bit Rate: The number of binary digits ("bits") comprising an information signal transmitted over a communications channel per second.

Circuit Switching: A switching technique whereby a particular circuit through-connection is established and maintained for the real time duration of a particular communication, as for telephony and Datel exchange line services.

Codec: A "coder-decoder" equipment item which codes and decodes signals in accordance with preset coding "rules", generally coding an analogue signal into a digital signal format and decoding a digital signal back to its analogue form.

Common Channel Signalling: A technique whereby the control signals required to establish and supervise service signal path interconnections through sequential stages of switching systems are communicated over a common, dedicated link between the stages which is separate from the service signal paths and shared in common by a large number of signal path connections. The technique applies to (computer) stored program controlled (SPC) switching stages and the control signals pass between the processors (computers) controlling the establishment and supervision of the interconnections.

Concentrator: An item of equipment placed between a terminal exchange and subscriber terminals which terminates a number of incoming subscriber circuits, which may or may not all be simultaneously active, and by means of controlled switching, concentrates the traffic from the incoming circuits onto a smaller number of outgoing circuits to the exchange, providing two-way communications links for active subscribers.

Crosstalk: The aggregation of unwanted signals induced or coupled into a transmission channel from other channels in a system and interfering with and thereby degrading, to some extent, the wanted signal which is being transmitted over the channel.

Data Modem: An item of "modulator-demodulator" equipment interfacing computer equipment to the telecommunications network to achieve data transmission between separated computer installations. The modem converts the (digital) data signals produced by the computer equipment into an analogue form suitable for transmission over a telephony channel and re-converts them at the receiving end into the digital form required in the operation of the distant computer terminal equipment.

Data Terminal Equipment: A customer terminal equipment item providing the communications network interface with a computer system.

Datel Services: A generic term for the data transmission services provided by Telecom at a variety of bit rates over the telephony network. Switched Network (DXL) Datel services are provided at data transmission speeds up to 4800 bit/s over switched voiceband circuits; Private Line (DPL) Datel Services operating at speeds up to 48 kbit/s are provided over dedicated point-to-point lines leased to customers.

Digital Signals: Electrical signals which comprise a sequence of discrete pulses, whose spacing determines the signal "rate" (e.g. 64 000 pulses or "bits" per second for digitally coded speech telephony signals). Sets of digital signals are multiplexed by interleaving the pulse trains of one signal with those of other signals by a technique called time-division multiplexing (TDM).

Digital (Signal) Devices: Electronic devices used in circuits performing functions involving digital signals.

Distortion: A measure of the degree by which the characteristics of a signal are modified by the characteristics of a telecommunications system or channel.

Duplex Transmission: Full duplex transmission provides both ways simultaneous transmission and reception over a transmission channel; half duplex transmission provides both ways transmission and reception, but not simultaneously.

Equaliser: A transmission sub-system which restores the characteristics of a transmitted signal which have been degraded by the inherent non-uniform attenuation and delay characteristics of the transmission system over a band of frequencies.

Frequency Division Multiplexing: Refer "Analogue Signals".

Group, Supergroup, Supermaster Group: Standardised structural signal grouping arrangements in the hierarchical scheme for multiplexing analogue telephony signals in bands of the frequency spectrum using FDM techniques - See "Analogue Signals".

Group Switching Stage: An internal switching stage in an exchange which might be interconnected with a subscriber switching stage and/or other group switching stages.

Integrated Circuit (IC): A microelectronic device performing a specified electronic function and comprised of a number of individual, interconnected electronic elements fabricated on a tiny wafer of semiconductor material.

Josephson Junction Device: Refer "Superconductor Devices".

Laser: An acronym of "Light Amplification by Stimulated Emission of Radiation". An active device for the generation of optical signals of precise wavelength and coherent (constant) phase or for the amplification of such signals. Lasers can be fabricated from particular solid crystalline materials (e.g. ruby), liquids, or gases, the atoms of which can be electrically "excited" to release the photons of light energy which coherently add to produce the output signal.

Linear (Signal) Devices: Electronic devices used for performing functions involving analogue signals.

Logic Array Device: A general purpose logic device capable of once-only internal configuration by special processes to enable it to perform a custom-designed logic function.

Logic Device: An electronic device which simultaneously accepts a number of digital input signals and produces one or more output signals whose instantaneous condition is predictably determined by the design of the device and the instantaneous condition of the input signals.

Memory Device: A device containing a number of identifiable and accessible "cells", each of which can be caused to "store" a "byte" of information (each byte comprising a number of discrete "bits" able to take up one of two possible "binary" or "logic" states) and to provide, on electronic interrogation, an output representing the stored (or "memorised") byte. The memorising mechanism can be electromagnetic (ferrite cores, magnetic tapes and discs) or electronic (semiconductor RAM, ROM, PROM, EPROM, etc devices typed by codes to indicate their characteristics in regard to the storage and reading out of data).

Message Switching: A switching technique whereby a particular sequence of one-way circuits between switching nodes is established for the transmission of a (whole) message by switching control signals embedded in the message, with provision for temporary message storage at switching nodes until a free forward link becomes available, as for TRESS and Telex Services.

Microelectronics Technology: The group of technologies used in the design and fabrication of integrated circuits and other related miniaturised electronic circuit assemblies.

Microprocessor: A generic term to describe a range of micro-sized processors fabricated as semiconductor integrated circuit devices ("computer-on-a-chip") which, in association with similarly small IC devices performing memory and interfacing functions, can be flexibly programmed to perform control or data processing functions as a small equipment sub-assembly (e.g. as in a pocket calculator).

Modem: A modulator-demodulator sub-system performing modulation of signals for transmission or demodulation of received signals.

Modulation Demodulation: A technique whereby a carrier signal having constant characteristics and frequency is systematically modified by an information signal to enable the transmission of the information over a channel operating at the carrier frequency. Demodulation is the reverse process to recover the information signal after transmission.

Noise: The aggregation of unwanted signals appearing in a communications channel because of a number of natural electrical phenomena and interfering with and thereby degrading, to some extent, the wanted signal which is being transmitted over the channel.

Packet Switching: A data signal formatting and switching technique whereby the data in a "message" is formatted, with appropriate switching control signals, into a number of standardised "packets" for transmission between source and destination, where the message is re-assembled. The individual packets are "message switched" and all might not necessarily traverse the same "path" to the destination.

Photovoltaic Devices: Devices which produce an electrical output when subjected to light (or photonic) radiation.

Plesiochronous (Digital) Transmission: A technique in which the transmitter and receiver bit processing rates (i.e. the rates at which the bit stream comprising the signal is transmitted and received) are nominally aligned within specified limits throughout signal transmission, but where the electronic clocks controlling these rates in the transmitter and receiver are independent of each other, and where some "slip" can thereby occur.

Processor: A digital computer used to control, in real time, the operation of a (telecommunications) system, in accordance with sets of rules (computer programs) and data stored in the computer's memory.

Protocol: A standardised, services and/or network oriented, structured set of rules for the establishment, supervision and management of communications between customers requiring various types of related telecommunications services to be provided over a telecommunications network.

Pulse Code Modulation (PCM): As applied to voice communications, a technique whereby an analogue telephony signal is sampled 8000 times per second and its amplitudes at each sampling instant are measured and the values at each instant are coded as 8-bit digital numbers, expressed as pulses in a digital signal having a bit rate of 64 000 bits per second (bit/s).

Regenerator: A sub-system installed at intervals as required along digital transmission paths to recover, amplify, re-shape and re-time signals which have deteriorated in transmission.

Repeater: A sub-system installed at intervals as required along analogue transmission paths to amplify signals which have been attenuated in transmission.

Semiconductor Devices: Devices made from highly refined semiconductor materials (normally poor electrical conductors) whose electrical properties are modified by the precisely controlled addition of small amounts of other chemical compounds, referred to as "dopants".

Signal-to-Noise Ratio: A measure of the relative energies of the wanted signal and of the accumulation of (lesser) unwanted signals present in a telecommunications channel. The unwanted signals can result of from natural phenomena or from the coupling of signals in adjacent channels into the channel under consideration.

Simplex Transmission: One-way only transmission between a transmitter and a receiver.

Space Division Switching: An interconnection technique where circuit connections are made by physical switches.

Stored Program Control: (SPC) A term used to describe the technique whereby a computer (processor) is used for controlling the operation of a (telecommunications) system in real time - See "Processor".

Subscriber Switching Stage: The switching stage of an exchange which interfaces directly with the subscribers line.

Superconductor Devices: Devices, such as Josephson junction devices, made from cryogenic materials, i.e. which exhibit electrical properties (very low resistivity, high switching speeds, etc) at very low absolute temperatures (about -200°C) which are quite different from the properties exhibited at normal temperatures.

Switching:	The process of interconnecting two telecommunications terminals over a shared network of local, junction, and possibly trunk transmission links through switching nodes at which the various links can be accessed or interconnected.
Synchronous (Digital) Transmission:	A technique in which the transmitter and receiver bit processing rates (i.e. the rates at which the bit stream comprising the digital signal is transmitted and received) are precisely aligned throughout signal transmission by electronic bit-by-bit clocking processes, whereby the receiver clock is controlled by the transmitter clock.
Telematic Services:	A generic term for telecommunications services related to the transmission of recorded information messages (as in facsimile, teletex and videotex services).
Teletex Services:	A generic term for services related to the communication of recorded information (or messages) between communicating word processors. At the transmitting end, the information is input into computer memory by keyboard operation; and it can subsequently be transmitted at data speeds higher than those for Telex services to one or more receiving word processor terminals and further processed or accessed by means of printers, visual display units and other types of word processor peripherals.
Time Division Multiplexing:	Refer "Digital Signals".
Time Division Switching:	An interconnection technique for digital signal paths whereby connections are established by computer controlled alignment of time slot allocations for the paths for the duration of the required connection.
Transponder:	A (satellite) sub-system which receives a signal radiated at a particular carrier frequency, amplifies it and re-transmits it at a different carrier frequency.
Travelling Wave (Tube) Amplifier:	A device used in the amplification of ultra high frequency (UHF) and microwave frequency signals, whereby energy is interchanged between a helical delay line and an electron beam.
Videotex Services:	A generic term for computer-based public information services which are made accessible to customers, with varying degrees of customer-computer interaction, by telecommunications techniques and networks.

Wideband Services: Services requiring significantly more than the usual transmission channel capacity required for telephony (i.e. 4 kHz in analogue systems or 64 kbit/s in digital systems). Typically, wideband services include radio and TV broadcast programme transmission services, high speed data and facsimile transmission services, cable or closed circuit TV transmission services, Confravision services, etc.

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ACD:	Automatic Call Distributor
ADA:	A computer software programming language
AM:	Amplitude Modulated
ANA 30:	The electronic control sub-system of an L.M. Ericsson ARE 11 crossbar exchange system
ANSCS:	Australian National Satellite Communication System
ARE 11:	An L.M. Ericsson crossbar exchange system having electronic control
ARF, ARK, ARM:	L.M. Ericsson crossbar exchange systems having electro-mechanical control
ASTEC:	Australian Science and Technology Council
AUSTPAC:	Telecom Australia's Packet Switched Data Service
AXB 20:	An L.M. Ericsson telex exchange system having stored program control (SPC)
AXE:	An L.M. Ericsson exchange system having stored program control of analogue or digital switches
CCITT:	International Telegraph and Telephone Consultative Committee
CCR:	Call Charge Record
CCSS:	Common Channel Signalling System
CHILL:	A computer software programming language
CLI:	Calling Line Identification
CMOS:	Complementary Metal Oxide Semiconductor
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
CTV:	Cable Television
DAV:	Data Above Voice
DDS, DDN:	Digital Data Service, Digital Data Network
DIV:	Data In Voice
DOR:	Data on Radio
DRCS:	Digital Radio Concentrator System
DRS:	Digital Radio System
EPROM:	Erasable Programmable Read Only Memory
FDM:	Frequency Division Multiplexed
FDMA:	Frequency Division Multiple Access
FM:	Frequency Modulated
HF:	High Frequency
HLL:	High Level (Computer Programming) Language
IC:	Integrated Circuit
IDN:	Integrated Digital Network
IDTN:	Integrated Digital Telephony Network
ISD:	International Subscriber Dialling
ISDN:	Integrated Services Digital Network
ISO:	International Standards Organisation
LSI:	Large Scale Integration
MCVD:	Modified Chemical Vapour Deposition
MESFET:	Metal-Semiconductor Field-Effect Transistor

MFC:	Multi-Frequency Code
MOS:	Metal Oxide Semiconductor
NMC:	Network Management Centre
NOC:	National Operations Centre
PABX:	Private Automatic Branch Exchange
PAD:	Packet Assembler-Disassembler
PAL TV:	Phase Alternating Line Television
PAMTS:	Public Automatic Mobile Telephone Service
PASCAL:	A Computer Software Programming Language
PCC:	Primary Control Centre
PCM:	Pulse Code Modulated
PROM:	Programmable Read Only Memory
PSE:	Packet Switching Exchange
PSN:	Packet Switched Network
PSTN:	Public Switched Telephone Network
RF:	Radio Frequency
RAM:	Random Access Memory
ROC:	Regional Operations Centre
ROM:	Read Only Memory
RSS:	Remote Switching Stage
SBS:	Small Business System
SCC:	Secondary Control Centre
SDL:	System Description Language
SDM:	Space Division Multiplexed
SPC:	Stored Program Control
SSB:	Single Side Band
STD:	Subscriber Trunk Dialling
TDMA:	Time Division Multiple Access
TDM:	Time Division Multiplexed
TTL:	Transistor-Transistor Logic
UHF:	Ultra High Frequency
VF:	Voice Frequency
VHF:	Very High Frequency
VAD:	Vapour Axial Deposition
VLSI:	Very Large Scale Integration
VSB:	Vestigial Side Band
WDM:	Wavelength Division Multiplexed