The Evolution of the Inland Telecommunications Network

K. E. WARD, C.ENG., M.I.E.R.E.†

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The development of the inland switched telecommunications network over the past 25 years has been the story of unprecedented growth and technical innovation, which has allowed the establishment of a fully-automated service. This article reviews the historical development of the network and describes plans for its future evolution using digital switching (System X) and digital transmission techniques.

INTRODUCTION

A *White Paper*, published in 1957, outlining the British Post Office (BPO) plans to automate fully the telephone system heralded the start of an era of 25 years of fundamental change to the network that is described in this article. The *White Paper* concluded that the 2 steps, namely, simplified charging and automation, "together constitutes the most sweeping and radical reform since the Post Office took over the telephone service from the National Telephone Company in 1912".

The extent to which the needs of customers are met, in a cost effective manner, is largely conditioned by the capabilities of the network. It is the core of the Business and comprises the telephone exchanges and interconnecting transmission paths disposed so that customers can make satisfactory calls to all other users in an economic manner. The inland network can be considered as a number of discrete sub-networks connected to form the total network. Component networks comprise: the local network from customers' premises, to and including local exchanges; the junction network which includes junction tandem exchanges and the trunk junctions between local and trunk exchanges; and the trunk, or main network of trunk exchanges (known as *main network switching centres* (MNSCs)) interconnected by trunk, or main network transmission links. Special-purpose networks such as the Telex and data networks are provided for services that cannot be handled by the telephony network because of technical or economic constraints.

† Network Strategy Department, British Telecom Headquarters

GROWTH OF THE NETWORK

There has been an ever-increasing growth in the network over the past 25 years as illustrated by Figs. 1, 2 and 3, which show the major network parameters of connexions, calls and capital assets. The increasingly sophisticated demands from customers, together with the reduction of price to customers (in real terms) arising from network management efficiency and technical innovation, has resulted in a large increase in originating traffic (see Fig. 2) and the introduction of a variety of new services. The network is characterized by massive investments in plant having economic lives of several decades; Fig. 3 shows the increase in such investments (at 1981 price levels) and how the balance of costs has swung towards exchanges owing to the greater impact of technological progress on trunk and junction transmission plant.

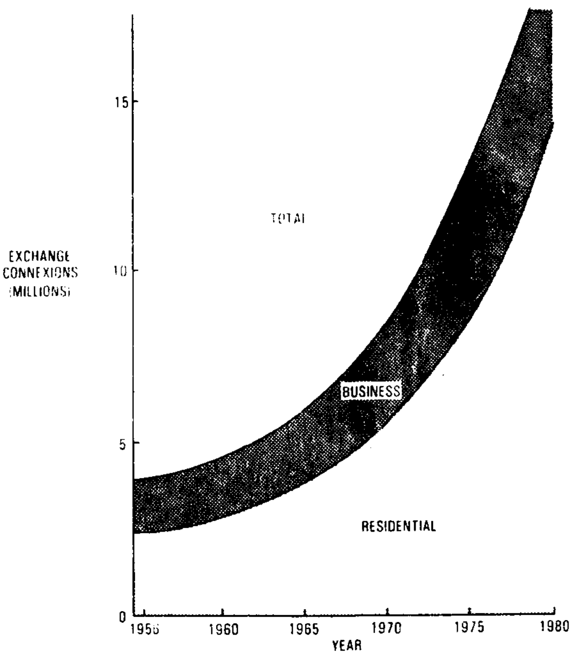


FIG. 1—Growth of exchange connexions

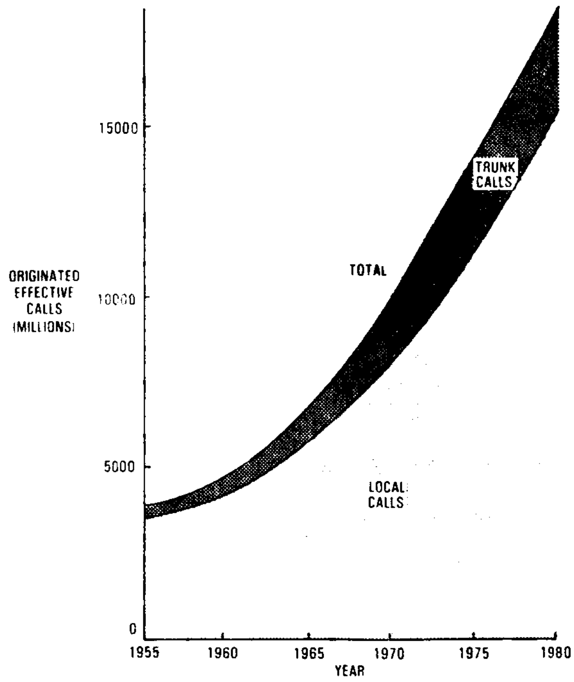


FIG. 2—Growth of originating effective calls

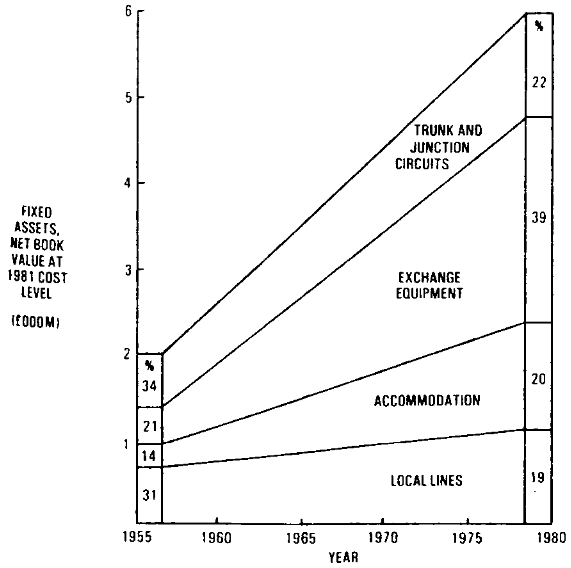


FIG. 3—Growth of network assets

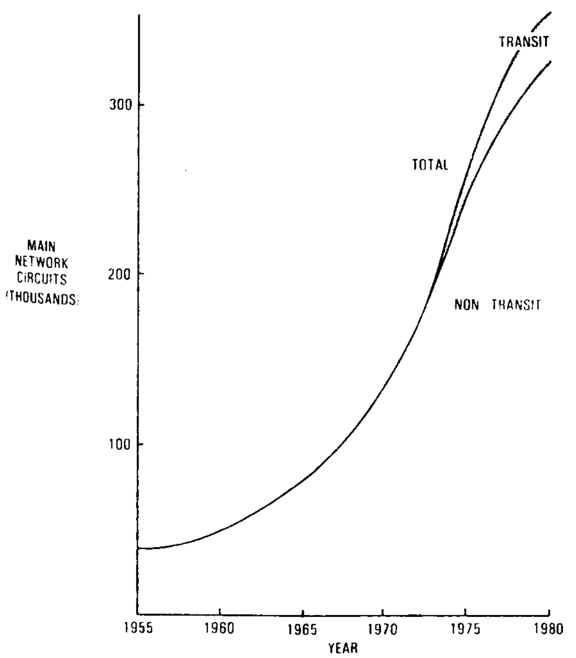


FIG. 4—Growth of main network circuits

NETWORK DEVELOPMENT

THE MAIN NETWORK

The most dramatic development during the past 25 years has occurred in the main network, which has grown tenfold (see Fig. 4), and changed from a largely manual system to full automation where all customers can dial their own trunk calls. Planning for the change from a manually-controlled trunk service to full automation commenced shortly after the end of the Second World War when, in 1946, the Post Office Trunk Mechanization Steering Committee was set-up to recommend the policy for the mechanization of the main network. The Committee recommended that single operator automatic control of the majority of trunk calls (that is, trunk mechanization) should be the first objective.

Trunk Mechanization

By the mid-1950s, the main network comprised 26 fully inter-connected *zone centres* and about 250 *group centres*, many of which were mechanized, and interconnected to meet the "1933 Transmission (and Routeing) Plan" shown in Fig. 5.

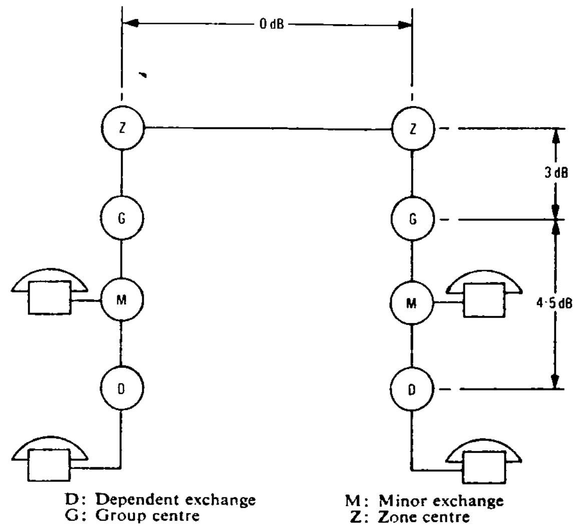


FIG. 5—1933 Transmission Plan

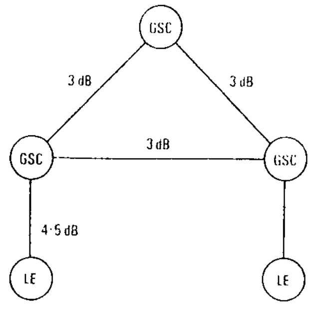
Semi-automatic routeing was carried out on a non-register basis, the single controlling operator dialling a routeing-dependent code of between 3 and 15 digits, obtained from a local set of routeing instructions contained in a visible index file (VIF).

Subscriber Trunk Dialling

The first step towards the introduction of full automation, known as *subscriber trunk dialling* (STD), was to introduce a fundamental tariff change to simplify call charging. Charges had been computed on the basis of call duration and radial distance between originating and terminating local exchanges. However, the need to determine the charges to about 6000 exchanges from any given exchange would have introduced considerable equipment complexity under full automation. Therefore, in 1958, a system of *group charging* was introduced in which the country was divided into 637 charging groups, each covering an average area of about 400 km^2. This reduced by a factor of 10 the charge list for any given exchange. The relationship of charging to distance was obtained by measuring the distance between hypothetical charging points in each charging group. Care was taken in the formulation of charging groups to minimize charging anomalies arising from call charges not strictly relating to distance between exchanges. The most obvious anomaly relating to exchanges on opposite sides of a fee boundary was avoided by charging calls between exchanges in home and adjacent charging groups at the same (local) fee.

On the 5 December 1958, Her Majesty the Queen dialled the inaugural STD call at Bristol, and the UK network entered an era that was to reach full automation in 1979, the twenty-first anniversary of the introduction of STD. The STD scheme adopted was constrained to involve minimum cost and disturbance and was largely conditioned by the existing network, namely a 2-wire switched non-register controlled Strowger system. It consisted of the use of a single translation of dialled digits into routeing digits by a controlling register-translator (RT) located at parent automatic trunk exchanges, termed *group switching centres* (GSCs), usually located at existing group and zone centres. The routeing digits directly controlled the Strowger switches in up to 3 trunk exchanges (except in director areas where incoming RTs were provided) and this was analogous to the previous single operator control under trunk mechanization.

Until the advent of STD, each customer in the UK was identified by a name representing the exchange (or linked-number scheme) and a local number. The introduction of STD made it necessary to convert the exchange name into a unique code that could be dialled and recognized universally.



GSC: Group switching centre
LE: Local exchange

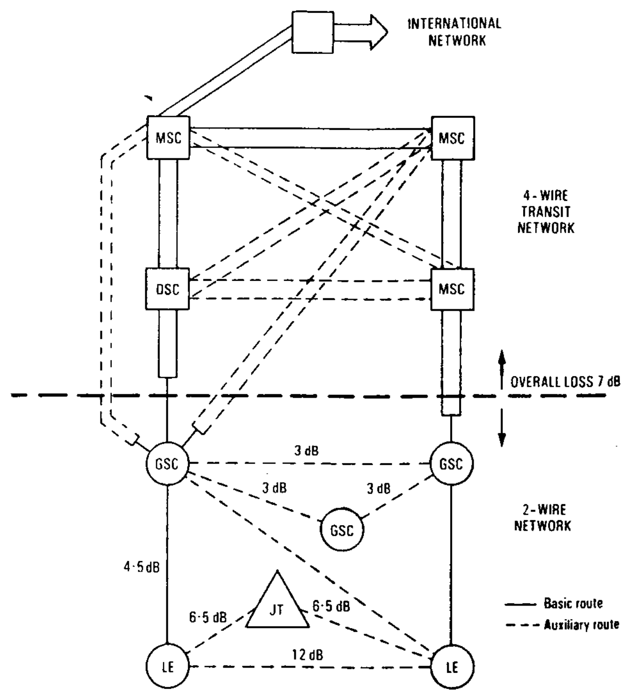
FIG. 6—1933 Transmission Plan modified for STD

The national number scheme adopted allocated some 700 national number group (NNG) codes to charging groups and GSC catchment areas. Each code consisted of 1, 2 or 3 digits; hence, the national number comprised the NNG code and a local number. The number length, including the trunk access prefix 0, was constrained to a maximum of 9 digits to conform to international recommendations. Following the use of letters to represent exchange names in director areas, it was decided to make the STD codes similarly recognizable, for example, Leicester had the code (0)LE3; thus trunk codes were allocated on a somewhat random basis. However, in preparation for the sectorization of London, the use of letters in both director areas and STD codes ceased in 1969 in favour of an all-figure number (AFN) scheme.

The 1933 Transmission Plan specified for trunk mechanization was modified for the introduction of STD (see Fig. 6) to connect local exchanges direct to their parent GSC and to limit STD connexions to a maximum of 2 trunk links (that is, 3 GSCs). This was necessary to minimize post-dialling delays and to provide a better tolerance to transmission loss. Full direct dialling required a traffic routeing between every GSC and NNG, that is 378 GSCs × 700 NNGs = 264 600 routeings. The inevitable result of the limitation on traffic routeing was that full STD could not be provided by the network. Even the provision of a large number of economically unjustified routes would not have significantly increased the access because of the limitations of the RTs on routeing digits and translation capacity.

The Transit Network

To overcome the limitations of the 2-wire GSC–GSC network to provide full customer-to-customer dialling, a separate basic transit network was established. It consists of 9 fully interconnected *main switching centres* (MSCs), and 28 *district switching centres* (DSCs), the transit exchanges collectively being known as *transit switching centres* (TSCs). The provision of *basic* traffic routes, that is, GSC-to-parent DSC, DSC-to-parent MSC, was mandatory to ensure that a basic or hierarchical routeing was always available between all customers. However, *auxiliary* routes between all parts of the network were provided where economically justified. This required the definition of the 1960 Transmission Plan shown in Fig. 7, to which the present network conforms. The transit network which was established to carry traffic that could not justify routeings on the 2-wire (GSC) network, carries a small proportion, about 6%, of the total originating trunk traffic. However, about 60% of the traffic routeings, mainly between places with little or no community of interest, are carried on the transit network. To ensure that acceptable post-dialling delays are achieved, fast multi-frequency (MF) signalling is used with fast (crossbar) switching. Transmission performance standards are met by switching all calls on a 4-wire basis within the transit network. The TSCs are register controlled, with each register controlling its own switching equipment on receipt of the 3-digit NNG code, which is sufficient to identify the terminal GSC. Once the terminal GSC is reached, the



DSC: District switching centre
GSC: Group switching centre
MSC: Main switching centre
JT: Junction tandem exchange
LE: Local exchange

FIG. 7—1960 Transmission Plan

final digit of the NNG code is repeated followed by the rest of the dialled number. The gradual transfer of traffic from the operator-controlled trunk-mechanization network to the transit network commenced in 1971 with the connexion of Kingsbridge, Wolverhampton and Worcester, and was completed by 1979.

Interim Modernization

In 1966, it was decided to order crossbar systems as an interim modernization measure to bridge the gap between the run-down of Strowger orders and the development of digital trunk exchanges. This resulted in the provision of Plessey 5005 Crossbar equipment, designated *TXK1*, at new GSCs, second unit GSCs, and sector switching centres (SSCs) in London. The first TXK1 GSC, at Dover, was brought into service in 1973 and there are, at present, about 80 in service varying in size from 4000 E to several small GSCs in the Highlands of Scotland with an initial capacity of about 20 E.

The period under review has also seen progress in the signalling field, where a new standard one voice-frequency (1VF), 2280 Hz, signalling system designated *SSAC9* was introduced to supersede the old pre-war 2VF system (SSAC1).

International Access from the Inland Network

Access from the inland to international network, on a manually-controlled basis, continued to grow from its modest beginnings in 1891 until, in 1973, a limited subscriber dialling access was given from the London director exchanges to Paris. This access was extended in the following year, enabling all director-area customers to gain international subscriber dialling (ISD)—now known as *international direct dialling* (IDD)—access to 5 of the principal continental countries. At present, IDD facilities are provided in about 90% of GSCs, allowing 99% of UK customers access to over 100 countries. The international network access prefix is 010. Access to the Irish Republic is obtained directly from the inland network by using STD codes.

THE JUNCTION NETWORK

Over the past 25 years, the junction network has increased in size from 200 000 circuits to about 1 million circuits. At the beginning of the era, access to customers on nearby exchanges over the junction network was obtained by dialling local codes followed by the customer's local number. In large towns and cities served by a number of exchanges, a range of customers' local numbers was usually shared between the exchanges to form a linked-numbering scheme area to give a uniform dialling procedure. Special dialling codes were used for access to exchanges outside the linked-numbering scheme area. In the 6 very large linked-numbering scheme areas (that is, London, Birmingham, Manchester, Liverpool, Glasgow and Edinburgh) letters had been introduced into local numbers to assist customers in dialling numbers of 7 digits; the first 3 letters identified the exchange, followed by 4 figures. The large number of exchanges in these 6 areas, combined with the use of letters, made it desirable to use an exchange system with a high degree of flexibility in respect of routeing. This was achieved by using the translating facilities of the *director* exchange system, the director being a particular form of register-translator. In a smaller link-numbering scheme area, a central main exchange was generally surrounded by a number of satellite exchanges and the system referred to as a *non-director* area.

The unprecedented expansion of the telecommunications service in the major cities, such as London, together with the shortage of accommodation in city centres and the need to improve transmission performance and provide for new facilities, forced a re-appraisal of the plans for switching trunk and junction traffic in cities.

Sectorization

For London, a special team known as the *London Trunk and Junction Network Task Force*, was set-up to study how future developments should be achieved. They reported in 1965, concluding that a policy of sectorization should be adopted. This required that the 12 trunk, 3 toll and 7 junction tandem units serving over 350 local director exchanges should be relieved, for growth, by the establishment of 7 new telephone switching centres known as *sector switching centres* (SSCs) located about 13–14 km from the centre of London in the 7 outer Telephone Areas. The 4 central Telephone Areas, occupying a central circle of about 6 km radius, would be served from existing central switching units (CSUs), augmented as required. To allow incoming trunk and adjacent-charge-group calls to be routed direct to the SSCs, it was necessary as a prelude to sectorization, to re-allocate the 3-digit codes of individual director exchanges so that the appropriate sector (or central area) could be identified by the first 2 digits of the local numbers. Customer and administrative disruption was minimized by removing the 3-letter identification of local director areas and instituting all-figure numbering (AFN).

Plans were formulated for the efficient routeing of the 5 separate types of traffic; that is, incoming trunk calls, international calls, local adjacent-charging-group calls, within-charging-group calls and operator handled calls. The first SSC opened in 1974, and currently 6 of the 7 SSCs are operational with a total switching capacity of 24 000 E. Although the numbering schemes in the other director areas were re-arranged with the introduction of AFN, to facilitate the introduction of sectorization, studies established that there was no operational or economic justification for changing.

The Junction Transmission Network

Paper core quad trunk (PCQT) cable, mainly laid in earthenware ducts or deep-level tunnels, has been used almost exclusively to provide junction circuits. Most cable pairs used for audio circuits are loaded with 88 mH coils spaced at 1·83 km intervals to provide an adequate frequency response over the range 300–3 000 Hz. Where transmission limits are exceeded, amplification is used, mainly by 2-wire repeaters most of which are of the negative-impedance type. To meet growth, the capacity of existing cables has been increased by using selective pairs as bearers for transmission systems using pulse-code modulation (PCM) digital systems. Initially, 1·5 Mbit/s 24-channel systems were used, the first being introduced in 1964, and there are some 4000 systems now installed in junction networks throughout the country. These systems have now been superseded by the new European standard, 2 Mbit/s 30-channel systems, which are being installed in ever increasing numbers.

LOCAL NETWORK

The local network of lines from local exchanges to customers has proved remarkably resistant to the impact of technological development. A reduction in costs has been achieved by using polyethylene sheathing for cables, automatic cable jointing machines, and the substitution of aluminium alloy for copper. There has been a progressive move to put plant underground for ecological reasons, and as a move towards direct pre-cabling to customers' premises. The reliability of the network has been greatly increased by the introduction of cable pressurization of local-main cables during the 1960s.

The major changes in the local network over the past 25 years have occurred in the exchange sector. At the start of the period, about 22% of exchanges (over 1300) were manual and the rest Strowger. Manual exchanges were rapidly replaced during the first decade (see Fig. 8) but the last manual exchange, at Portree on the Isle of Skye, was not closed until 1976. From the mid-1960s onwards, modern local exchange systems were progressively introduced in the local network, as shown in Fig. 8. These comprised 2 versions of crossbar exchanges: namely, the Plessey TXK1 (the first of which was opened in 1964 at Broughton) and the STC TXK3 versions, together with the TXE2 small reed-relay electronic exchange which was introduced in 1966. Large reed-relay electronic exchanges, designated *TXE4*, were introduced in 1976. Currently there are 514 crossbar exchanges, 1228 TXE2 exchanges and 134 TXE4 exchanges operational in the local

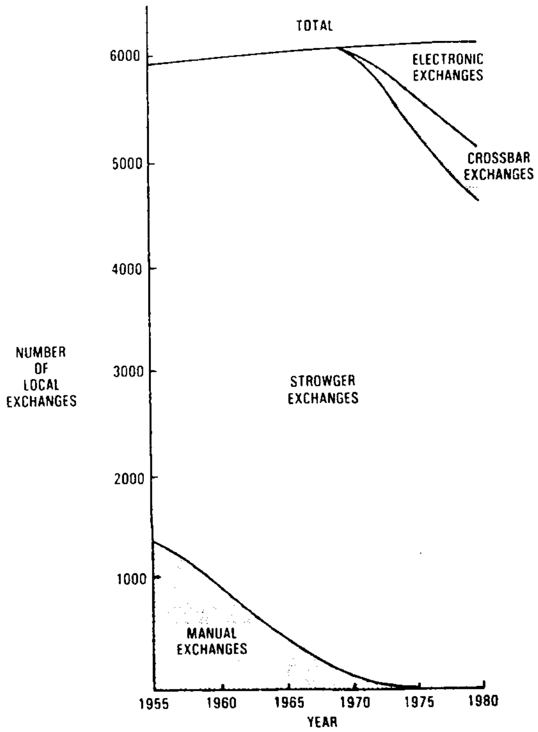


FIG. 8—Recovery of manual local exchanges and penetration of modern exchanges

network. There has also been some enhancement to Strowger director exchanges by the introduction of stored-program control (SPC) and electronic directors to replace their electromechanical counterparts.

The difficulty of meeting the high growth of exchange connexions led to the introduction of shared service which, in 1960, comprised nearly 25% of all connexions. Since then, there has been a progressive decline in the proportion of connexions that are shared service to about 10% at present, although the total number of shared-service connexions is higher than it was in 1960.

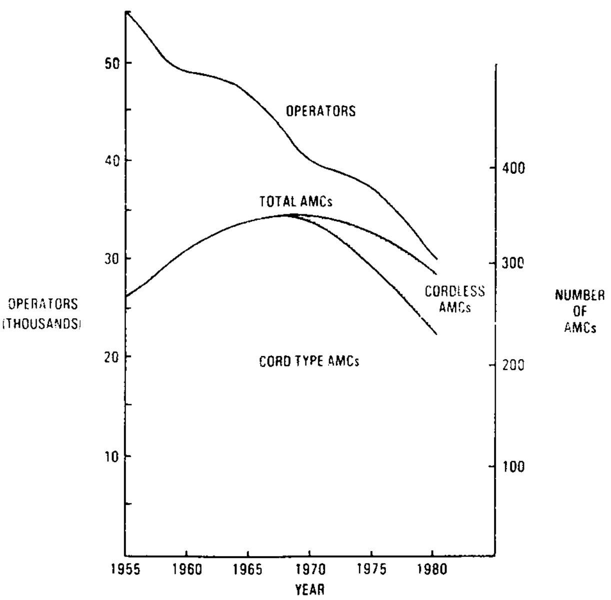
OPERATOR SERVICES

The progressive automation of the network from trunk mechanization through to the current situation of full STD access has inevitably resulted in a run-down of the operator force (as shown in Fig. 9), the closure of small auto-manual centres (AMCs), and changes to the nature of the operator service. The AMC has assumed the role of an assistance point for customers requiring help from an operator in obtaining a call, together with specialized services such as directory enquiries (DQ) and credit-card calls. Modernization of bridge- and sleeve-control AMCs is being carried out by the use of cordless (CSS1) switchboards, which now constitute nearly 25% of all AMCs.

In the last decade or so, considerable advances have been made in operating procedures for recording operator controlled calls and bringing them to account, leading, for instance, to the introduction of microprocessor based automatic call-recording equipment (ACRE). Similarly, studies of DQ work have led to improved procedures and methods for presenting up-to-date DQ records for easy and rapid operator search. At present, microfiche records are under evaluation for general introduction, and the retrieval of information on to visual display terminals (VDTs) from computer files is under consideration.

NON-VOICE NETWORKS

The past 25 years have seen a considerable growth in non-voice type services and the establishment of specialized networks to handle them. In particular, the widespread commercial use of computers has resulted in a growing need to provide facilities for the transmission of data over the network.



AMC: Auto-manual centre

FIG. 9—Operator run-down and AMC modernization

The Telex Network

Telex, one of the oldest examples of a digital service, was originally provided over the public switched telephone network (PSTN) using a carrier signal of 1500 Hz. It was eventually decided that the service could be provided more economically by a dedicated network, and so a manual service using switchboards located in London and major provincial centres was established in 1954.

In 1958, an automatic service was introduced, using Strowger equipment. The Telex network comprised 6 fully interconnected zone centres located at London, Birmingham, Bristol, Glasgow, Leeds and Manchester, with area exchanges established in charging areas where justified by the concentration of customers. The conversion of the inland Telex network to automatic working was completed in 1960. In order to provide facilities for the disposal of telegrams direct to Telex customers, access was provided from the inland teleprinter automatic switching system (TASS)—the switched network used for telegram transmission—to the Telex network. As public telegram traffic declined, it was transferred to the Telex network and the TASS network closed. Manual switchboards were used in London and main provincial centres for enquiry and assistance calls.

Economic transmission was provided using multi-channel voice-frequency (MCVF) telegraph systems which allowed 12 Telex circuits (and subsequently 24) to be provided over a single voice channel. The transmission performance plan for the network ensured that distortion between teleprinters was not worse than that of 5 normal MCVF circuits in tandem. The early MCVF systems, using amplitude modulation techniques, were succeeded by frequency-shift keying systems with their inherently greater voice immunity and insensitivity to level variations. In turn, these systems are now being superseded by time-division multiplexed systems which produce a composite digital signal at 64 kbit/s and have a capacity for 240 Telex circuits at 50 bauds; they interface to group-band modems (modulators/demodulators) or a 64 kbit/s channel of a primary PCM system. Initially, the private circuit digital data service will provide the 64 kbit/s bearers for such systems.

During the 25 years up to the present time, the Telex network has grown an astonishing fiftyfold (see Fig. 10). From the start, the proportion of external Telex calls has been high and today about 57% of all Telex calls are for overseas destinations. The number of exchanges increased from 11 to 51. However, apart from the introduction of a small number of SPC remote concentrators in London, to augment the multiple capacity of existing Telex exchanges, the technology has remained virtually unchanged. The Strowger equipment used in Telex exchanges is now obsolete, fault prone, inefficient and limited in its capability to provide advanced facilities for customers. It has therefore been

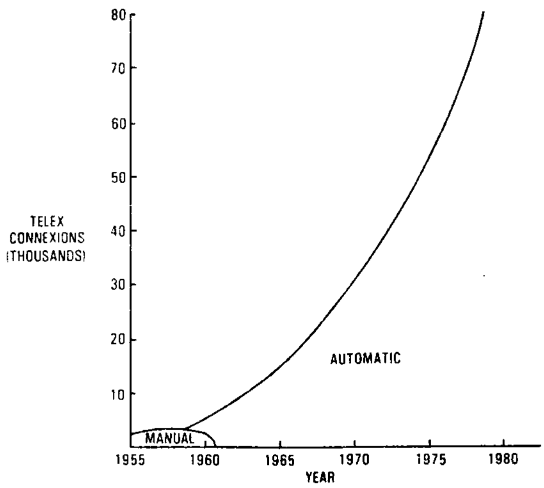


FIG. 10—Growth of Telex connexions

decided to progressively modernize the network by the use of an SPC digital switching system. This system has the capability of handling data at 110, 200, 300 and 600 bit/s with the possibility of extending the speed range up to 9·6 kbit/s. It also provides advanced facilities, such as store-and-forward, multiple address, delayed delivery, broadcast, speed and code inter-working and call re-direction. Current plans envisage the installation of 11 such exchanges by the mid-1980s, which will replace 22 Strowger Telex exchanges and serve about 35% of Telex customers.

In the longer-term, it can be expected that the future of the Telex service will be heavily influenced by other text communications services due to be introduced, such as fast facsimile and Teletex. The latter uses standardized intercommunicating wordprocessors that enable text to be prepared, edited and then transmitted at 2400 bit/s fully automatically between storage devices incorporated in the Teletex terminals. The British Telecommunications Teletex service will use the Telex network, the PSTN and the packet-switched network (PSN). A migration of Telex users to the Teletex service can be expected, but Telex, in its basic form, is likely to be required well into the 1990s. There will be a need to intercommunicate between the Telex and Teletex services and this will require interconnexion of the Telex network, PSN and PSTN.

Data Transmission Services

Datel

During the early-1960s, the need to interconnect remotely sited computers and terminals began to arise and was met, using the readily available PSTN and also leased lines, by using modems to interface with customers' data terminal equipment; this converted digital signals to analogue form for transmission over a network designed for voice services. Up to the present time there has been a sustained high growth of data terminals as shown in Fig. 11 and the UK has considerably more terminals than any other European country. Developments in modem technology have progressively extended the data transmission rates that can be carried over the PSTN from the original Datel 100, introduced in 1964, to provide data transmission at 50 bit/s over the Telex network or 110 bit/s over private telegraph circuits, to the 9600 bit/s half duplex or the 1200 bit/s full duplex systems available today. It is expected that 2400 bit/s full duplex will become feasible in the near future with further technical development. A summary of the Datel Services is given in Table 1.

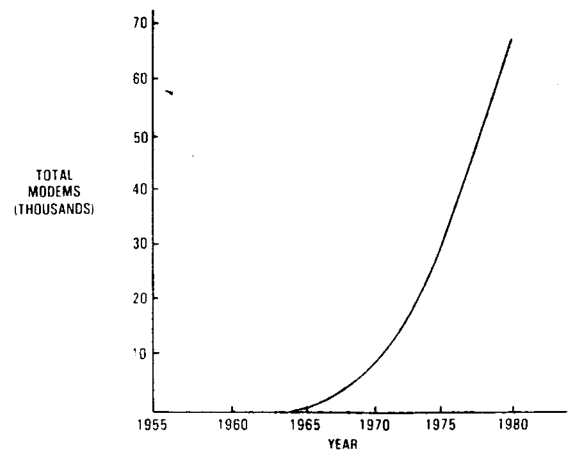


FIG. 11—Growth of Datel connexions

Switched Data Network

Although the ubiquitous PSTN provides cheap and reliable Datel services on a network wide basis on demand, it was designed for voice services and imposes severe technical limitations on data transmission owing to bandwidth, error rate and slow call set-up. Because of these limitations, and

TABLE 1
Summary of Inland Datel Services

Service	Year	Signal Path	Transmission Speed (bit/s)	Mode	Remarks
Datel 100	1964	Telex PC	50 110	Asynchronous Asynchronous	Duplex or half duplex
Datel 200	1967	PSTN PC	200 200	Asynchronous Asynchronous	Speeds up to 300 bit/s possible over PSTN and PC
Datel 600	1965	PSTN PC	600 1200	Asynchronous Asynchronous	Speeds up to 1200 bit/s possible 4-wire PC required for duplex working
Datel 1200 Duplex Service	1980	PSTN	1200	Asynchronous Synchronous	
Datel 2400	1968	PC	2400	Synchronous	4-wire PC required
Datel 2400 Dial Up	1972	PSTN	2400	Synchronous	Can be switched to 600/1200 bit/s when 2400 bit/s not possible
Datel 2412	1977	PSTN PC	2400 2400	Synchronous Synchronous	May be necessary to switch to 1200 bit/s on some connexions 4-wire PC required
Datel 4800	1980	PSTN PC	4800 4800	Synchronous Synchronous	May be necessary to switch to 2400 bit/s 4-wire PC is required
Datel 4832	1978	PC PSTN (Stand-by)	4800 4800	Synchronous Synchronous	4-wire PC required May be necessary to switch to 3200 bit/s
Datel 48K	1970	Wideband Circuit	40·8 k 48 k 50 k	Synchronous	

PSTN: Public switched telephone network
PC: Private circuit

the considerable user requirements for within-house systems, the majority of users systems (about 70% of Datel modems) operate over leased lines. The ability to equalize permanent leased lines and provide 4-wire transmission enables data rates of 9600 bit/s full duplex or higher to be achieved on voice-band circuits, or 48, 72 and 120 kbit/s over group-band circuits which are the equivalent of 12 voice circuits.

Although there will continue to be a need to provide in-house networks, it has been recognized that technological development and standardization are leading to new applications that could require interconnexion between private systems. Hence, there is a need for a better switched data service than can be provided over the PSTN. The earliest experimental high-speed switched data network was opened in 1970. It was a 48 kbit/s manually-switched network interconnecting London, Birmingham and Manchester, but customer reaction was disappointing and it was closed down. However, in the early-1970s, consideration was given to the establishment of an automatic switched data service. Of the 2 techniques, *circuit* and *packet* switching, the latter was considered most attractive because dynamic multiplexing was more suited to the predominant use of remote terminals accessing high-speed computing facilities. It also offered a number of attractive features to the user such as inter-working between terminals of different data rates, error-checking and correction on a link-by-link basis, alternative network routeing, dynamic multiplexing on customers' local ends enabling a single physical link to support a number of simultaneous transactions to a variety of destinations, and so on. Additionally, the packet-switched network will support simple character-type terminals, either directly connected or accessing the packet-switched network via dial-up connexions over the PSTN.

To test the market for a packet-switched service and enable the BPO, users and the data processing industry to improve their understanding of the techniques and potential offered, it was decided to establish an experimental packet-switched service (EPSS). The experiment formally opened in 1977 with 3 packet switching exchanges (PSEs), based on the Ferranti Argus 700E processor, located in London, Manchester and Glasgow and interconnected by 48 kbit/s links. The network was equipped with 57 packet ports serving customers (in addition to those required for inter-PSE links) and 89 character terminal ports accessible via the PSTN. The experiment was most successful; a liaison group was established as a forum for the interchange of customer experience in adapting systems and applications to packet-network working and valuable work was also done in the area of high-level protocols.

To meet the increasing commercial market for a public packet-switched service to the international standards that emerged during the period of the EPSS, it was decided to establish a national packet-switched service (PSS), a view supported by the Government sponsored National Committee on Computer Networks (NCCN). The network, using Telenet TP4000 equipment supplied by Plessey Controls Ltd., was opened in 1981 as a 9-node network interconnected by 48 kbit/s links and capable of supporting 450 packet ports and 1250 character ports. Current plans envisage an expansion of the network to 20 nodes in 1982.

Private Data Circuits

To exploit the increasing availability of digital transmission plant to improve the leased line data services, a private circuit digital data service (PCDDS) is planned to be introduced in 1983. It will comprise a national 2048 kbit/s network from which individual circuits will be derived by means of dedicated PCDDS muldexes (multiplexer/demultiplexer) and extended digitally to customers' premises over the local network to give synchronous user rates of 2400, 4800, 9600 and 48 000 bit/s full duplex. A 6 + 2 bit envelope will be adopted to provide sophisticated in-service monitoring and maintenance aids with user rates reiterated to 64 kbit/s for transmission over PCM systems. The muldex equipment will be located at exchanges, designated *multiplexing sites*, which will be located in areas of high data demand. At strategically placed multiplexing sites, known as *cross-connexion sites*, flexibility for interconnecting individual 64 kbit/s channels will be provided.

With the penetration of digital switching (System X) and transmission plant into the network, a circuit-switched data service will become more viable and it is proposed to provide such a service over the integrated services digital network (ISDN), which will provide 64 kbit/s channels for non-voice services into customers' premises. A pilot ISDN is scheduled to be available in London in 1983.

NETWORK MODERNIZATION

Although today's network is fully automatic, enabling all customers to dial their own trunk calls, with about 90% of international traffic direct dialled to more than 100 countries, it suffers from a number of constraints. The main network, in particular, is controlled by electromechanical Strowger and crossbar switches and, apart from the transit network, routes its traffic entirely by Strowger pulses. This apparent lack of modern technological progress largely arises because of the widespread introduction of Strowger equipment and the extraordinary flexibility of such equipment to cater for changes in requirements by the *ad hoc* addition of register-control and specialized relay-sets. However, the decision to provide 95% of STD access via 2-wire switched step-by-step, in-band signalling routeings has imposed severe constraints on its further evolution. In addition, by today's standards, it is slow, noisy, fault prone, with large accommodation requirements and limited in its capability to provide the customer and administration facilities that can be seen as potential requirements for the future. It is also dependent on semi-precision mechanical production and adjustment to small tolerances, which make its manufacture and maintenance highly labour-intensive, expensive and sensitive to inflation. During the 1960s, it became apparent that with the continuing high growth in traffic, severe economic penalties could result from the continuing use of existing technology; therefore, a number of major network studies were undertaken.

UNITED KINGDOM TRUNK TASK FORCE

In 1967, a special multi-disciplined team, the *United Kingdom Trunk Task Force* (UKTTF), was established to study the problems of the main network and to produce long-term strategic proposals for its modernization. Extensive computer-assisted studies were carried out taking account of forecast growth, future cost trends, technological development and potential new services. The results indicated that the most economic solution for the main network would be to provide SPC digital exchanges interconnected by digital transmission systems, with common-channel inter-processor signalling; that is, an integrated digital network (IDN) in CCITT† terminology. Indications were that the total network costs, in terms of annual charges, would be reduced by about 50% compared with a continuation of the existing space-switching/analogue transmission network. It was also apparent that significant economic advantages could be achieved by the introduction of digital transmission systems into a space-switching environment and this stimulated the development of high-capacity digital transmission systems which are now being introduced into the network.

ADVISORY GROUP ON SYSTEMS DEFINITION

Also in the late-1960s, a joint BPO/Industry team called the *Advisory Group on Systems Definition* (AGSD), was studying

† CCITT — International Telegraph and Telephone Consultative Committee.

fundamental criteria on which to base ongoing switching developments. These studies ranged over the whole development process, but took particular account of network implications. The work effectively laid the foundations for the System X family of digital exchanges using micro-electronic technology, integrated digital switching and transmission, SPC, and common-channel signalling. System X, the first exchanges of which are being currently introduced into the network, has therefore been developed in the context of an overall strategy for the evolution of the UK network.

LOCAL EXCHANGE MODERNIZATION

Modernization of local exchanges also came under scrutiny in the late-1960s when an investigation into the economic and practical aspects of the accelerated replacement of Strowger local exchanges was carried out. A large number of renewal strategies were studied, which led to a policy for the accelerated replacement of all Strowger local exchanges by the mid-1990s, and a decision to introduce, as an interim modernization measure, the widespread use of reed-relay switching local exchanges (TXE2 and TXE4). In addition to improving service to the customer and reducing costs, this interim modernization step has proved particularly valuable in building-up manufacturing and operating experience of electronic switching systems, thus enabling the progression into the future digital era to be planned with some confidence.

NETWORK MODERNIZATION STRATEGY

In the mid-1970s, as the development of digital transmission and switching (System X) systems matured, an extensive investigation was carried out to determine the policy for modernizing the network by the accelerated replacement of analogue plant with digital and to evaluate the options for converting the network to an IDN. The studies took account of practical circumstances, manpower aspects, financial constraints and manufacturing implications. Since they encompassed all sectors of the network, the evaluation was a particularly complex process which required extensive computer assistance. The results of the studies indicated that:

(*a*) The difference in the economics of rapid and slow rates of network conversion was marginal.

(*b*) Future customer needs would include an improved quality of service and a wider range of services. Judicious use of digital plant would enable a significant proportion of customers to be brought within the catchment area of digital plant in return for a relatively modest outlay.

(*c*) The early modernization of the main network was essential to improve the quality of service given to the customer and to provide a nationwide foundation for the introduction of new facilities and services.

(*d*) There was a need to enhance existing modern reed-relay electronic exchanges to provide supplementary telephony services comparable with those provided from System X digital exchanges.

(*e*) The full potential of the digital network to carry an increasingly sophisticated range of new services would only be realized by extending digital working down to the customers' premises, together with enhanced customer-to-network signalling, to form an integrated services digital network (ISDN).

Resulting from the conclusions of the strategy studies, a network modernization policy is now being implemented. The main elements of the strategy are:

(*a*) To deploy System X equipment in such a way as to maximize the service capabilities to those customers who will put the highest value on them. The target is to interconnect the major UK cities by a high-capability integrated digital network by the mid-1980s.

(*b*) To replace all trunk and tandem exchanges with System X by the early-1990s with complementary digital transmission modernization to give a total IDN.

(*c*) To provide complementary System X local switching capability coincident with the installation of trunk exchanges, taking account of the marketing potential for new services, so that the service capability can be brought to customers most likely to benefit from it.

(*d*) To eliminate large Strowger local exchanges from the network by the early-1990s, and all Strowger by the mid-1990s.

(*e*) To launch a trial of an ISDN as soon as possible.

(*f*) To replace the remaining crossbar and electronic local exchanges by the year 2015.

THE INTEGRATED DIGITAL NETWORK

Maximum benefit from digital systems can be achieved only if switching and transmission are deployed in a coherent manner as a network of digital switching centres interconnected by digital transmission links to form an IDN; that is, speech signals are encoded and multiplexed into the PCM format as they enter the network at the originating local exchange, and then are transmitted and switched in digital form through the network until they reach the destination local exchange where they are demultiplexed and decoded back to their original form. This achieves significant network economies and permits unified treatment of a variety of services that can be encoded and multiplexed together into a common digital format for transmission over common digital paths, with sophisticated digital processing where necessary.

Network Structure

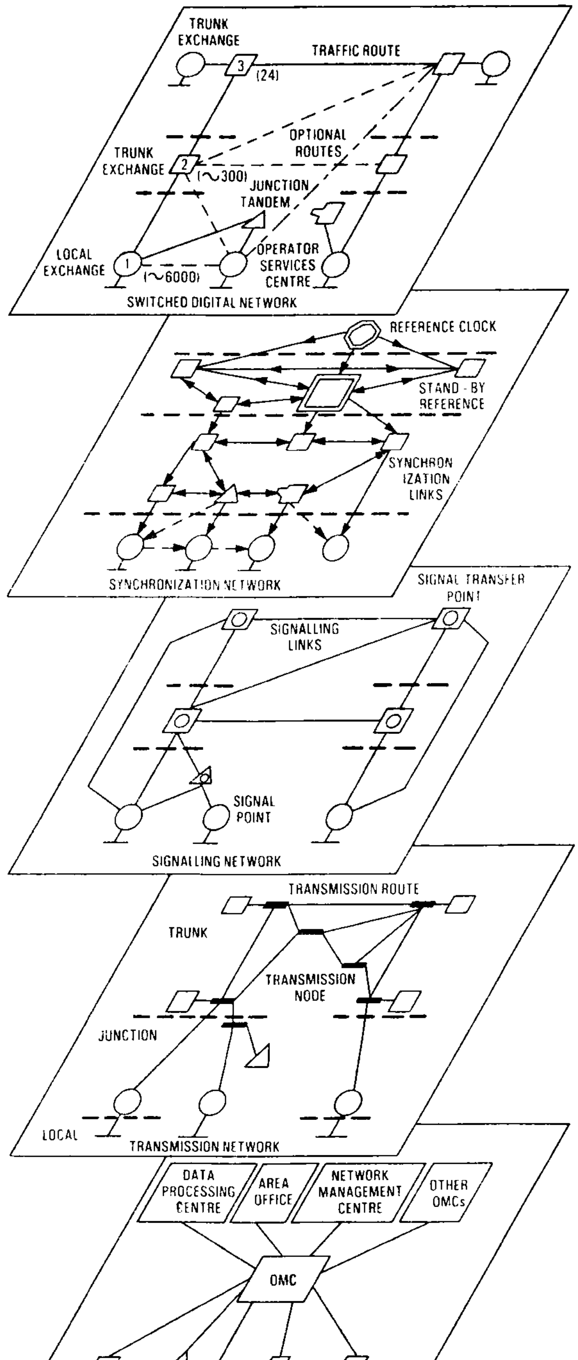
The IDN now being introduced represents a fundamental change in network structure. It comprises 5 separate but interdependent component networks (see Fig. 12); namely, the switched digital network, the signalling network, the digital transmission network, the synchronization network, and the administration network.

Switched Digital Network

The switched digital network comprises the digital exchanges and their interconnecting traffic routes. The introduction of the 30-circuit basic transmission module (instead of the presently used 12-circuit module), together with reduced switching costs, increases the level of traffic required to justify direct optional routes between switching centres. This, together with the use of bothway traffic routes, has the effect of reducing the number of traffic routes required in the 1990s from approximately 17 000 in an analogue network to about 5500 in the IDN. Automatic alternative routeing (AAR) will be employed to allow for re-routeing of traffic under congestion and breakdown conditions, with the consequent improvement in quality of service. The new network will be hierarchical, as at present, but will comprise 3 instead of 4 tiers.

Signalling Network

Inter-exchange signalling will be between exchange processors in the form of labelled messages over a common 64 kbit/s signalling channel conforming to the CCITT Signalling System No. 7 specification as described elsewhere in this issue. A separate signalling network, analogous to the switched telephony network, will be established as a common transport service for telecommunications and administration messages. The signalling network will comprise signal transfer points (STPs) whose processors receive signalling messages, recognize their destination and re-transmit them, interconnected by signalling links to form a hierarchical network.



OMC: Operations and maintenance centre

FIG. 12—Structure of the integrated digital network

Security will be provided by diversity of signalling links and automatic re-routeing of signalling messages under plant breakdown conditions.

Digital Transmission and Synchronization Networks

When digital transmission links are used to interconnect digital exchanges, the exchange clocks and incoming bit streams must be at the same average frequency or information will arrive at exchanges at a different rate than it can be processed, with consequent errors known as *slip*. The IDN will be synchronized to a high-stability national reference clock by a hierarchical structure of synchronization links interconnecting the exchanges over which messages are passed to keep all exchange clocks in step.

Administration Network

The administration and management of the network will be carried out from *operations and maintenance centres* (OMCs) and *network management centres* (NMCs). The OMC is designed to be the focal point for a catchment area of exchanges. In addition to providing a concentration/control point for man–machine communication, with its exchanges, it carries out maintenance control, remote manipulation of exchange stored data and call-accounting functions. Network management is the dynamic surveillance of traffic flowing through the network, together with the re-routeing of traffic to overcome network congestion and plant failure conditions. This function will be carried out at a number of NMCs. Interconnexion of OMCs and NMCs to the various exchanges and data-processing centres will be by data links that constitute the administration network.

THE FUTURE

The past has seen the decline of the agricultural age and the emergence of the industrial era supported by powerful developments in physical transportation. Current trends suggest that, in future, service industries will dominate. The product of the service sector is information which requires to be collected, stored, manipulated, retrieved and communicated. The rapid growth of data services is evidence of this trend. The telecommunications network will therefore assume an even more important part of the infrastructure of society and be a key element in the economic health of the country.

The micro-electronic revolution that has provided the means for modernizing the network is now penetrating home and office. Text processing will assume growing importance in the emerging "electronic office". Such an office will utilize the convergence of office machinery, computing and communications (sometimes known as *Telematics*) to provide a single paperless integrated system for the capture and manipulation of information in electronic form. The need for such units to communicate with corresponding units will add to the scale and nature of the traffic to be provided for in the network. Powerful microprocessors can also be expected to penetrate the home, paving the way for a wide variety of applications such as shopping from home, automatic billing of utility services, new forms of interactive entertainment and education, electronic mail and newspapers, and information retrieval. The latter has already been introduced into the UK network, under the name of *Prestel.* Electronic funds transfer, already extensively used between banks, will also link shop and bank over the network, and widespread penetration of such a service is predicted.

It can therefore be seen that the balance of person-to-person communication will progressively shift from the traditional face-to-face and postal mail methods to telecommunications, and such a move will become intensified by the need for energy conservation for transportation. The era of the "information society" has arrived, and the future network will need to handle a wide variety of voice, data and visual services. It will deal with information communication, not just telephony, and the traditional functions of switching, transmission and signalling will need to be supplemented by information recognition, storage, processing and retrieval to create a single-service-providing active network. The complex effect on society, commerce and industry of an enhanced telecommunications service together with technological progress, can be expected to generate ever-increasing demands on the network, creating the need for flexibility to respond at short notice. The network will need to be resilient to the effect of over-loading and breakdown, and have a high survival capability, since society will rely on it more and more.

The Integrated Services Digital Network

The provision of the IDN provides a firm basis to meet the demands of this future, providing a common network infrastructure for the conveyance of a wide variety of information in digital form. But, as long as the customer is connected by the conventional local line to a standard PCM codec, the service potential will be severely constrained. However, if the IDN is extended down to a customers' premises by digital transmission, with enhanced customer-to-network signalling and an appropriate customer/network interface, then the all-purpose network necessary to meet the demands of the future can be created. Such a network is known as the *integrated services digital network* (ISDN). The necessary interfaces, signal requirements and protocols are being determined and injected into international discussion as an input to the formulation of standards for an international ISDN. The most significant future network development will therefore occur in the local network with the widespread penetration of digital transmission down to the customers' premises. Currently, it is planned to interconnect customers' terminals with System X exchanges using an 80 kbit/s transmission system, providing for simultaneous transmission of 64 kbit/s (for speech or data) and an 8 kbit/s data channel together with 8 kbit/s to provide the necessary enhanced customer-to-network signalling. For digital PABX customers, a 2048 kbit/s digital line system will be used to access the ISDN in which thirty 64 kbit/s channels can carry either voice or data traffic, with common-channel signalling provided at 64 kbit/s. It is intended to establish a pilot network in London, in 1983, to evaluate in the field the implications of the ISDN and to test customer reaction to the wide spectrum of new services that can be provided. The ISDN will then rapidly penetrate the network in the latter half of the 1980s coincident with its modernization.

Satellites

The future terrestrial network can be expected to be complemented by a satellite based overlay network offering advanced digital communications services. Such specialized satellite services (SSSs) will use cheap small-dish earth stations located at customers' premises and will allow greater flexibility in providing services, with the facility for multi-destination broadcasting of information. Agreement has already been reached with European Telecommunications Authorities in the European Space Management Authority (EUTELSAT) for capacity in 2 future satellite systems from the mid-1980s; namely, the European Communication Satellite (ECS), which is being constructed by a Consortium headed by British Aerospace, and Telecom 1, a French Government project which is planned to provide domestic services in France. The European Orbital Test Satellite (OTS) is currently being used to evaluate SSS applications and commercial trials of small dish satellite systems are scheduled to commence later this year.

In the more distant future, customers are likely to require a telecommunications service with far greater mobility where a telephone number will identify a person wherever he may be located. A universal pocket telephone accessible over a nationwide mobile-radio system can be envisaged where the businessman will carry a briefcase data terminal and display to receive electronic mail and messages.

CONCLUSIONS

The past 25 years have seen a remarkable evolution of the inland network allowing full automation to be provided together with the introduction of data services. The future will see even more revolutionary changes necessary to meet the needs of an information-based society and to take advantage of technological developments in micro-electronics, fibre optics and satellites. Although the telephony service will continue to dominate, a wide variety of new services will penetrate the network. The foundations of the future network are now being laid by the rapid introduction of digital switching and transmission to modernize the network. This approach to the digital era is made with some confidence since the decision to go digital has been backed by many years of research and development experience stemming from the invention of PCM, in the 1930s, by an Englishman, Alec Reeves. Experimental coders using thermionic valves were constructed in the early-1950s, followed in 1958 by the extensive introduction of practical PCM systems in the field. Similarly, digital switching systems have been researched since the 1950s, with experimental systems carrying live traffic in the late-1960s and early-1970s.

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