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EDITORIAL

Automatic switching was introduced into the UK network 75 years ago in May 1912. In some respects, this could be considered a retrograde step: the sophisticated control functions resident in the manual operator were replaced by an inherently dumb network. Over the years, considerable skill and ingenuity were applied to these switches to reintroduce some of this intelligence, but it was not until the advent of digital electronics could the more complex information flows required to meet increased customer expectations be achieved. Throughout this period, the network evolved slowly, being constrained by such factors as the dominance of the voice telephony service and the dependence on the switching technology available. In recent times, the increase in demand for information technology services highlighted the inflexibility of the network and prompted the introduction of digital switching and transmission techniques and the concept of the integrated services digital network. But what of the future. As the demand by the customer for greater or variable bandwidth increases, it will become economic perhaps to remove some of the central control exercised by the local exchange and distribute it to terminal equipment at the customer's premises and thus become the genesis of a new multi-service network. This issue of the *Journal*, after giving a brief description of the original developments in automatic switching in the UK, looks at how the network might evolve in the future, and discusses how asynchronous time division techniques already employed in some local area networks might be applied to the public network.

75 Years of Automatic Telephony in the UK

UDC 621.395.34

This article gives a brief insight into the early years of automatic switching in the UK and serves as a Forward to a number of articles on switching and network evolution to celebrate the 75th Anniversary of the opening of the first automatic exchange in the UK.

INTRODUCTION

The first patent for automatic telephony was taken out in the USA by Messrs. McTighe, Connolly and Connolly in December 1879 (see Figure 1), and with improvements in August 1881[1]. However, the system would not work efficiently or economically because of the friction of the moving parts and the need to derive considerable mechanical power from simple electromagnets directly in the line circuit. A separate power drive was introduced by Connolly in 1883 as a means of overcoming these problems.

It was on 12 March 1889 that Strowger's first application for an automatic switch was made, with some clarification being given in 1890. Many of the essential features were contained in these proposals; namely, the use of rows of contacts on a curved surface, vertical motion followed by rotary, and complete release in one action. Problems arose with the accurate alignment of the contacts in the cylindrical banks and for a brief period the design was modified to that known as *flat disc.* Such a switch was installed in La Porte, Ind., USA in November 1892. With this design, it proved difficult to increase the capacity of the switch and, in June 1895, the first switch having the present form of bank was installed, again in La Porte.

Making a call was a slow and inconvenient process for the subscriber which was not alleviated until an efficient dial sender was patented in August 1896.

EARLY AUTOMATIC SWITCHING IN THE UK

The first demonstration of automatic telephony in Europe was given in November 1898 in London by the Automatic Telephone Exchange Company of Washington, who owned the Strowger patents. These ideas were taken up very rapidly in Europe, but in the UK some time elapsed before automatic working was introduced[2].

The first public automatic exchange was installed at Epsom and brought into service on 18 May 1912. This equipment was manufactured by the Automatic Telephone Manufacturing Co., Ltd. Similar equipment was installed at Post Office Headquarters. This was in reality a PABX and opened on 13 July 1912. Over the next few years, several differing automatic systems were tested[3].

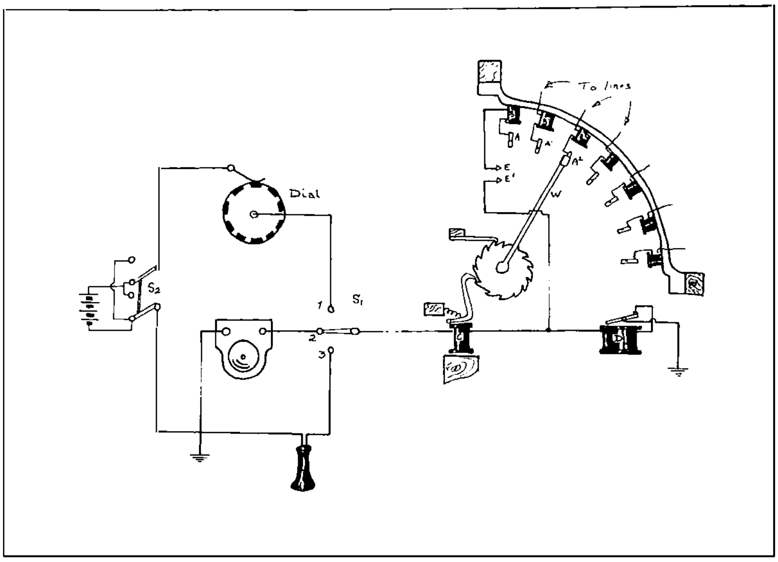


Figure 1
Extract from the McTighe and Connolly patent

An alternative system, known as the *Lorimer* system, manufactured by the Canadian Machine Telephone Company of Toronto, Canada, was installed in Hereford[4] and brought into service in August 1914. Originally, this equipment was planned to go into Caterham Valley exchange, but because of the high proportion of junction traffic which still required operator intervention, a site with a higher proportion of local calls was eventually chosen.

The Lorimer system was characterised by the use of mechanical power supplied by a continuously driven motor via a series of shafts, gears and clutches, and used a telephone on which the required number was preset by operating a series of levers.

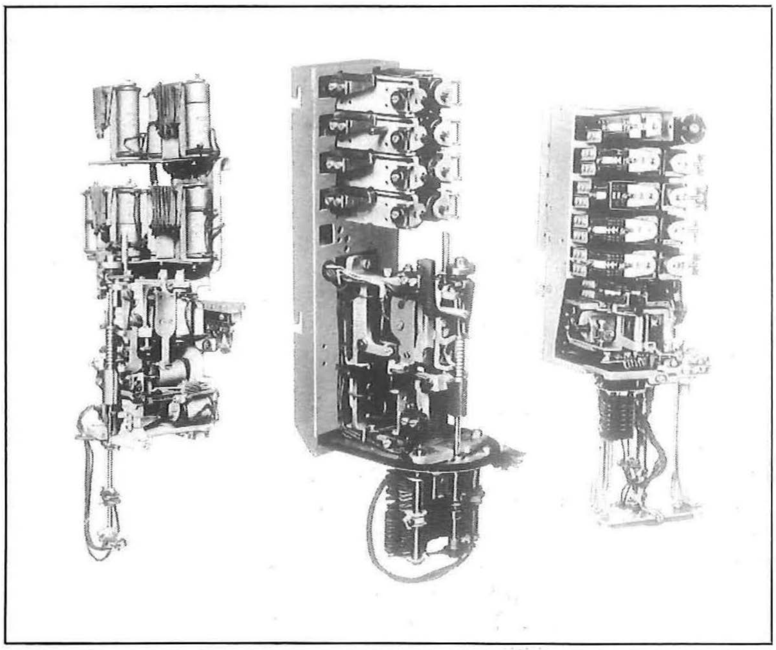
In October 1914, the Western Electric Company's system was opened at Darlington[5]. This system had some similarities with the Lorimer system: principally the use of power drive and rotary switching mechanism. Dialled digits were stored on a register which was then re-allocated once the call had been connected.

Siemens' automatic equipment was installed in Grimsby[6] and was fully in service by September 1918. The equipment used two-motion selectors with three banks of contacts. The upper bank, or private bank, accommodated the test wires on a 10 × 10 matrix. The two lower banks each had only five levels which represented the odd and even digits respectively. The rows of contacts were so spaced to give the correct sequence during vertical stepping under the control of the dial pulses.

Considerable development took place over the next few years and several examples of each type of equipment (except the Lorimer) were installed[7, 8]. In July 1922, the Relay Automatic Telephone Company installed a 480-line public exchange at Fleetwood[9]. This system had no rotary connectors, but used relays to effect the connection path.

Multi-office, or linked-number working was introduced in October 1916 with the opening of Blackburn exchange[10]. Numbers on this exchange were allocated in a different range (levels 3–5) to the nearby Accrington exchange (level 2).

Figure 2
Strowger 2-motion switches



Early Strowger switch   Pre-2000-type switch   2000-type switch

In the early 1920s, consideration was being given to extend automatic working in the large conurbations such as London, Birmingham and Glasgow. A development by the Western Electric Company had been adopted by the Bell Telephone Companies in America and the Post Office had started negotiations for the introduction of the 'panel' system in London. However, in 1922, a development of the Strowger system with the addition of a 'director' was demonstrated and was subsequently adopted in November 1922 as the standard for large conurbations[11]. The adoption of this system effectively paved the way for the standardisation of switching equipment in the UK (see Figure 2).

FROM EPSOM INTO THE FUTURE

This article has given a brief account of the introduction of automatic switching in the UK. The following two articles are extracts reprinted from *The Post Office Electrical Engineers' Journal* and are contemporary accounts of the opening of the first public automatic exchange at Epsom. Subsequent articles look at the possible future trends in telecommunications switching, at network evolution using asynchronous time division techniques, and at the digital derived services network now being installed.

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The Strowger Automatic Exchange at Epsom

By W. J. Bailey, A.M.I.E.E.

Automatic Switching equipments of the Strowger two-wire type have been installed for the Department at Epsom and at the Official Switch, General Post Office, London, both replacing existing manual common battery signalling systems.

The contracts were placed with the British Insulated & Helsby Cables, Ltd., whose telephone works have recently been acquired by the Automatic Telephone Manufacturing Co., Ltd.

In this article it is proposed to deal principally with the Epsom equipment, as it has a greater number of special features than is provided for the Official Switch, viz. meters, coin box stations, electrophone subscribers, trunk (long-distance) circuits, etc. In the case of Epsom the mechanism will be on trial by the public and in the other case by Post Office officials of all grades at headquarters.

No doubt there will be a spirit of rivalry between the two classes of users to win the favour of the "mechanical girl".

Even as politeness, patience, and compliance with instructions smooth the working of the manual system, and encourage the operator to rise to the occasion during the busy hour and yet not be lax during the slack period, so a fair treatment of the calling device placed at the disposal of the subscriber, patience in operating the dial, no foolish experimenting to determine how fast or how slow it is possible to operate the mechanism to the breaking down point, with never failing care to replace the receiver, will tend to produce the best results and be the essence of the lubricating oil to smooth the working of the mechanical operator.

To give advice to those about to operate, we must add the following instruction to the famous negative of Punch—Don't—hustle or slow down the dial of the calling device.

As regards the choice of Epsom for the first public experiment, the following facts are in its favour: Its relatively high percentage of local traffic—actually it had the highest of any of the original London Post Office exchanges—the nature of its climatic conditions, the character of its telephoning public, its proximity to headquarters, and the special nature of some of its arrangements are such as will afford a good opportunity for testing the working of one of the several systems of automatic switching equipments which has attained success as a practical working system.

Epsom forms part of the outer London area, and has direct communication by means of junction lines with the manual exchanges at the London Central Exchange, Croydon and Sutton, and also trunk or "long distance" line connection with Leatherhead.

The local subscribers are on the message rate system. One penny is charged for each originated local call, twopence for each originated junction call for London Central, Croydon, and other exchanges in the London area, and various rates for long-distance or trunk calls.

In these circumstances it is not possible to dispense entirely with operators. So far as is known it is not possible to provide meters which will differentiate between calls on such a varied tariff; therefore, a manual switchboard and a small operating staff are still required for attending to such classes of service as originated trunk call records, coin box stations, electrophone service, etc.

All incoming traffic from the manual exchanges will be intercepted at this manual switchboard. This avoids the necessity for equipping a special position at each of the manual exchanges (Croydon excepted) with a calling device and a transfer multiple between it and the other positions.

A position at Croydon Exchange will be fitted with a calling device for use at night time, when all outside communication with Epsom will be concentrated at Croydon.

Each subscriber's line is equipped with a meter which registers only originated successful calls to other subscribers on the automatic system. The meters will not register any calls incoming to a subscriber, nor any call made for trunk service, information, complaint, nor for connection to subscribers on the manual exchanges.

Originated calls for trunk service will be ticketed by the Epsom operator.

Bailey, W. J. The Strowger Automatic Exchange at Epsom. *Post Off. Electr. Engs. J.*, Jul. 1912, **5**, p. 121.

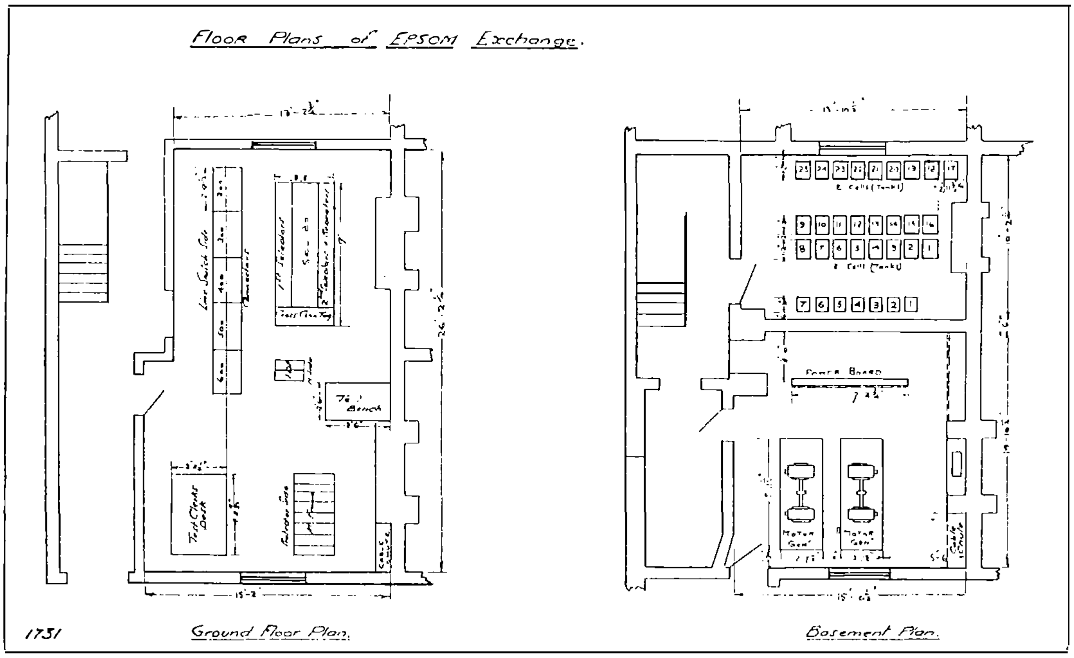
The exchange operators at London, Croydon, and Sutton will ticket all effective calls coming direct from the automatic subscribers over the junction circuits.

The insertion of coins for calls to and from public coin box stations will be supervised by the Epsom operator, who will have facilities for offering Trunk calls to engaged subscribers.

Some authorities are of the opinion that an automatic exchange of about 500 lines is a size where that system begins to show an economy. It is necessary, therefore, in considering the experiment from an economical point of view that the special nature of some of the requirements should be taken into account.

A record of the cost of maintenance will be kept and compared with a manual exchange of similar size, and the results will be awaited with interest.

A lay-out plan showing the location of the various parts of the equipment is given in **1**.



1.—Lay Out.

The present exchange building, originally an ordinary dwelling house, has had to be strengthened to carry the increased weight of the new equipment. The arrangement of the apparatus may, therefore, not be above criticism, and yet may not unreasonably be considered the best possible in the circumstances.

The power plant occupies two rooms in the basement.

The automatic switching equipment is installed on the ground floor, and consists of—

Five line switchboard units, each having 100 line switches, 100 meters, 10 ordinary connectors, 1 test connector, 1 trunk offering connector and two master switches.

Eighty first selectors, 40 second selectors.

One special selector for coin box station and 4 figure numbers.

The ultimate size of the system is arranged for 1500 numbers.

The auxiliary items on the same floor are as follows: 1 Testing bench, 1 Test desk, 1 Main Frame, and 1 I.D.F.

The Information and Trunk Switchboard is installed on the first floor.

[The article then went on to give a detailed description of the switching equipment.]

Epsom Telephone Exchange: Conversion to Automatic Switching.

By R. W. Callender.

The first public automatic telephone exchange was opened at Epsom, Surrey, on May 18th, 1912.

The equipment, which is of the "Strowger" type, is for five hundred lines, and was installed by the Automatic Electric Company of Chicago. A fortnight only has elapsed since the opening, but the experience gained in this interval has been sufficient to leave no doubt that, like many a forerunner in mechanical appliances designed for improving the precision and economy previously attained by fallible and expensive human operations, it has come to stay.

Many of the subscribers have already given profuse expression to their whole-hearted appreciation of the new telephone service, whilst the only exception brought under notice locally has been that of one gentleman who complained that the finger-holes in the calling device were too small for his fingers.

It is possibly not too much to say that no one thing has ever been constructed or created that pleased everybody; and it will be a sufficient tribute to the ingenuity and resource of our American cousins to testify that their bulletins of the Strowger automatic telephone system which reached us from time to time prior to its installation in the "Old Country" were not too fulsome or exaggerated.

With the rapid growth of the telephonic demand experienced in this country during the last few years, and the more recent assimilation of the late National Telephone Company's subscribers into Post Office Exchanges, exchange transfers have now become quite ordinary items in the daily life of telephone engineers. But there were circumstances connected with this one, chiefly on account of the types of exchanges concerned, which rendered it more than ordinarily interesting, and this must be the writer's excuse for thus offering his observations.

Hitherto, the subscriber had had little or nothing to contribute towards the actual transfer operation; this time, however, he or she were to be important assistants, and the issue was dependent to an appreciable extent upon his or her intelligent co-operation. Many of the subscribers were "Ex-National Company", who had but recently been subjected to the inconvenience of duplicate sets of apparatus pending their transfer to the Post Office C.B.S. Exchange, and it was considered inadvisable to again subject them to similar inconvenience.

Accordingly, modifications of the then existing C.B.S. operator's cords were designed locally, which allowed either the old C.B.S. or the new automatic telephones to work to the old C.B.S. Exchange prior to the transfer, and also permitted the recovery of the C.B.S. instruments and batteries and their replacement by the automatic instrument by one visit on the part of the fitter. Further, the signalling "earths" associated with the "A" lines at all C.B.S. telephone stations were connected to the automatic instruments through 6 point 2-position switches, which were all fixed with the same end uppermost, in order that the subscribers could be requested by postal communication to push the switches down at a given time for the transfer, and thereafter to make their calls in accordance with printed instructions supplied to them. The reversal of the switches was to remove the "earths" from the "A" lines and thus leave the circuits in the proper condition for C.B. working.

The date ultimately fixed for the transfer was May 18th, at 3 p.m., and one wondered during the few minutes preceding the critical moment how far, and with what degree of accuracy, the subscribers would respond to the request made to them. The banks of selector and connector spindles were also contemplated with a good deal of interest, as it was realised that in a few moments many of them would be jumping into life, ratchetting upward, rotating and dropping down again at the individual wills of the calling subscribers.

The engineering operations inside the exchange to effect the transfer were not in any way unusual. Two main frames were involved, the C.B.S. equipment was disconnected by withdrawing the heat coils from the old one, and the new automatic equipment joined up by withdrawing wooden wedges from between the line springs and the heat coils on the new one.

These frames were on different floors, and it was essential that all the old heat coils should be withdrawn before any of the new ones were joined up; otherwise "loops" formed by the "earth"

Callender, R. W. Epsom Telephone Exchange: Conversion to Automatic Switching. *Post Off Electr. Engs. J.*, Jul. 1912, **5**, p. 189.

on each A and B line at the C.B.S. Exchange ends would have plunged[*] the line switches of any circuits joined up beforehand at the automatic end. Nevertheless, the whole operation was completed in the space of two minutes.

An officer was posted at the selectors to attempt for a short period to count the number of spindles operating together, but the large number so operating combined with their rapidity of movement and the neutral colour of the mechanism made this an impossible task.

An examination of the master switches, however, showed that none of them were "hunting" for selector trunks, thus proving that all calls which were being properly made were "going through" without being delayed by an insufficient number of selectors; and this, despite the fact that each master switch was controlling one hundred line switches.

Immediately after 3.2 p.m. operators and test clerks began calling the subscribers and requesting them to make experimental calls to certain numbers which had been allotted to telephones fixed in various positions in the switch and test rooms, and the subscribers were then informed that local calls would be "free" up till 5 p.m. on that day.

Nearly all the subscribers reversed their switches as they had been requested, but many of them failed to use the calling device correctly, dialling numbers which brought them to the "dead level" and "dead number" lamps on the manual board and then trying to call again without the necessary operation of replacing the receiver for a new start. Others appeared to hesitate for a long time on the second or third digit of the number they were calling and thus "held up" selectors for an unduly long period.

Yet others assumed that inner London and remote London Exchanges were proper for the "long distance" call, which of course brought them to the "information" operator; and it was said that one subscriber complained because he could get no attention although he had been *shouting* oh! for a long time. No doubt he was duly instructed to use the cipher (o) on the calling device.

All this kept the operators very busy instructing subscribers in the use of the dial, and on this account only it was as late as 8 p.m. before all those subscribers who were available to answer calls had been obtained.

Two circuits developed line faults during the transfer afternoon, and twenty-four subscribers could not be obtained by reason of premises being closed, or the subscribers being away from their homes for the time being; but the satisfactory condition of these last mentioned circuits was ascertained by testing for "condenser"; and early on the following Monday morning the whole of the 340 subscribers had been spoken with.

All the junction circuits were proved by 3.30 p.m. on the Saturday. It was necessary to hold each of the outgoing junctions "engaged" after it had been proved, to prevent them being mechanically picked up again for test by the selector.

Great credit is due to the operating staff for the efficient and willing way in which their new operating movements were carried out. Especially is this so in view of the fact that their opportunities for practice beforehand had been very limited, by reason of the manual board being in the hands of wiremen right up till the morning of the transfer day.

Much interest in the transfer was shown by the "Press," there being many reporters present to whom demonstrations of automatic working were given.

One of these gentlemen immediately after witnessing the heat-coil operation at 3 o'clock went into the Exchange call office cabinet and dialling the office of his newspaper, there and then sent his "copy" *by Automatic Telephone* for insertion in the afternoon's edition.

The transfer was watched by Mr. E. J. Ivison of the Engineer-in-Chief's Office, Mr. Edmunds of the Controller's Office, and also by Mr. Gomersall, the acting Superintending Engineer of the South Metropolitan District, who was of course responsibly interested.

In addition to the modifications of the operators' cord circuits, already referred to as necessary for working the automatic instruments on the C.B.S. Exchange, temporary internal modifications had to be made in the following cases: Intercommunication sets, counter communication sets, private branch exchanges, main sets with simple extensions, and plug and socket wiring, and in some of the cases permanent modifications were necessary to adapt them for automatic working.

[* *Note*: The line switches detected the loop from the subscriber's line and made the connection to a free first selector by causing a plunger, or finger, on the end of a pivot arm to operate a set of contacts. In the modern Strowger exchanges, this function is provided by a uniselector circuit.]

Some Possible Trends in Public Telecommunications Switching

D. M. LEAKEY, B.SC.(ENG.), PH.D, D.I.C., F.C.G.I., F.ENG., F.I.E.E., F.I.E.R.E.†

UDC 621.391.345

Hitherto, advances in technology have led to improvements in existing telecommunication network elements such as switching and transmission, but have had little impact on the structure of the network itself. This article considers ways in which the network might evolve to match new technology in order to improve responsiveness to customer demand and to reduce costs. Among the topics considered are integrated management systems, distributed exchanges and more advanced switching technology involving novel multiplexing methods.

PREFACE

Attempting to forecast the future tends to reflect a personal view of possible global trends and, as such, should not be confused with the policy issues or the strategic plans of any particular administration. It also tends to focus on particular topics to the questionable exclusion of others. The primary role should be one of stimulating debate. It is in this spirit that this article is offered.

INTRODUCTION

What factors are most likely to influence change? In the case of public telecommunications a convenient categorisation of such factors includes:

(*a*) the nature of the past evolution and how the thrust of this evolution might extend into the future;

(*b*) the nature of the service the public telecommunications network will be expected to provide including the influence of any competition; and

(*c*) future opportunities posed by the existing and emerging underpinning technologies.

Concerning the historical factor, in service terms the original introduction some 75 years ago of step-by-step automatic switching could be regarded as a retrograde move when compared with that offered by the then existing manual systems. The manual systems incorporated a flexible switching approach with the control vested in intelligent distributed common controls (the operators) co-ordinated by intelligent central controls (the supervisors). Where advantageous, common-channel (orderwire) signalling was incorporated with a rich repertoire of commands. Call-control communications with the subscriber employed a high-level code (plain English) and a large selection of special facilities was available (for example, ring back when free, call transfer, etc).

In contrast, the original automatic systems could neither imitate this system organisation nor provide the friendly subscriber interface. The overall control of the step-by-step switching stages became vested in the actual subscriber who had to dial a sequence of almost meaningless digits (a form of machine code). Subscriber facilities, charging methods and call routing flexibility were also reduced to a minimum.

However, these criticisms must not detract from the admiration due to the original pioneers of automatic switching. Nevertheless, subsequent developments in automatic switching can be viewed as an effort to restore the standard of the manual service without resorting to the economically impractical expedient of the widespread reintroduction of manual control. To date, this progress has resulted in very flexible switching based on pulse-code modulation and time-division multiplex, versatile control based on stored-program (computer) techniques and powerful common-control signalling, all coupled to the additional bonus of multiplexed junction and trunk systems to reduce transmission costs. However, there are still areas in need of improvement to return to the manual standard of service.

The second factor concerns the nature of the service likely to be demanded by the users. Traditionally, the role of public telecommunications has been seen predominantly as the simple transfer of unmodified information as and when required by the many millions of subscribers (now more reasonably referred to as customers). With the advent of digital systems this might be called *basic bit transport*. However, with the increased demand for data communications and the growing reliance of business customers on telecom-

† Chief Scientist, British Telecom

munications, additional facilities are becoming more important. To provide some order in the categorisation of such facilities, it is convenient to consider them as occupying a series of levels:

- Level 4—Specific customer applications (for example, funds transfer).
- Level 3—Generic communication services (for example, electronic mail).
- Level 2—Intelligent network features (for example, Freefone, time dependent routing etc).
- Level 1—Basic bit transport.

No further comment will be made on levels 3 and 4, except to point out that a network operator cannot ignore the growing importance of the higher levels and must design the lower levels so that they can provide the necessary support in an adequate manner.

The demand for the more advanced services is likely to be very customer dependent, and again it is useful to provide some form of broad categorisation, as follows:

(*a*) *Large (International) Business Customers* These are able to make early and effective use of advanced services, particularly those associated with data communications.

(*b*) *Small Business Customers* These are likely to follow when particular services become established.

(*c*) *Residential Customers* These are probably more interested in a first-class low-cost basic service and the real necessity for advanced services can often be over-estimated.

The main technological advances relevant to telecommunications are likely to continue to be those related to integrated electronics, optical fibre and components, and system and software design methods. However, they can be applied in two ways. The first is to improve the existing network elements, such as switching, without modifying the manner in which they carry out their basic role. The second goes deeper in that the technologies can impact on the network structure itself and modify the boundaries between the network elements.

The impact of new technologies on switching and transmission has already been seen, but this has not affected the network structure to any marked degree, a structure which was dimensioned largely to complement electromechanical technology. The question therefore arises as to whether further advantage can be gained by evolving the network to match the new electronic technologies. In practice, such a network reorganisation now appears desirable at the very least in order to improve responsiveness to customer demand, and probably vital in order to reduce costs if an operating company is faced with competition.

The network reorganisation is likely to modify the form and function of the exchange element. This factor, plus the need to meet the demands of the basic customer classes in a manner which reintroduces more of the important features of the manual exchange, forms the central theme of this article.

BASIC NETWORK EVOLUTION

The existing telephone network comprises local exchanges serving a radius of some 5 km with connection to the customers predominately by copper pairs, each pair carrying a single telephone channel. The local exchanges are interconnected by direct routes or by a hierarchy of trunk exchanges, with typically three levels in the hierarchy. The local junction circuits traditionally employ single-channel transmission over copper pairs which is now being replaced by lower-order digitally-multiplexed systems over the same copper medium or, more recently, over optical fibre. In contrast, the long-distance trunk circuits have been equipped with multiplex working for a considerable time, initially employing analogue techniques over copper pair and coaxial cable, but now increasingly using digital techniques and optical fibre.

In parallel with the basic circuit-switched network, and often sharing only parts of the transmission medium, there are also provided general-purpose circuit-switched or packet-switched data networks plus the ubiquitous Telex network. In many countries, where competitive tariff structures make their use attractive to business customers, these networks are further supplemented by private leased-line networks.

How is this basic structure likely to evolve? The advent of digital switching and transmission, stored-program control and common-channel signalling, all based on relatively recent advances in integrated electronics, has resulted in exchanges which are physically very much smaller than their analogue counterparts. At the same time, the exchanges can be larger in terms of the maximum economic line size which can be handled. These factors, coupled with the removal of the need to maintain strict call routing criteria to maintain transmission performance plans, have led to the possibility of trunk networks with fewer trunk exchanges (a reduction of the order of five to one) and with the exchanges organised effectively as a single-layer hierarchy. This permits better utilisation of equipment, particularly under unbalanced high-load conditions. To enhance this improvement, call routing control can be vested in centralised management units.

However, it is in the local network that the more far reaching changes are occurring. Because of pressures created by business customers, it is becoming necessary to provide a far more responsive and flexible service. For example, the provision of a new leased circuit should be executed in a time measured in minutes. A directory number change might be carried out immediately on request. These response rates imply that the majority of service change requests must be accomplished by software or data changes, with the physical equipment provision and connection being carried out on a more routine basis in anticipation of demand.

To provide the necessary common pool of equipment in the most economic manner, all services should be provided over common low-cost circuits. A complete network reorganisation to achieve this aim cannot be installed overnight. This suggests that, in a service area, there will be created an overlay modern network servicing those customers demanding the premium service, with the less demanding customers remaining on the old network until it is finally removed. In turn, the new network itself will become obsolescent and be replaced in a similar manner. However, such an event is best moved to the distant future by incorporating as much low-cost 'future proofing' as is possible.

To cater for this scenario, the local network is likely to evolve into a basic form as illustrated in Figure 1. Customers will be served from remote multiplexors connected to the parent exchange over optical-fibre cables. Singlemode fibre is to be preferred in that, although likely to be grossly under utilised in the short term, it can provide the basic infrastructure to support the wideband services anticipated in the future.

The remote multiplexors can be provided as part of the customer premises equipment where the traffic demand is sufficient, or they can form part of the public network where services are provided to a variety of smaller customers. The multiplexor can be located in a convenient building basement or equivalent accommodation, and probably only as a last resort in the somewhat vulnerable traditional street cabinet.

Connection to the individual customers from the multiplexor is unlikely to exceed some one kilometre in length and can employ copper cable or optical fibre carrying analogue or digital signals as the demand and economics dictate. Eventually an all-digital ISDN†-like service will be common, but primarily because it will be the cheapest solution, with the special facilities providing the bonus.

At the multiplexor, the various services are brought together as a single digital stream. The multiplexor is intelligent in that the services can be allocated to the appropriate channels remotely under software control. It also contains the necessary equipment to permit comprehensive network management in terms of quality-of-service measurement and fault avoidance. Where necessary for use in the more remote locations, it can provide an emergency local service when the main feeders to the parent exchange are faulty.

The optical-fibre link to the parent exchange might span 20 km without repeaters. Thus, the service area of the parent exchange increases considerably compared with that possible using copper-based distribution systems. The precise location also becomes less critical.

At the parent exchange, the conventional main distribution frame (MDF) gives way to a digital electronic service access switch where individual or blocks of channels can be routed depending on the service requirements. In turn, the parent exchanges are interconnected directly or via the trunk exchanges by means of the digital electronic access switches. These access switches are software controlled and,

†ISDN—Integrated services digital network

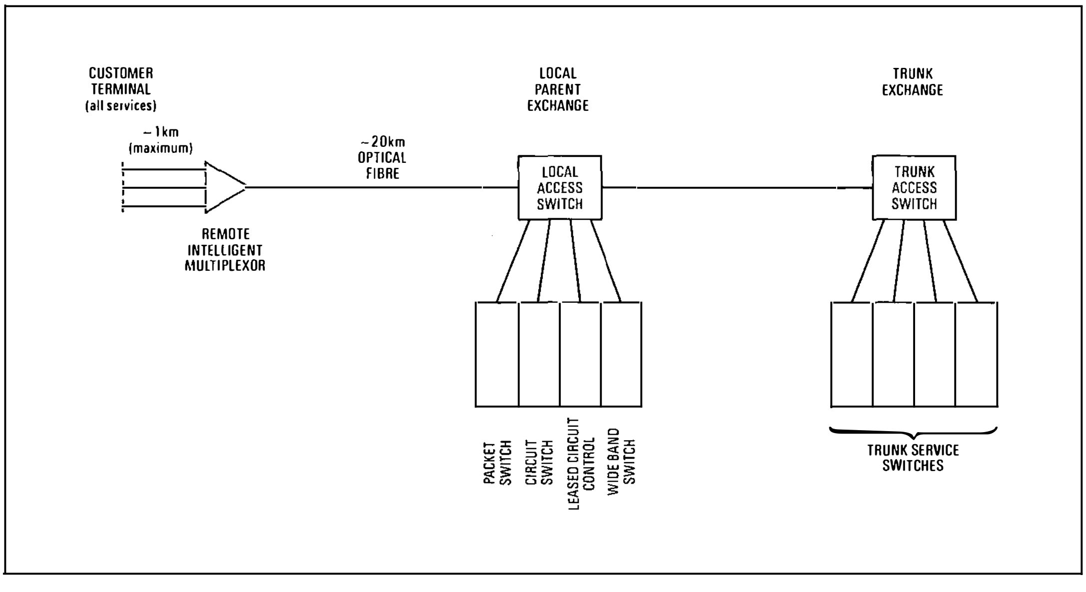


Figure 1
Possible future network architecture

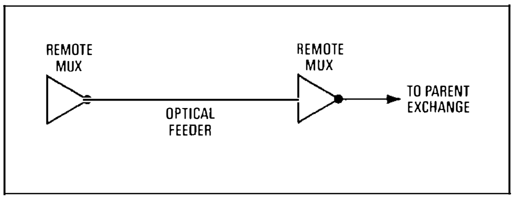
providing adequate equipment is available, network reorganisation can be controlled remotely. In many cases, differentiation between local, junction and trunk circuits becomes unnecessary, and channels can be utilised purely on the basis of traffic demand.

The various exchange switching units connect to the access switch. Figure 1 illustrates four basic types: narrow band circuit switch, packet switch, leased circuit control, and wideband switch. As a result of this reorganisation the conventional 'exchange' no longer provides the customer line units which currently account for a large proportion of the physical equipment.

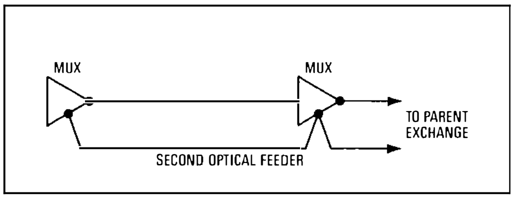
Two evolutionary trends are likely from the very basic network structure illustrated in Figure 1. To make better use of fibre capacity, one fibre pair can feed more than one multiplexor as illustrated in Figure 2(*a*). However, security of service is likely to dictate that at least two separate fibre pairs should be provided to a particular multiplexor with physical route separation to minimise the potential loss of service due to cable damage. This gives rise to a feeder arrangement as illustrated in Figure 2(*b*). Immediately, the possibility of a loop feed system becomes evident as illustrated in Figure 2(*c*). In an extreme case, the loop might terminate on physically separate parent exchanges.

Developments in carrier multiplex techniques are also probable. Two-way transmission over optical fibres can be incorporated by using a simple form of wave-division multiplex (WDM). Digital synchronous insert-and-drop of channels at each remote multiplexor would also provide considerable economies when compared with existing plesiochronous methods. Equally, WDM might be used with each remote multiplexor allocated a unique wave-division channel. In practice, it is probable that a combination of techniques will be used. Synchronous multiplex techniques are likely to be used for the narrowband 64 kbit/s services with WDM catering for the wideband channels to be added at a later date so as to provide the necessary 'future proofing'.

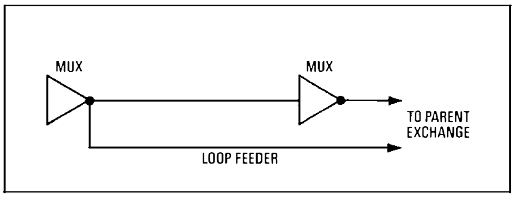
Figure 2
Possible evolution of local distribution network



(*a*) Shared optical fibre feed



(*b*) Dual optical fibre feed



(*c*) Loop feed
MUX: Multiplexor

Radio techniques are also likely to gain in importance both for mobile and quasi-fixed service provision. The remote multiplexors could be strategically sited so that, when equipped with the necessary radio equipment, they could provide service to a local cell of cordless telephones. The wireless PABX is already becoming a commercial reality and the techniques used could also be extended to the public network.

The use of optical fibre or radio in the local network raises questions concerning power feeding to the remote multiplexors and the customer terminals. After much discussion and dissent, it is likely that multiplexors will be provided with local battery storage and local charging, with the terminals being powered from this source if copper connection is used, or locally powered where copper would otherwise be redundant. Primary cells with power failure indication might be used for the cheaper terminals, with secondary cells and mains charging for the more expensive variants. Such arrangements are not only likely to be cheaper than retaining line powering, but would also remove the need for an electrical safety barrier.

NETWORK MANAGEMENT

In spite of the widespread introduction of automatic switching, until relatively recently the network management functions remained largely manual. Where they were automated, a somewhat piecemeal approach was common. However, integrated computer-based management systems are now being introduced and it is likely that this trend will continue at a rapid pace.

To appreciate the nature of this trend, it is convenient to divide the management function into several categories:

(*a*) the monitoring of equipment performance and the reporting of malfunctioning equipment,

(*b*) the monitoring of traffic loading and the reporting of potential equipment under-provision,

(*c*) short-term network restructuring to bypass faulty equipment and to ease overload

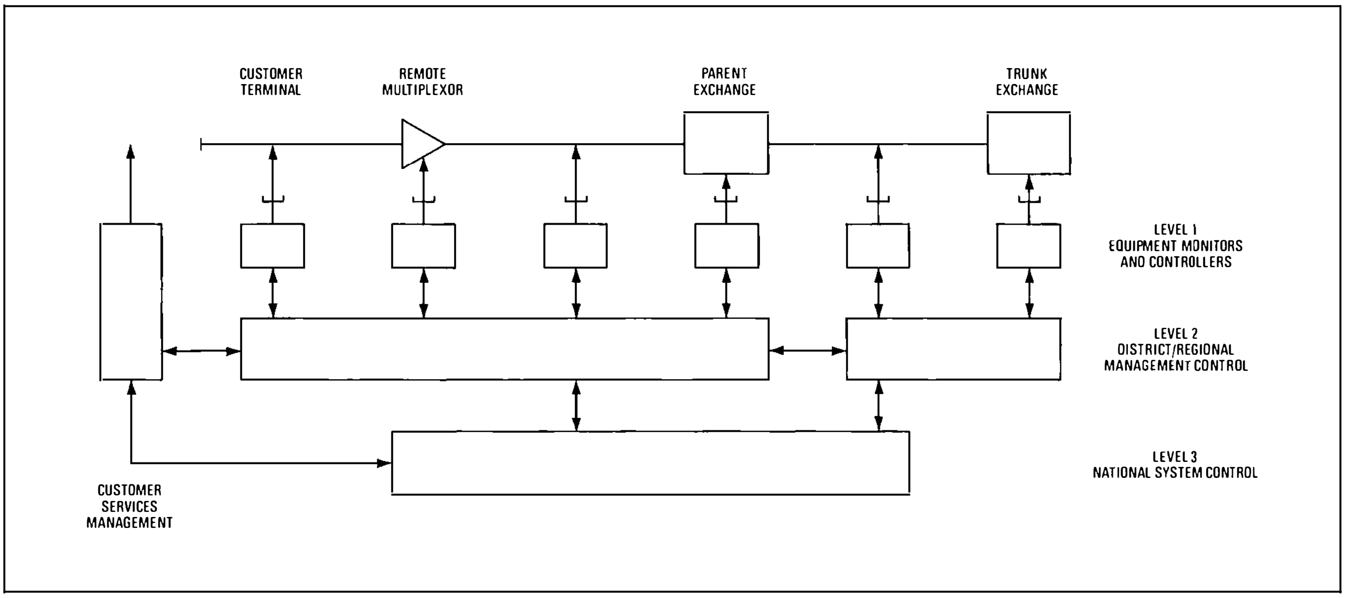


Figure 3
Network and services management

conditions,

(*d*) the compilation of statistics to provide data for future network restructuring and growth,

(*e*) customer services management including service connection, access to special services, charging etc., and

(*f*) special service provision where access to central databases is required; for example, non-standard numbering.

To perform these functions, an integrated management hierarchy is preferred. A possible structure is illustrated in Figure 3. At the lowest level (level 1), equipment monitors and controllers deal directly with particular network elements. At the middle level (level 2), the function of the local monitors is co-ordinated on a district or regional basis. At the top level (level 3), appropriate management is co-ordinated on a national basis. In parallel with the network management system, there is a customer services management system with a regional level for ordinary customers and a national level to provide integrated management for large business customers. The two systems are functionally separate in that the customer has no interest in the internal organisation of the network, but only in the service provided as seen from the periphery. An example concerns the performance of a leased circuit, which, although comprising a series of connected elements, each with its own network monitor, is seen by the customer as a single entity.

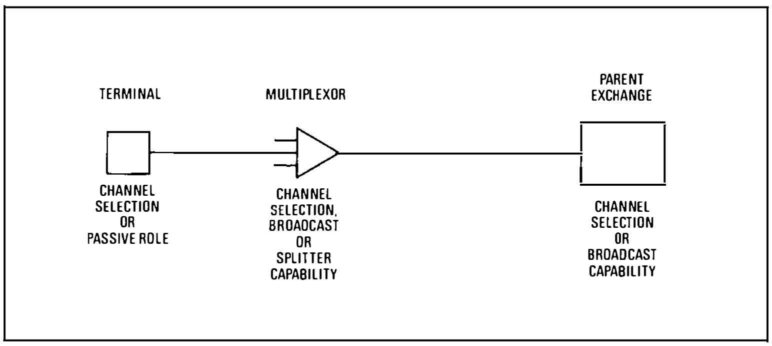
The details of such a network and customer services management structure are not relevant in the present context, except in that it is important to note that it includes considerable computing power and data storage capability, which can take over many of the functions previously carried out by the exchange control. Examples include call charging analysis, directory number translation, preferred route analysis and special services handling. In the limit, the exchange control could retain only those functions to establish, supervise and terminate a basic call.

THE DISTRIBUTED EXCHANGE

The result of the network and management control evolution, made possible by advanced technology, but driven by the need to reduce costs and improve service, is that the traditional boundaries between local distribution, switching and trunk transmission are becoming blurred. This is particularly evident in the local exchange.

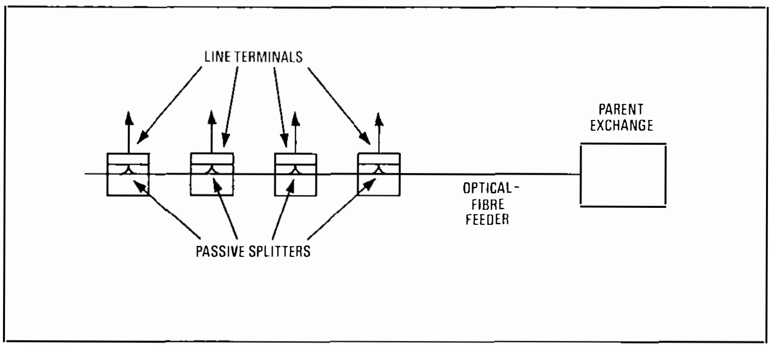
Traditionally, the route or called-customer switching function has been centralised in the exchange. In contrast, in broadcast systems, of which cellular radio is an example, channel selection is vested in the terminal. In the general case, as illustrated in Figure 4, selection can reside within the parent exchange, within the remote multiplexor or within the customer equipment. These alternatives are available for copper, optical-fibre and radio distribution systems, the particular choice being based on available bandwidth and realisation costs. Cable television distribution systems also illustrate the choice possible as can be seen by comparing a tree-and-branch system with a switched-star approach.

Figure 4
Call routing function location



An interesting possibility involves the use of optical-fibre distribution as illustrated in Figure 5. The customer terminals are connected to the fibre bus by means of passive taps. All of the terminals receive all of the channels, with the required selection occurring within the customer's terminal. The system is equivalent to one employing a remote multiplexor, but where the multiplexor is distributed with the customer apparatus. For transmission from the terminal to the parent exchange, a suitable free channel is allocated on a return path by using either a different fibre or a different wavelength to avoid interference. The use of a different set of time-slots is feasible providing due allowance is made for the overall time delay along the fibre.

Figure 5
Optical-fibre bus distribution system



To provide for wideband broadcast services, other wave-division channels can be brought into use as and when the relevant technology becomes available at an economic cost. Two-way broadband communications is also feasible up to the maximum usable bandwidth available. To that extent the system can be said to be well 'future proofed'.

Many variants are possible on the basic theme. Local point-to-multipoint radio can be employed where physical connection is difficult. Combinations of radio and optical fibre are also possible. Thus, there exists a spectrum of realisations employing various transmission methods, switching at various points, with central and dispersed multiplexing and with star, bus or loop feeders. No doubt preferred configurations will emerge, but at present these are difficult to predict.

The distributed approach will also extend to the exchange control. As already suggested, the exchange control might consist of little more than the basic call-control functions with an interface to the management control network for the more specialised services. However, even the basic call-control functions can be centralised, locally distributed or distributed to the multiplexors and the customer equipment. There could also be a well-defined software interface with the special service functions such that the development of the special functions can be carried out in isolation from the exchange control design.

Summarising these possible trends, the effect on the traditional exchange is likely to include:

(*a*) a considerable reduction in the hardware content particularly as a result of the removal of the customer line unit function,

(*b*) a considerable reduction in the control functionality vested in the exchange,

(*c*) migration of part of the switching function to the remote multiplexors and the customer terminals,

(*d*) special facilities management vested in the management control network, and

(*e*) the use of digital synchronous multiplex, analogue (WDM) multiplex and other techniques in a balanced manner to make best use of available underlying technologies.

To make this all feasible, the various interfaces, both hardware and software, must be defined in an adequate manner to permit correct functioning: this is by no means an easy task.

MORE ADVANCED SWITCHING TECHNOLOGIES

The system evolution described can take care of all existing telecommunication and broadcast requirements to form a switched-circuit narrow and broadband service, coupled with packet-switching and leased-line services. The detailed realisation of such an integrated system will be dependent on the market demand and the prevailing legislation, factors which are likely to vary greatly between countries.

However, in spite of the potentially all-embracing nature of the possible service, it is probable that the mixed circuit and packet-switching feature will at some time give way to more advanced approaches, approaches which have already reached the experimental and trial stages.

The first alternative likely to be introduced is based on an advanced form of packet switching normally referred to as *asynchronous time division* (ATD) [1]. With this approach all the input signals, including speech and video, are packetised with the packets being transmitted over a wideband circuit in a time sequenced manner. Routing is performed by the packet switch reading the packet header information and routing the packet on the fly. Information delivery times are restricted so as to limit overall delays to an acceptable level particularly for conversational speech and vision services. Although experimentally such an approach has been possible for a considerable time, it is only with the very recent advances in semiconductor technology that it has become a potential commercial rival to the more conventional approaches. Note that ATD also removes the need for conventional multiplexing.

In the more distant future ATD could be superseded by a further approach referred to as *code division multiplex* (CDM) or *code* *division multiple access* [2]. In CDM systems, all channels pervade all of a particular carrier medium both in the frequency and in the time domain. The method of multiplexing and demultiplexing (and routing) is based on pattern recognition techniques, the individual signal carriers being unique code patterns either in digital or analogue form. Channel separation involves the use of correlation detectors, devices which can separate signals on the basis of amplitude time patterns even where the patterns overlap time. Ordinary frequency-division multiplex is an elementary extreme form of such a system where the patterns are sinusoidal. A somewhat more complex system might employ Walsh Functions or pseudo-random sequences.

In terms of conventional electronic components, correlation detectors are very complex, but the rapid advances in integrated electronics can render this disadvantage negligible. Potential advantages of CDM include improved immunity to impulsive and frequency selective interference, inbuilt cryptography and an ability to optimise automatically individual channel performance over a given medium as the loading varies. Loading above the design limit decreases signal-to-noise performance, and there is no sharp cut off in the number of channels which can be carried.

These advantages should ensure that the technique has an exciting future, but, at present, the complexity tends to limit its use to special military applications.

However, it is interesting to note that the CDM technique is far from novel. It is the approach adopted by human beings (and animals in general) when they attempt to listen to a particular speaker in the presence of other speakers (the so-called cocktail party situation). Thus the use of CDM is already widespread.

CONCLUSIONS

At the beginning of the article it was suggested that there was still some way to go before the service offered by an automatic telephone system matched that of the manual exchange. At least in terms of flexibility of service it appears that we are seeing the remaining shortcomings disappear, and added features, such as a rapid response to service requests, introduced as definite improvements. In terms of a conversational approach to customer/equipment interaction, this can now also be introduced by means of computer compiled sentences, and, with added artificial intelligence, may approach the standard of the human operator. Alternatively, it might be argued that we are all becoming accustomed to using keyboards and in many cases we prefer this type of interaction to that involving a second person.

However, the major trend now beginning to be seen is the transformation of the network to match electronic technology, rather than the use of electronic technology in a electro-mechanically generated environment. It is this change which promises the major benefits in terms of service, cost and flexibility. It is also destroying some of the basic concepts as to what constitutes an exchange and the manner in which switching and transmission equipment interface. The result is likely to be the gradual demise of the exchange as a well defined network element. Switching will be spread out even as far as the customer equipment, as is already the case with radio systems. Control functions will be defined over a network management hierarchy so that, where appropriate, actions can be initiated on a national or even an international basis.

However, as with existing generations of equipment, the new subsystems will require accurate specification to ensure satisfactory interworking. This network specification task is becoming more complex as the service requirements increase. Whether international standardisation bodies can meet all of the challenge is open to some doubt unless motivations are modified.

Influential groups of system suppliers and/or network operators might be more able to formulate adequate specifications and standards to meet the timescales required by the service demands. Whatever the approach, considerable research and development at the network level will be required to back up the work, a necessity which is often grossly underestimated.

If the task becomes too onerous, the inclusion of intelligent features should enable interworking standards to be less precise. Such intelligent features were of course a feature of the original manual systems and probably enabled them to function without precise interworking specifications at the functional level.

Is this yet another area where a return to past practices is required?

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Biography

David Leakey graduated from Imperial College, London University in 1953, and was awarded a doctorate in 1958. From 1958 to 1963 he worked at the GEC Hirst Research Centre on the design of electronic exchanges. He then moved to GEC Coventry to take charge of the exchange development group and, in 1965, he became Technical Manager of the Public Exchange Division. After a brief spell as an academic, he returned to GEC, ultimately becoming Technical Director of GEC Telecommunications Ltd. He joined British Telecom as Deputy Engineer-in-Chief in January 1984, and became Chief Scientist in July 1986. Since October 1984, he has been a Vice-President of the Institution of Electrical Engineers.

Network Evolution Using Asynchronous Time-Division Techniques

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The evolution of public networks is being directed toward multi-service capability in order to allow the more efficient provision of both existing services and new services. Asynchronous time-division (ATD) techniques are already employed for implementing multi-service networks such as local area networks. This article discusses the benefits of applying such techniques to the public switched domain and outlines some gradual evolutionary paths which would lead towards a universal ATD multi-service network. Some of the design issues of a public ATD multi-service network are also discussed.

This article is a revised version of a paper which first appeared in British Telecom Technology Journal and takes into consideration some recent developments.*

INTRODUCTION

Public telecommunications networks have evolved and will continue to evolve in order to make better use of the existing high capital investment. The constraint on the evolutionary process is that networks remain economic throughout their evolution. To meet this constraint, the evolutionary process occurs through a combination of two economic forces:

- *Technology driven evolution* occurs because the inevitable replacement of obsolete equipment is more economic with new technology.
- *Demand driven evolution* occurs because of the pressure for new and improved network capabilities which can generate additional revenue through the provision of new services or by carrying additional traffic of existing services. Network providers may accelerate the demand growth by the provision of equipment in anticipation of the demand growing.

† Network Systems Department, British Telecom Engineering and Procurement

* LITTLEWOOD, M., GALLAGHER, I. D., and ADAMS, J. L. Evolution toward an ATD multi-service network, *Br. Telecom Technol. J.*, Apr. 1987, **5**(2), p. 52.

TABLE 1

Typical Service Characteristics

Service Class	Peak Bit Rate (kbit/s)	Burstiness (Ratio of Peak to Mean Bit rate)	Mean Call Holding Time (s)
Voice	16–64	2:1	180
Text	1–64	2:1	1–2000
Image Data	64–2000	10:1	1–2000
Video	<140 000	5:1	3000

A single public-network provider has little control over the changes in the available technologies or in the demand for services. In anticipation of either the arrival of more economic technology or the demand for services changing, network providers should endeavour to use the most flexible network architectures and technologies that are consistent with economic network operation.

Future service demands are uncertain and their characteristics vary widely as indicated in Table 1. Consequently, network providers need the facility to try out new services, with any of a wide range of characteristics, cheaply. Multi-service networks (MSNs) provide this flexibility, with single-layer MSNs accommodating errors in forecasts of traffic and service more cheaply than separate single-service networks [1]. The evolution to a digital network has been a fundamental step toward an MSN, and the evolution to an asynchronous time-division (ATD) network is proposed as the next step [2].

In ATD networks, packets of information are switched according to their associated headers, without time-slot reservation, and have historically been used for low-bit-rate data. More recently, advances in ATD technology have led to it being preferred for private local area networks (LANs), such as Ethernet and the Cambridge Ring, because of the ability to cope economically with a wide range of service characteristics, including wideband and variable-bit-rate services. The interconnection of these private MSNs using a public ATD MSN would allow a maximum range of services to be provided with reduced interfacing complexity.

Technological advances have occurred in optical transmission techniques, integration technology and processing technology. These advances will reduce the relative costs of wide-area broadband ATD networks with respect to existing telephony networks. This has led to the rapid growth of world-wide research interest in evolving toward a public broadband MSN which uses ATD techniques [2–7].

The performance requirements of a public MSN, especially under overload conditions, are much stricter than those of private networks, which may not need to provide a full range of services, may have more predictable traffic patterns and may have lower availability demands. The Orwell protocol [10], which has been developed within British Telecom (BT), satisfies the public network requirements of guaranteed low packet loss and delay, even under overload conditions. The adoption of the Orwell protocol to control congestion in private LANs, metropolitan area networks (MANs) and in public wide area networks (WANs) would further reduce the complexity of interfacing private and public systems and hence reduce the costs of providing new services.

The reduction in cost of broadband ATD equipment and the availability of the Orwell protocol to provide guaranteed network performance make evolution toward an ATD multi-service network possible. This article shows the desirability and feasibility of this evolution by:

(*a*) indicating the technological trends that are making broadband ATD equipment cheaper,

(*b*) reviewing the advantages of ATD techniques,

(*c*) proposing gradual evolutionary paths toward an ATD MSN which would satisfy the needs of business, residential and mobile customers, and

(*d*) outlining a feasible MSN architecture and identifying some protocol requirements.

TECHNOLOGICAL DRIVE FOR NETWORK EVOLUTION

Many evolutionary steps in telecommunications have been technology driven. It is only after a technology becomes available that ways are devised to profitably use it. For instance, services such as videotex, facsimile and Teletex have been modified to take advantage of the 64 kbit/s streams of the integrated services digital network (ISDN).

Optical transmission technology is maturing to provide greater communication potential at a low marginal cost. The use of ATD switching and multiplexing with optical transmission will remove the difficulty of tailoring service parameters to match network parameters. To make full use of this network flexibility, call-control software that is more complex than current single-service network software is necessary, and can be provided only if the improvements in processing technology continue.

Transmission Technology Drive

The costs of optical-fibre systems, which provide much greater bandwidth, require fewer repeaters, have greater reliability and have significantly reduced electromagnetic noise problems, are dropping rapidly as the world market expands. This trend is expected to continue through improved device-integration techniques, automated bonding, and higher-throughput fibre-manufacturing techniques.

In a typical telephony network, approximately 40% of the capital investment is in the customer access network (CAN). Consequently, the marginal cost of providing broadband services is greatly dependent on the cost of upgrading the CAN, and this cost is dropping quickly because of optical-fibre technology. Already, optical fibres are being used to distribute signals to remote equipment, from where coaxial cables can be used to provide economic broadband access. There is also interest in upgrading existing copper pairs, which may be feasible for the shorter access lines. With these advances, the transmission of broadband services over the CAN is becoming more economic for entertainment and commerce.

The use of coherent optic techniques will enable a large number of separate broadband channels to be carried using a single fibre. Its use in the trunk network will allow the economic provision of wide area broadband services, which will stimulate even greater use of the services available over a broadband CAN.

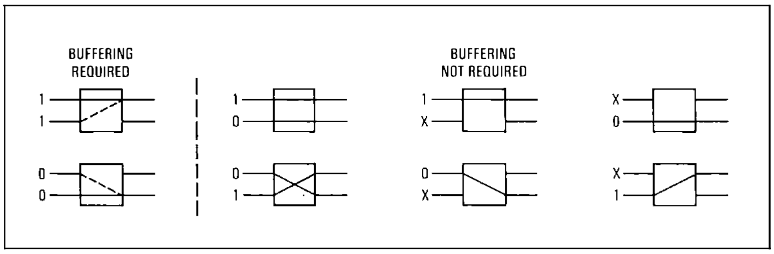
Switching Technology Drive

The high logic speeds of very large scale integration (VLSI) devices enable time-division techniques, both synchronous and asynchronous, to be used for broadband switching. These techniques, coupled with the ever increasing level of integration, reduce the amount of hardware required for the production of switching and multiplexing equipment.

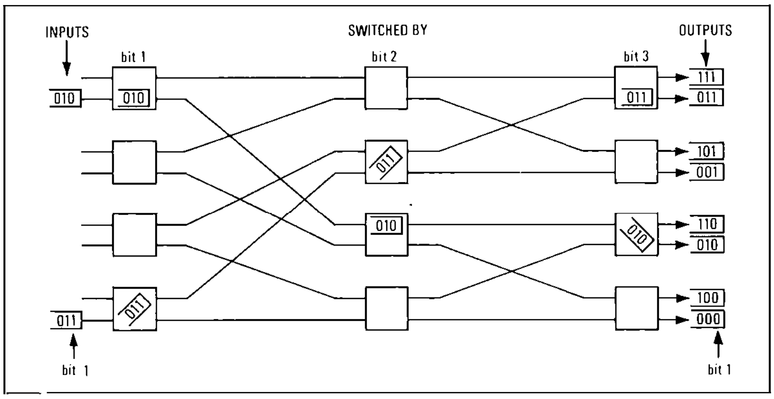
The low cost of VLSI also enables some low-level functions to be implemented economically in hardware, and decentralised to increase the performance and robustness of a system whilst reducing the complexity and the performance requirements of its software. ATD systems make use of decentralised low-level processing to switch packets† and provide flexible bandwidth allocation by dynamically determining the allocation of time-slots.

For instance, some ATD switch architectures switch packets and allocate time-slots by using only the information contained within their headers. The operation of a simple

† 'Packets' are the basic information units of an ATD network and include user data and a header. They are sometimes referred to in the literature as *cells* in order to distinguish them from the 'packets' of slower X.25-like protocols, which cannot be used for broadband services.



(*a*) Operation of a 2 × 2 switching element



(*b*) An 8 × 8 multistage interconnection network for switching

Figure 1
Simple switch element

switching element is shown in Figure 1(*a*), where packets with a '1' in their header are steered to the top output and packets with a '0' are steered to the bottom output. If contention for an output occurs, buffering is required within the cell. These elements can be interconnected to form larger multi-stage switches, as shown in Figure 1(*b*), where successive header bits are used in each stage of the switch. The use of simple switching elements enables the construction of cheaper switches with high throughputs.

No matter what type of switching is used within a network, however, it is still necessary to determine the path of a call and whether or not it should be accepted given the existing loads along the connection path.

Processing Technology Drive

Reduced processor costs, more powerful software tools and improved software structures will enable the greater distribution of processing, and the successful design and coding of more complex software systems. In turn, this enables the provision, in a manageable fashion and tailored to particular customers, of advanced call-control and supplementary facilities. There will be continuing growth in the demand for these services, which allow more convenient use of the network, provide increased switching and transmission efficiency and enable the sharing of other common resources.

BENEFITS OF AN ATD MULTI-SERVICE NETWORK

Whilst there may be a technology drive toward cheaper broadband ATD systems, it is the network and service benefits of broadband ATD networks that have created the most interest:

- *Inherent rate adaption and flexible bandwidth allocation*, within the limits of the physical connections, are provided by ATD techniques. The actual rate of a connection is dependent upon the rate of arrival of packets, which can be flexibly agreed upon, and not upon the bit rates of the lines or channels along the route. Unused bandwidth is freely available to other connections and so high efficiency can be obtained.
- *Statistical multiplexing* of variable bit rate connections for greater transmission efficiency is possible using ATD techniques. As indicated in Table 1, nearly all services are bursty which makes them amenable to variable bit rate coding. For instance, variable bit rate video coding will provide better quality for a lower average bandwidth. Video is expected to be a major broadband service and so efficient transmission is very important.
- *Service independent switches* can be provided using ATD switching techniques. The switches will have a particular maximum service bandwidth, but the use of the bandwidth available, by different services, is not restricted.

In addition to the inherent advantages of ATD techniques, a common data and signalling network, as provided by an ATD MSN, should use processing more efficiently and provide simpler interworking. For instance, the common-channel signalling network, which uses CCITT† Signalling System No. 7 and carries signalling messages which control the telephony network, is more efficient. However, its design is orientated toward the transfer of signalling and it is unsuitable for the transfer of higher bit rate or lower delay variable bit rate services. Also, the transfer of data in packet networks can only be controlled by a separate signalling network if interworking facilities are provided. A single ATD MSN that carried signalling and data would be more efficient, would not require interworking, would hence require less total software and would be consequently more robust.

SERVICE REQUIREMENTS

Voice services will continue to be the major revenue earner for public network providers in the near future and must be carried cheaply.

† CCITT—International Telegraph and Telephone Consultative Committee

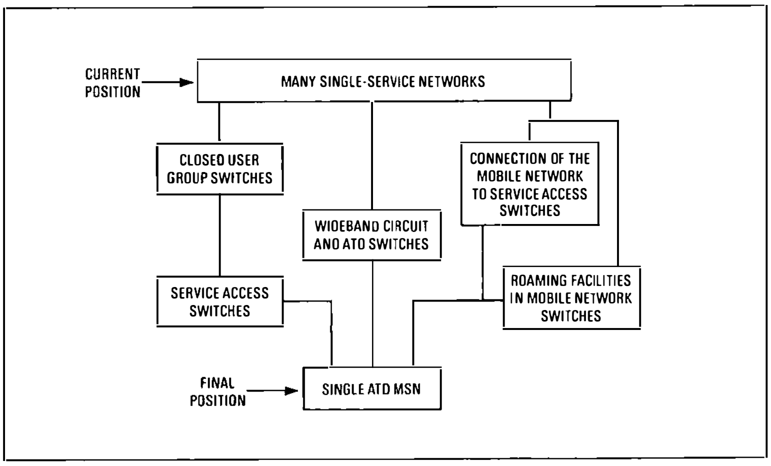
To carry voice, the MSN must interwork with the telephony network and meet its delay, error rate and availability requirements.

The ISDN integrates voice and narrowband data to use more efficiently the existing copper CAN. Its imminent introduction has coerced switched services into two classes, those using the 64 kbit/s streams provided by digital telephony networks and those using the low-speed high-integrity X.25 data networks. A single MSN will have to support both of these service classes if smooth evolution is to be possible.

The separation of services into the two ISDN service classes will continue, but it will never be economic to provide some services within either of these classes. The distribution of entertainment video is not economically viable over the 64 kbit/s ISDN, but it is a potentially large revenue earning service which could be supported by a broadband CAN. Also, many high-speed business services, such as file transfer and image data transfer, cannot economically be coerced into 64 kbit/s channels. An MSN should satisfy these needs also.

There is a great deal of uncertainty about future services, their parameters and their traffic. A single MSN reduces the necessary risks because only errors in total traffic are costly. The following sections indicate some of the expected services required in the business, residential and mobile sectors and the small steps that could be taken for smooth evolution towards an ATD MSN. Each step is optional and would be taken when or if the expected additional revenue is greater than the cost. Figure 2 summarises the proposed evolutionary paths to a single ATD MSN.

Figure 2
Evolutionary paths towards an ATD multi-service network



ATD: Asynchronous time division
MSN: Multi-service network

Business Service Evolution

Business customers have demonstrated, through their use of LANs and leased lines, their need for bit-carrying services that are not currently provided by public networks. LANs have been widely used to provide multi-service local communication for office automation and distributed computer systems. Large numbers of dedicated lines have also been leased to enable high-speed data communication between either LANs or computer systems. The evolution of public networks to provide the bit-carrying services required, over wider areas and with more efficient use of transmission resources, seems inevitable.

Business: Step 1—Closed User Group Switches

Broadband variable-bit-rate services, such as direct LAN-to-LAN connection or variable-bit-rate video, can most cheaply be carried by using ATD techniques with statistical multiplexing. An ATD switch could provide the logical meshing of customers, with dynamic bandwidth allocation, using a star-wired physical configuration. In turn, efficient broadband data communication should make the distribution of processing more economic and lead to even greater demand.

This desirable bandwidth flexibility can be provided to the public only by using switches with call-control and charging facilities. However, the need for such a full software system can be temporarily avoided through the use of closed user group (CUG) switches. These switches would be rented to a customer or a consenting group of customers with no call-based charging for intra-group connections, which would be carried using permanent virtual circuits.

The alternative to ATD switches is synchronous digital cross-connects running at fixed bit rates. These do not allow the dynamic allocation of bandwidth and hence are not efficient for LAN interconnection or for the transfer of high-speed variable-bit-rate services such as compressed video.

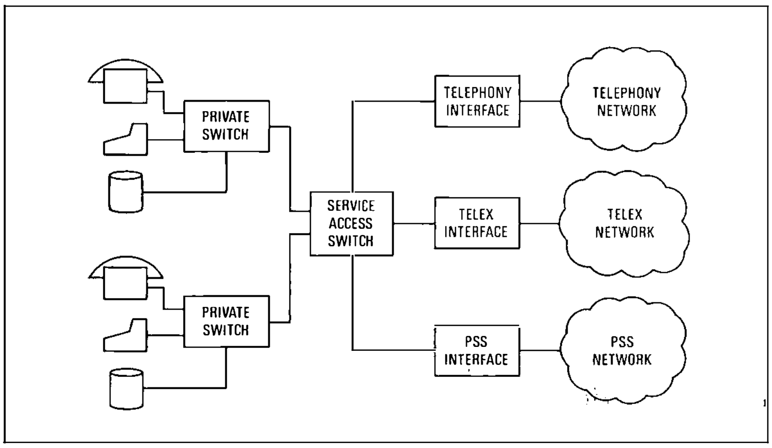
Ideal customers of CUG switches would be geographically distributed companies that make significant use of telecommunications services for internal communication. Data and signalling networks, such as X.25 networks, could also use CUG switches for low-delay trunk switching, and thus reduce the need for meshing to contain delays. The messages of these networks would have to be split into smaller packets upon entry to the CUG switch and then recombined upon exit.

A single CUG may require multiple switches, either because of the wide area needed to be serviced, or because of the high total throughput required. CUG switches could be easily networked together to solve this problem. Also, several small CUGs could be put on one physical switch, but with the logical separation of the different groups, to allow the software-controlled reconfiguration of CUGs and the overlapping of CUGs.

Business: Step 2—Service Access Switches

The integration of voice, data and image services on public network access lines can be achieved by adding network interfaces to CUG switches to upgrade them to enhanced service access switches (SASs). An SAS would provide permanent virtual circuits to public networks as if they were members of the CUG, as indicated in Figure 3, and provide a standard protocol interface which would also allow access to emerging networks with new services. For instance, ATD SASs would simplify the connection of customers to a public broadband ATD network, which would be implemented in Step 3. Importantly, an ATD SAS would enable dynamic sharing of network interface resources. Connections carrying existing services would pass via public networks which would provide all charging, routing and supplementary facilities, and so the SAS control software would be much simpler than a local exchange.

Figure 3
Use of a service access switch



PSS: Packet switched service

By progressing from CUG switches to SASs, the ATD switch technology would be allowed to mature to meet the reliability requirements of public telephony networks and the integrity and security requirements of public data networks. Whilst the technology is maturing, however, it can still economically provide services, which would otherwise be unavailable, through CUG switches.

Business: Step 3—Broadband Local Exchanges

Groups of businesses which have insufficient traffic to warrant CUG status can be serviced by broadband local exchanges provided in their business district. The call-processing software of these exchanges will be the major additional cost because it must incorporate routing, charging and supplementary facilities, and provide the necessary security.

The complexity of the software of an ATD local exchange should be less than the software of a corresponding circuit-switched exchange because processing can be distributed for increased simplicity by using cheap communication. Also, the low-level functions can be provided by ATD switches, and so less software control will be necessary.

Wider-area business communications requirements can be satisfied by the interconnection of broadband local exchanges to form a public MSN. This interconnection, which can be accomplished by using existing trunk transmission, would require network control for the allocation of transmission and switching resources, routing, charging and intelligent network services.

Mobile Service Evolution

The market for mobile services such as carphones and hand-held telephones is growing rapidly and will eventually include data services. Only these low-bit-rate services can be supported by the limited ether bandwidths available for cellular radio transmission. The complication for mobile service switching is that the switched path of a mobile service connection may change as either of the terminals roams. There are several distinct advantages that the use of ATD techniques and systems can provide to mobile networks:

- *Simpler network interfacing* is possible with the integration of voice and data services in the mobile network and in the access to the main network by using ATD techniques. Only a single interworking unit would be required.
- *More efficient variable-bit-rate transmission* is offered by the statistical multiplexing of services such as data, video and perhaps voice. Also, congestion can be relieved to a limited extent by gradual degradation rather than call termination or any other circuit-rationing technique.
- *More efficient low-bit-rate transmission* is offered by ATD networks. It is expected that mobile voice communication will continue to use a 16 kbit/s encoding scheme because of the limited bandwidth available in the ether. This will not be efficiently carried by the 64 kbit/s channels of the ISDN. In an ATD network, packets could be switched without disassembly, with good transmission utilisation and with lower delays.
- *Simpler control* of the connection to roaming terminals is possible with some ATD switch architectures, notably the Orwell ring, which allow routing by using logical addresses. A significant proportion of the cost of the provision of mobile services is attributable to the need to redirect connection paths when terminals cross cellular boundaries. A network based on Orwell rings would allow this redirection to be performed more easily than an equivalent circuit-switched network.

Mobile: Step 1—Connection to an ATD SAS

The problems of multiple network access can be overcome by connecting the mobile network to the main network via the SASs installed for the business sector and treating it as a customer with multiple, geographically separated access points. The mobile network must be responsible for distributing the costs to the users.

Mobile: Step 1(a)—Roaming Facilities in Mobile Network Switches

In parallel with Step 1, the actual mobile network can evolve to take advantage of ATD switches with roaming facilities to reduce the complexity and hence the costs of mobile network control. A narrowband ATD mobile network may precede a non-mobile ATD MSN.

Mobile: Step 2—Connection to an ATD Public Network

Packet voice, using a 16 kbit/s coding scheme, can be carried with greater efficiency if the packets are not disassembled to fill a 64 kbit/s channel. The connection of the mobile network to an ATD public network would allow mobile traffic to be carried entirely as packets. Whole 64 kbit/s channels would not need to be wastefully reserved and the delays experienced would be less.

Mobile: Step 3—Amalgamation with the ATD Public Network

The non-mobile MSN could also allow users to be connected to a range of network ports thus allowing advanced call redirection facilities to be implemented. This could lead to a high degree of commonality between the mobile and non-mobile networks. If amalgamation of the mobile and non-mobile MSNs were viable, the networks could share switching, transmission, maintenance and management resources.

Residential Service Evolution

There are three major broadband services which are attractive to the residential market and could be provided over a broadband CAN:

(*a*) *Entertainment video services* could be provided over the CAN with advantages over current ether distribution. High-definition television (HDTV) and switched video library services could be provided or the number of channels available on common aerial television (CATV) systems could be increased.

(*b*) *Videophone services* could be carried as 64 kbit/s synchronous channels, but there will be a significant increase in quality if a variable bit rate coding scheme is used with an average of 64 kbit/s and a peak bit rate of the order of 2 Mbit/s. This peak bit rate may be supportable by using existing links from distribution points to the customer premises. A coding scheme of this bit rate could be implemented with lower speed and hence lower cost technology, such as microprocessors.

(*c*) *Information distribution* such as the electronic distribution of shopping catalogues and newspapers should be more convenient and economic than current hardcopy distribution schemes. To provide print quality images on screens within a few seconds, bandwidths greater than 1 Mbit/s are necessary.

It will be inefficient to switch parallel 64 kbit/s channels to provide broadband services, especially those services which have short holding times or are bursty in nature. For this reason, ATD switch architectures are being considered for broadband services.

Residential: Step 1—Wideband Circuit and ATD Switches

Separate wideband circuit switches, however, are being considered for broadcast entertainment video services because of the following characteristics:

(*a*) Video services require much higher bandwidths than other services required in the residential market.

(*b*) Broadcast entertainment services are expected to have high traffic peaks corresponding to popular time-slots. Multiple broadcast channels could swamp a small ATD concentrator.

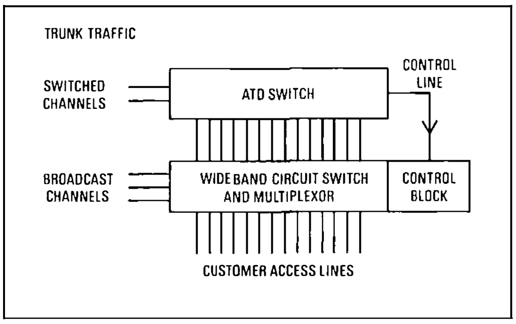
(*c*) Broadcast services require switching of few inputs and so simple crosspoint tapping systems can be used.

(*d*) Long call holding times will be typical of entertainment video.

(*e*) Existing television receivers can be used with current signal coding.

(*f*) The expected high demand for entertainment video makes a dedicated switch more economically viable.

Consequently, a broadband broadcasting circuit switch may be used initially for the distribution of entertainment television. The switched communicative services would be multiplexed on to the access lines with the required TV channels. The advantages of an ATD MSN are mostly retained if an ATD



ATD: Asynchronous time division

Figure 4
Hybrid local exchange

switch is used to carry switched communicative services including the signalling to control the broadcast services. The suggested configuration of a local exchange is shown in Figure 4.

Residential: Step 2—Multi-Service Local Exchange

An ATD switch, without the broadcast video services, has much lower throughput requirements, but it may still be required to carry some switched broadband services, such as still-image transfer and even non-broadcast video services. By allowing some broadcast video, an ATD local exchange may evolve to become a true multi-service exchange as it becomes cheaper to switch greater throughputs. There are some major stimuli for the transition from a hybrid local exchange, with both ATD and circuit switches, to a wholly ATD local exchange:

- *Complementary busy hours* can be expected for switched commercial and broadcast entertainment services on some routes. Flexible transfer of bandwidth between services is simpler with ATD techniques.
- *Statistical multiplexing of video signals* is possible if variable-bit-rate packet codecs are used. Packet video codecs provide similar quality to constant-bit-rate codecs with much lower average bit rates. It will be important to carry high-bandwidth video services efficiently, especially on low-capacity trunk routes of which there will be many in the foreseeable future.
- *Greater integration of services* is possible by distributing broadcast broadband services via the ATD MSN. The network will have the advantages of a greater pool of switching and transmission resources and the network provider will have fewer maintenance and management problems since only ATD switches would be used. The need for greater integration of services will grow as the use of switched broadband services, such as videophone and video library services, becomes more common and the proportion of traffic provided by the wideband circuit switches decreases.

The proliferation of packet video decoders is necessary for the transition to a network consisting solely of ATD switches. The decoders can be located either in the customers' premises or at a remote concentrator site, depending on the relative cost of transmission systems and decoders, and the potential for decoder sharing, which is service dependent.

The transition to the use of solely ATD switches can be performed smoothly. As customers require more switched services and as packet decoders become more prevalent, the network provider can shift the video load from the wideband circuit switches to the ATD MSN. The network provider is not committed to the transfer occurring within any particular timescale.

IMPACT OF SERVICE REQUIREMENTS ON ATD IMPLEMENTATION

For smooth network evolution, it is essential that the ATD MSN be compatible with existing networks, so that the international performance standards for existing services can be met. In order to provide a flexible low-cost long-term solution, the careful selection of internal protocols and call-processing software structures is essential. These issues are discussed further.

Packet Delay Constraints

Care must be taken in the standardisation of public ATD protocols if delay requirements for voice services are to be met. In order to avoid intolerable echoes, international delay standards for the telephony network require a maximum national delay of 24 ms (CCITT Recommendation G.164). A further standard specifies a maximum cross-exchange delay of 450 μs (CCITT Recommendation Q.507). Both of these requirements may be met using packets with a 128 bit information field[11].

Existing delay standards, however, may be relaxed in future through the use of echo cancellers (CCITT Recommendation G.165) rather than the currently used echo suppressors. Echo cancellers will be installed which will allow a greater national delay without echo problems. For these reasons, packets with 256 bit information fields are considered acceptable and should provide greater efficiency.

Priority Schemes for Economy

The use of different priorities within the packets of an ATD network will allow the satisfaction of important individual service requirements even under overload conditions. Without this mechanism, all services must be provided with the integrity required by signalling (that is, the highest-integrity service) and the maximum delay required by voice (that is, the lowest-delay service). Without a priority scheme, these characteristics can be provided only by running the network permanently at low utilisation even under what would be overload conditions, which are almost impossible to avoid. A prioritised ATD network can be run at a higher utilisation and be economically justified by the reduced equipment requirements.

Given that a prioritised packet service is to be provided, it is essential that priority classes are chosen to enable simple and economic interfacing with existing networks. Quality-of-service parameters must be selected for each bearer service. For example, a low-delay service must be available for voice, a high-integrity service must be available for network signalling and it is expected to be efficient to provide a separate medium-delay medium-integrity service for packet video.

Packet Route Control

There are several schemes that have been proposed to control the routes taken by packets. The major routing scheme classes and their characteristics are described below.

Datagrams

Datagrams use long headers which contain sufficient information to control switches without reference to connection tables. Hence, the establishment and maintenance of connection tables is a burden for network control which is avoided by the use of datagrams. The routing information within a datagram header can take either of two forms:

(*a*) *Logical addresses* indicate the desired destination without indicating the physical route to be taken. The routes taken by packets of a connection are determined by using tables within the switch which may or may not be dynamically altered. A route server can be implemented easily since the same logical address can be provided for a destination independently of the location of the source.

(*b*) *Physical routes* indicate the route to be taken to the desired destination. Each switch along the route examines part of the physical route and some header manipulation is necessary in each switch so that succeeding switches are presented with the correct information. The route server requirements will increase rapidly as the number of sources and destinations increase or as the number of interconnected switches increases.

Rings naturally use logical addresses, since the packets perform a linear search for an exit point as they pass around the ring. Most other ATD switches use physical routes, but they can be adapted to use logical addresses by translating from the logical address to the physical route at the incoming port of the switch and adding this physical route to the packet header. The physical route may have to be removed at the outgoing port of the switch.

Virtual Circuits

Virtual circuits are provided by using call-identity numbers in the packet headers which act as references to access connection tables used for switch control. They have a high signalling and processing overhead during connection establishment, especially if the network comprises many smaller switches, but offer very good security. They may also be used to allow a greater addressing range for a given header size and hence are favoured whenever transmission efficiency or security is important. The connection tables must be maintained, which requires information to be transferred by using either datagrams or permanent virtual circuits, and hence a network using only virtual circuits may be unworkable.

Hybrid Schemes

Hybrid virtual circuit and datagram schemes can combine the advantages of each. Virtual circuit network access ensures security, but datagrams can be used internally for simpler and hence faster switching. In addition, the network can be divided into zones[7], such that datagrams are used within a zone and virtual circuits are used between zones. An entire zone can be considered as one switch for network control purposes and hence less signalling and fewer network control actions are necessary. However, where the datagram headers needed for a zone addressing range are too large, the zone can be split and the virtual circuit boundaries can be used to reduce the necessary header sizes at the expense of increased signalling and processing requirements.

Network Control

One of the most significant problems in evolving toward an MSN in the presence of existing networks is in providing compatible call-control procedures for both existing networks and existing access protocols[12]. For example, interfaces for X.25 and Q.931 access protocols must be provided. The close adherence to the well documented principles of the open systems interconnection (OSI) is desirable if this is to be successfully accomplished.

As mentioned previously, connectionless protocols will be favoured within ATD network zones. Existing network-layer protocols have been primarily developed to work above connection-orientated link-layer protocols and some, such as X.25, have serious problems when operating over a connectionless link-layer (ISO† Document TC/97 SC/6 N4208). The development of a protocol, such as NC4 (ISO Document TC/97 SC/6 N3440), which can utilise a connectionless service should be a fundamental part of the MSN call-processing development.

Generic call-processing software must be written if the network provider is to be able to change the types of switches used or the services provided. The use of inflexible software over flexible hardware will negate any advantages and hence efforts should be made to create a software structure which provides complementary flexibility.

The use of switch architectures which allow logical addressing and fast signalling will allow the much greater distribution of network processing resources more economically

†ISO—International Standards Organisation

than in current telecommunications systems and hence should help the evolution to an intelligent network†. Research is being carried out into new software techniques and structures which can make use of this potential to reduce system complexity, increase system reliability and increase system processing power. It is hoped that new network features can then be provided through the addition of new modules and the independent modification of existing modules.

Selection of Switch Architectures

A large public MSN will provide the processing necessary for the simple and efficient use of the network and its services, perform a high degree of concentration for maximum economy and provide the high throughputs expected for future telecommunications. The criteria for selecting the switching equipment to be used in the network should be based on these requirements.

The concentration of traffic allows the resource sharing necessary for economic network operation. Wherever concentration is performed there is a possibility of equipment overload which can reduce the effective performance of the network. The network operator requires maximum effective throughput under overload conditions and this can only be achieved with good overload control. The Orwell protocol[10] provides overload control, and guarantees that high-priority services experience sufficiently low delays and no packet loss under all conditions, but still allows the remaining bandwidth to be used flexibly and efficiently by other services. Switching equipment in the local network and statistical-multiplexing equipment throughout the network must perform some concentration, and it would be preferable that all such equipment use the Orwell protocol to reduce the complexity of the network through the use of a single overload control mechanism.

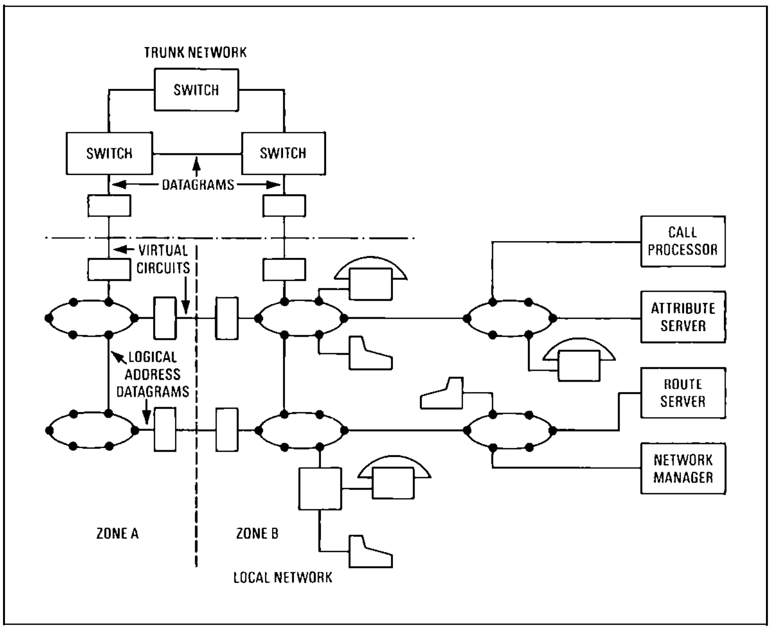
Most of the processing of the network is required at the network edges where user requests are interpreted and network actions initiated. For this reason, ring architectures, which use logical addressing, are favoured for switching at the level of the network hierarchy where network control modules are distributed. Orwell rings, which use logical addressing, can hence be used for both concentration and to simplify the distribution of processing equipment. Rings have the additional advantage of allowing the efficient broadcasting of information. It is expected that the rings will be physically small and that the access lines to a ring will be star-wired.

Trunk switches perform little concentration, but must meet very high throughput requirements. The Starlite architecture[7–9], which uses multistage interconnection network technology, offers higher throughputs at lower costs using current technology and so is preferred for trunk switching.

Envisaged ATD MSN Architecture

The proposed evolutionary paths end in a single ATD MSN, the architecture of which is shown in Figure 5. This architecture uses high-throughput switches in the trunk network and rings, which route by using logical addresses, in the local network. The Orwell protocol is used wherever overload is possible. Fast signalling within the local network allows the distribution of control resources such as call processors, network management units, routing databases and user-attribute databases. Flexibility is inherent in the architecture and hence the dimensions and the numbers of the various pieces of equipment can be determined as the service demand and equipment costs become apparent.

Figure 5
Envisaged ATD MSN architecture



Note: All links and concentration points will use the Orwell protocol for overload control

Charging during ATD Network Evolution

The regulation of public network providers, or the competitive market in which they exist, generally requires them to charge in proportion to the cost of providing the service. This should be easily accomplished because there is a great deal of flexibility in the charging schemes, or combinations of schemes, which can be used in an ATD MSN. For example, charges could be based on:

(*a*) packets sent,
(*b*) call holding time,

† In telecommunications literature, an 'intelligent' network is one which makes use of customer-related databases to provided enhanced services.

(*c*) quality of service required, or
(*d*) statistical estimate of the packets sent.

The actual charging schemes and rates can be determined when the amount of equipment necessary, its utilisation and its costs are known.

SUMMARY

The major points that have emerged from this study of ATD techniques and the possible evolutionary scenarios have been:

- There is general agreement that a single ATD MSN will have many benefits. A network which has the flexibility to carry all services and with reasonable efficiency is a sensible goal for network providers.
- To satisfy the service requirements of business, residential and mobile customers there are gradual evolutionary steps that can each be independently economically justified.
- The first stages of the evolution in the business sector are relatively simple and can provide greatly improved service. They offer an economic alternative to leased lines and more flexible service than digital cross connects.
- Care must be taken to ensure that the protocols used economically allow the provision of a sufficient range of services, which must include voice, data and video services.
- The switch architecture and protocol classes that can be used to construct an entire network have been identified. Evolution can consequently take place with an understanding of the final goal.
- The major effort needed before an ATD MSN can be achieved is the development of network control software, but as indicated previously, many economic benefits can be gained before this software need be developed.
- Whilst it is difficult to decide how an MSN should charge, it is technically feasible to charge in many different ways. There is no need to charge according to usage during the first two steps proposed for business evolution.

CONCLUSION

It appears that the evolution towards single public MSNs, which has been occurring though the introduction of digital equipment within public networks and the introduction of ATD LAN equipment on customers' premises, will be able to continue smoothly using ATD techniques. Since each step economically justifies itself, each network provider can determine the optimum rate of evolution and indeed the level of penetration according to the requirements of customers. The next step on the path to an ATD MSN is not a bold one.

ACKNOWLEDGEMENTS

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BIOGRAPHIES

Morgan Littlewood received a B.Eng. degree with first-class honours in Electrical and Electronic Engineering from Melbourne University in 1984. After graduating, he joined Telecom Australia Research Laboratories, where he was involved with the design of a Teletex/AUSTPACinterworking unit and investigated fast packet switch architectures. He is currently a consultant and involved with BT in the study of fast packet switch architectures and the evolution and control of multi-service networks.

Ian Gallagher joined BT as a student in 1969 and obtained a degree in Electronic Engineering from Sheffield University in 1973. He was involved with the development of TXE4A before transferring to the System X processor development group in 1978, where he was concerned with the design and testing of the CPU and memory area of the processor. He is currently the head of a group in the Network and Switching Technology Division investigating the requirements and design of the switch nodes of public multi-service networks and the ways in which they can be introduced.

John Adams received the degrees of B.Sc. and M.Sc. in mathematics from Leicester University in 1968 and 1970, respectively. He later returned to be awarded a Ph.D. in applied mathematics in 1979. After joining BT, he spent several years supervising the testing of digital exchange equipment, and in 1983 joined the Teletraffic Division at BT Research Laboratories to study the performance of high-speed LANs, where he developed the Orwell protocol. He is now in the Network and Switching Technology Division studying the applications of ATD in public networks.

The Digital Derived Services Network

G. J. ROBERTS, T.ENG., C.E.I., M.I.ELEC.I.E.†

UDC 654.02 : 621.395.345

The analogue derived services network was opened during 1985 to carry LinkLine 0800 and LinkLine 0345 traffic using Strowger switching principles. Premium service traffic using code 0898 was added at a later stage. This article explains how the network will be replaced with digital switches in a staged upgrade programme.

INTRODUCTION

The analogue derived services network[1] (ADSN) was introduced during 1985, by the then Trunk Services Division of British Telecom (BT) National Networks, in two stages. In April 1985, the network was opened on a trial basis, carrying LinkLine 0800 and LinkLine 0345 traffic, with a limited number of customers connected.

The LinkLine service allows calling customers to make calls at nil cost (Freephone) or local call charge fee, irrespective of the geographical location of the called customer. The call charge balance is billed to the called customer. The full public service was opened during July 1985.

Premium service traffic using code 0898 was introduced during January 1986 to serve an additional market sector. This service allows the calling customer to be connected to premium services, for example, Stock Market tips, whilst being charged at a rate in excess of the local call charge. The revenue collected is shared between BT and the Premium service customer.

A trial local 0800 automatic Freephone service was also introduced towards the end of 1986 to serve pilot catchment areas. Called customers receive calls via their standard public telephone line, but have the benefit of an 0800 number. As with Linkline 0800, the calling customer pays a nil charge for the call.

After the successful opening of the ADSN, which consisted of eight analogue switching nodes, it was decided that the network should be replaced with digital switching nodes, scheduled for completion in 1988, in keeping with BT's modernisation programme.

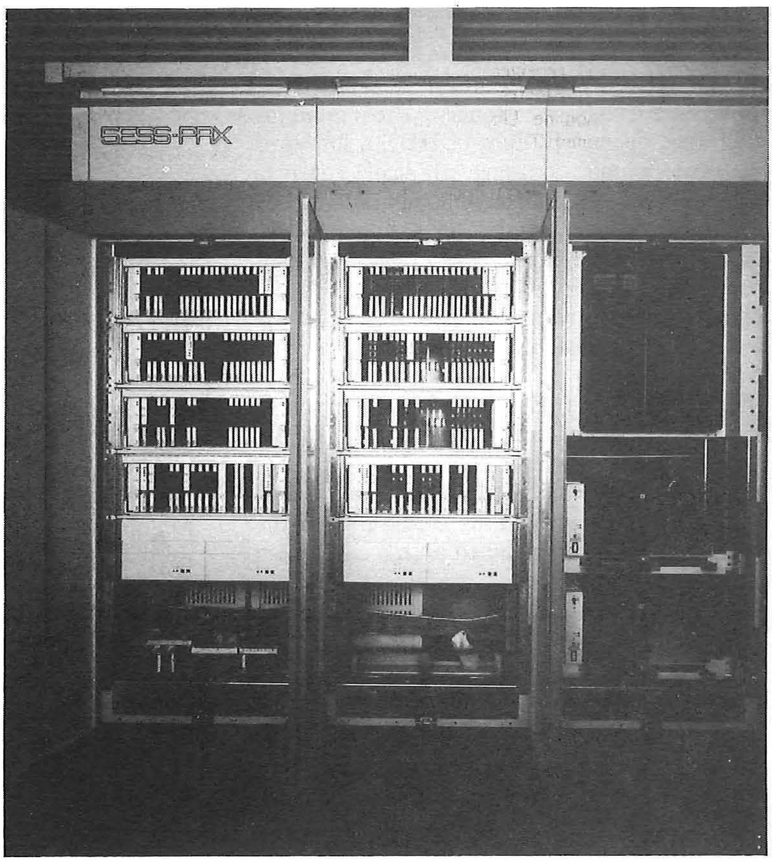
The digital switches will be supplied by AT&T and Philips Telecommunications (APT) UK Ltd. in a staged programme. Preliminary Phases 0 (3 exchanges) and 1 (6 exchanges) will involve the introduction of 9 digital sites, and a model in London, all equipped with 5ESS-PRX digital exchanges (Figure 1). Digital switching nodes will be supplied at each of the existing eight analogue sites with an additional unit in London. Later phases will include the introduction of centralised databases to increase flexibility and allow the introduction of new features and services. More information is given later in the article.

Initially, the digital derived services network (DDSN) will support the same LinkLine codes (0800 and 0345) and Premium service (0898) as the ADSN, with the benefit of enhanced network management and customer features. The DDSN will introduce enhanced customer facilities in the form of a centralised network database, improved customer charging/data collection capabilities, improved customer facilities and itemised billing.

† Trunk Network Operations, British Telecom UK Communications

A Glossary of Terms used in this article is included as an Appendix.

Figure 1
5ESS-PRX switch



This article explains the basic configuration of the DDSN and gives an insight into the architecture of the Phase 0 sites.

CALL ROUTING PRINCIPLES

Change-over Strategy

Interworking between the ADSN and the DDSN will be needed until the completion of Phases 0 and 1 of the digital programme. At this point, a gradual phased changeover of traffic and circuits from the analogue to the digital network will take place. The interworking and changeover strategy is explained later in the article. Consequently, call routing principles explained in this article are for the wholly DDSN environment.

Network Configurations

The DDSN will consist of eight fully interconnected digital derived service switching centres (DDSSCs) located at each of the existing eight ADSN sites—Cambridge, London, Birmingham, Leeds, Manchester, Guildford, Bristol and Glasgow—with an additional unit in London. Figure 2 shows a map of the locations.

Calling customers accessing the DDSN will do so via their own local exchange. The number dialled by the calling customer will be passed from the local exchange to the associated main switching unit (MSU). This MSU could be either analogue or digital. The MSU will examine the dialled digits and route the call to the DDSSC.

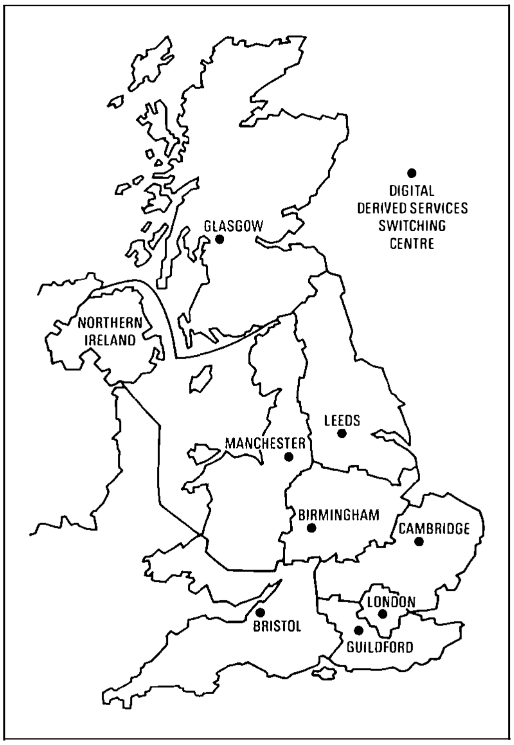


Figure 2—Nominal DDSSC catchment areas

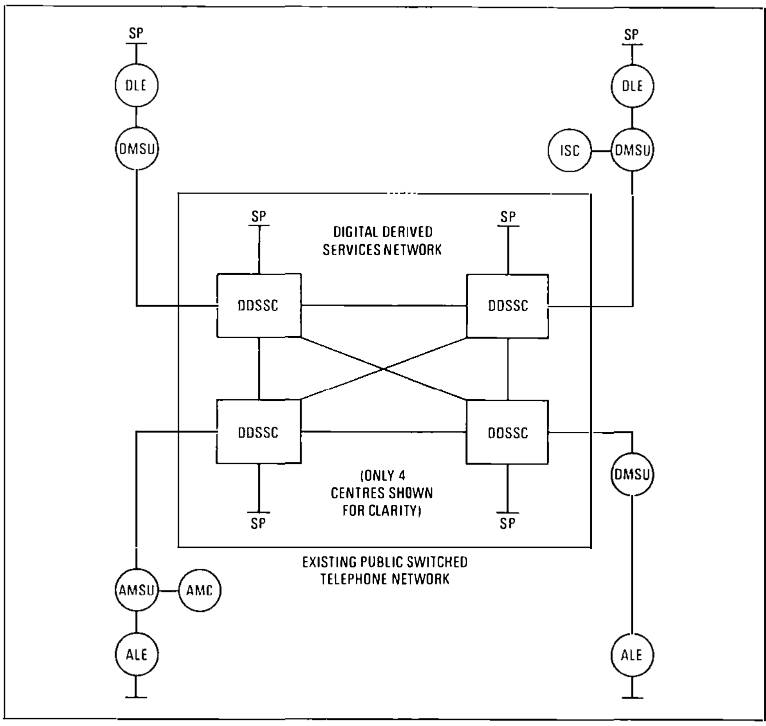


Figure 3 Network interconnection

Access to the DDSSC from the originating MSU will be via a dedicated route. The MSU will send the full number dialled by the caller, including the initial prefix of '0' if it is a digital unit, to the DDSSC where it is processed. Figure 3 shows the arrangement.

Number Examination

The home DDSSC will examine the number passed to it from the MSU and determine the DDSSC to which the called customer, known as the *service provider* (SP), is connected. This is achieved by reference to the individual site office dependent data (ODD), a software package which contains all call routing, charging and other miscellaneous parameters for the exchange. If the SP is connected to the home DDSSC, then the call will be connected directly via own-exchange switching stages. In circumstances where the SP is served by a distant DDSSC, then the call will be passed via a direct dedicated link from the home to the distant DDSSC, through the distant switch and then to the SP. All DDSSCs are fully interconnected.

SPs receiving high volumes of traffic will be connected directly to the DDSSC via dedicated links. It is planned to access customers carrying lower levels of traffic directly via their own public switched telephone network (PSTN) line on a local digital exchange multiple. It is proposed that this method of service will be slowly introduced in accordance with the analogue exchange modernisation programme. It will help to reduce the need for expensive hardware provision within the DDSSC, and thereby reduce overhead costs and permit a faster provision of service.

SWITCHING CENTRE EQUIPMENT

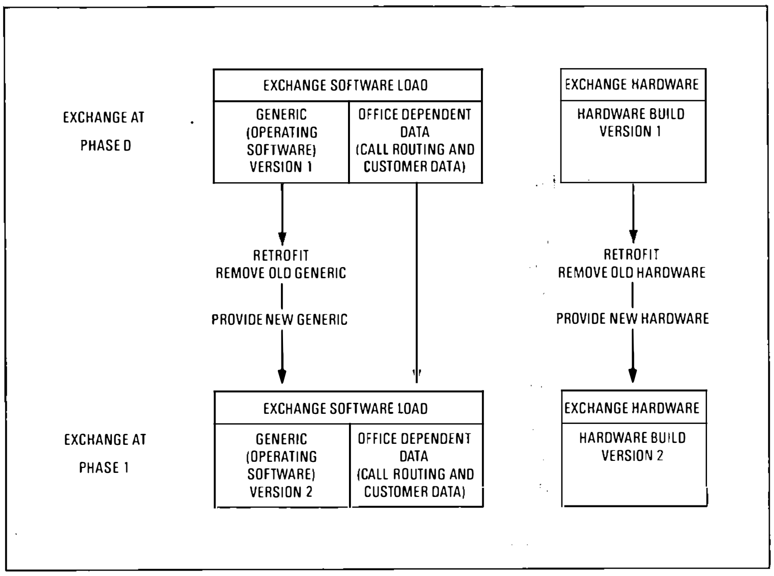
Network Improvements

The DDSN overlay network will ultimately provide improved transmission performance since the 2-wire switching element of the analogue call routing will be removed and replaced by digital techniques. Enhanced facilities for SPs will be provided in addition to those already available with the analogue network. BT will be able to improve control and monitoring of network performance when a centralised database is introduced in Phase 2.

The provision and phased introduction of the network (Phases 0–2) is taking place between 1985 and 1988, the evolution of which is outlined later in this article.

The digital units are readily enhanceable both in equipment quantities and facilities. This will enable upgrades and modifications by both BT and the supplier to be made quickly so that the needs of what is likely to be a rapidly changing environment can be met. System upgrades may involve hardware changes to complement software enhancements to the digital unit. The process of upgrading a switch, known as *retrofit*, to a new version of operating software, called the *generic*, can be implemented with minimal interference to service. The plan is to upgrade the three initial Phase 0 exchanges to Phase 1 site software status by the process of retrofit during 1987. Figure 4 shows the concept.

Figure 4
Retrofit concept



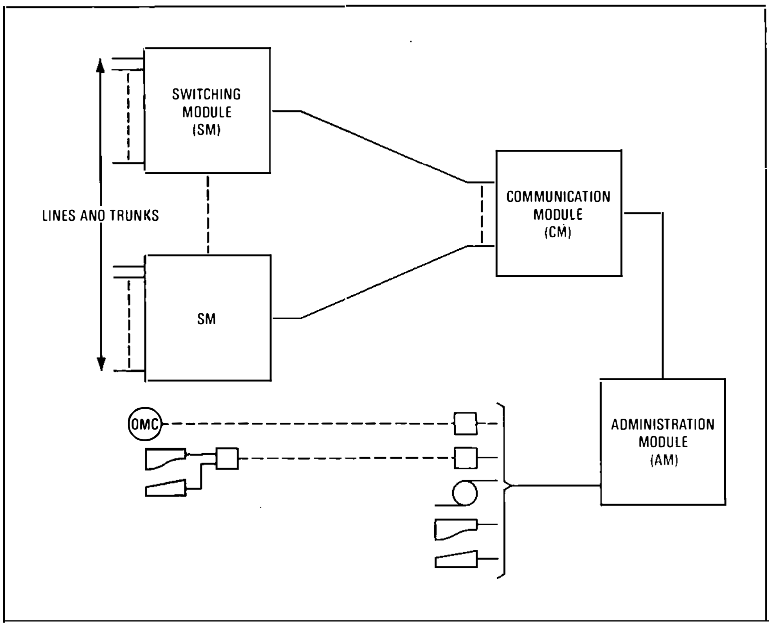


Figure 5—5ESS-PRX switch configuration

System Outline

The 5ESS-PRX uses a time-space-time switching structure based on a number of switching modules (SMs) interconnected by a communications module (CM). The SMs contain the time switches, and the CM a space switch. The modules are interconnected by optical-fibre links. An exchange will contain only a single CM and this is interconnected with an administration module (AM) via hard-wired links. The AM provides centralised control functions such as operations and maintenance support, inter-SM routing and time-slot allocation.

All SP lines, incoming and outgoing analogue trunks and 2 Mbit/s digital systems terminate on various types of peripheral units within the SM. Calls originating and terminating within the same SM are switched within the module, but calls originating and terminating on different SMs are connected via the CM.

The 5ESS-PRX uses the concept of distributed intelligence whereby most call-processing functions for ordinary straightforward calls are performed within the SM. A large percentage of call processing normally takes place in the SMs. The AM is only 'actively' used for processing calls between SMs and to other exchanges.

SYSTEM ARCHITECTURE

Figure 5 shows the basic configuration of the 5ESS-PRX with the interconnections between the switching, communications and administration modules. The various Phase 0 exchange modules and sub-units are described in more detail below. Additional hardware will be provided at Phase 1 exchanges, but since some sub-units are still subject to development they are not included. Major units within the system are duplicated for security.

Switching Module Peripheral Units

Switching module peripheral units are used to terminate links to SPs and to other exchanges, and to provide certain special exchange facilities. The peripheral units connect to the main body of the switching network by service groups. Peripheral units to be provided at Phase 0 DDSSCs are as follows:

Gated Diode Crosspoint Line Units

Gated diode crosspoint (GDX) line units (GDXLUs) provide terminations for conventional direct exchange line (DEL) type telephone lines; that is, providing digital-to-analogue conversion, battery feed, ringing current etc. GDXLUs could also be used for interfacing Signalling System AC No. 15E (SSAC15E) and SSAC15C signalling units to the exchange. A GDX is a matrix of semiconductor switches that can handle high voltages, such as ringing current and they are used as an analogue space switch to provide a subscribers' concentration stage. GDXLUs provided in DDSSCs will have a capacity of 256 SP lines with a concentration ratio of 4:1 giving 64 outlets into the exchange. See Figure 6.

Analogue Trunk Unit

The analogue trunk unit (ATU) provides a 2-wire loop-disconnect interface to the exchange. It can be used to provide direct dialling in (DDI) access to SPs via loop-disconnect circuits, pulse-code modulation (PCM) 2 Mbit/s time-slot 16 (TS16) (A1/1 and B1/1) or SSAC15A signalling units. ATUs contain analogue-to-digital conversion stages and signalling interfaces. An ATU can terminate up to 64 trunks with 64 outlets into the exchange to give a 1:1 concentration ratio.

Digital Line Trunk Unit

The digital line trunk unit (DLTU) is used for terminating up to 16 × 2·048 Mbit/s line systems. Each line system is terminated on a digital facility interface (DFI) within the DLTU. The DFI performs coding/decoding of the line bit stream for onward transmission into the exchange, and the insertion/extraction of timing/alignment information into and out of the line bit stream. There is no concentration stage on a DLTU; each (traffic) time-slot on each 2·048 Mbit/s has its own outlet into the exchange. See Figure 7.

Global Digital Services Unit

The global digital services unit (GDSU) does not terminate any external links onto the exchange, but is capable of providing the following internal exchange telephony services:

(*a*) conference call facility,
(*b*) transmission test facility for trunks and lines, and
(*c*) trunk and junction routining facilities.

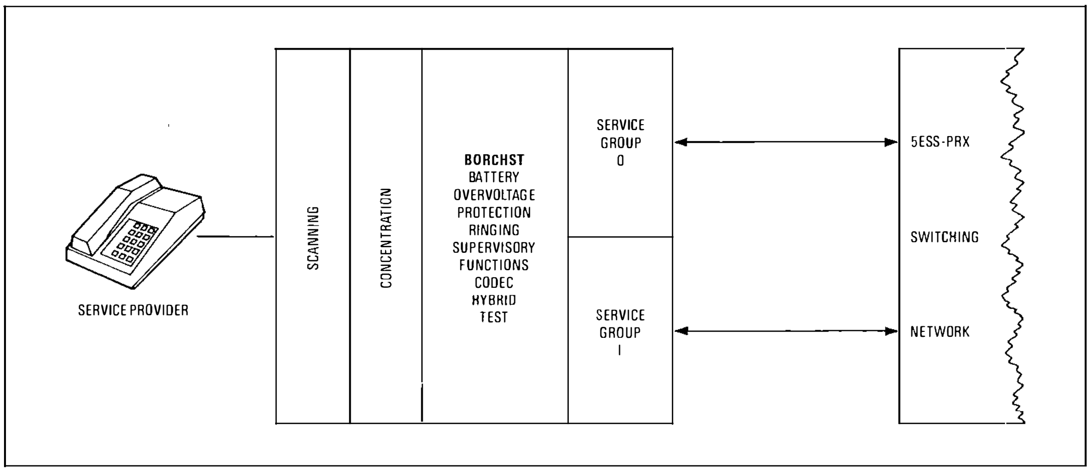


Figure 6
GDX line unit concentration

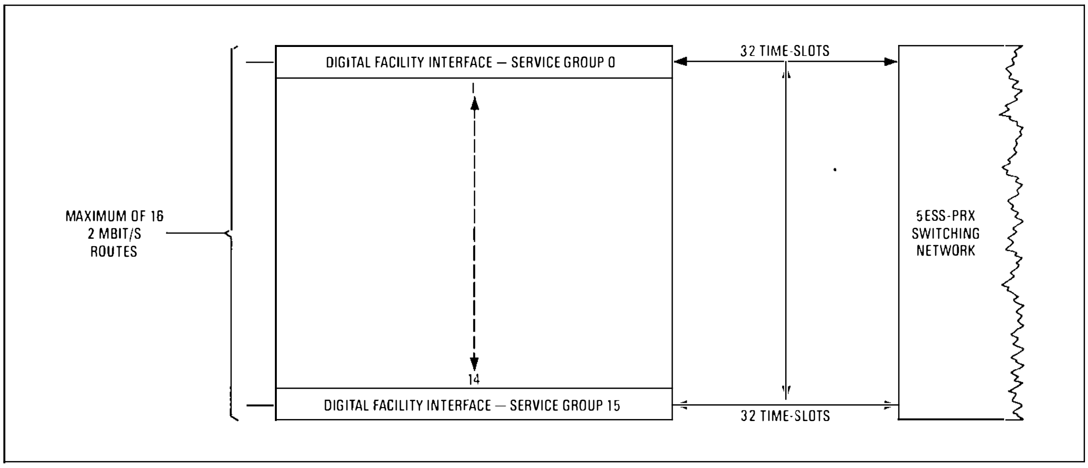
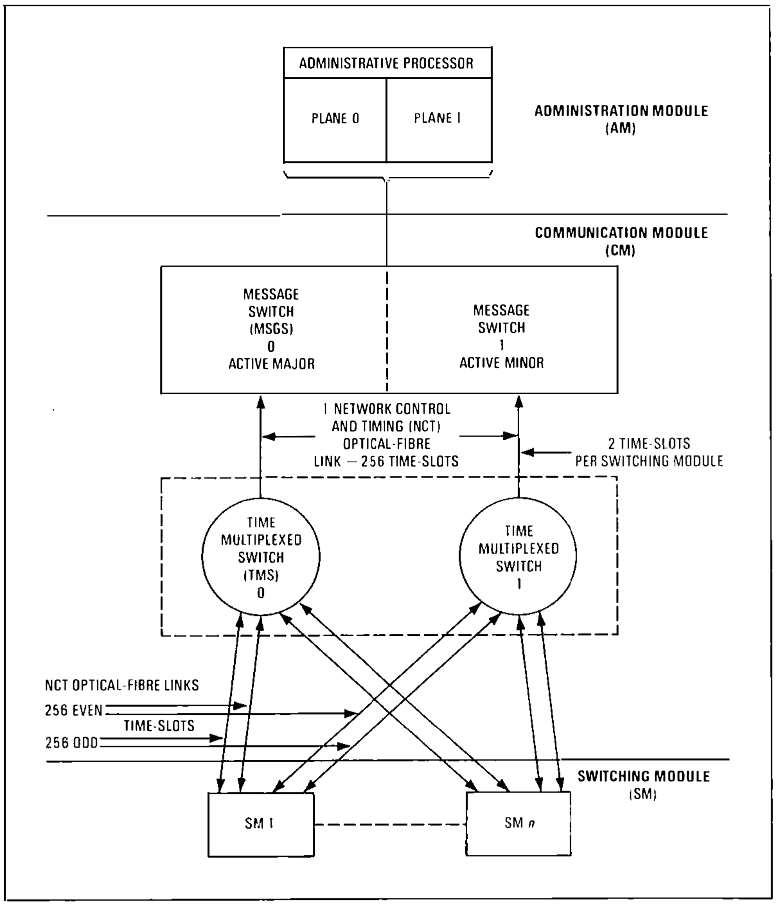


Figure 7
Digital line and trunk unit configuration

Module Metallic Service Unit

The module metallic service unit (MMSU) is a non-traffic unit used to provide a metallic test connection between a test console (trunk and line work station) and a selected analogue trunk or SP line.

Figure 8 Communication module units



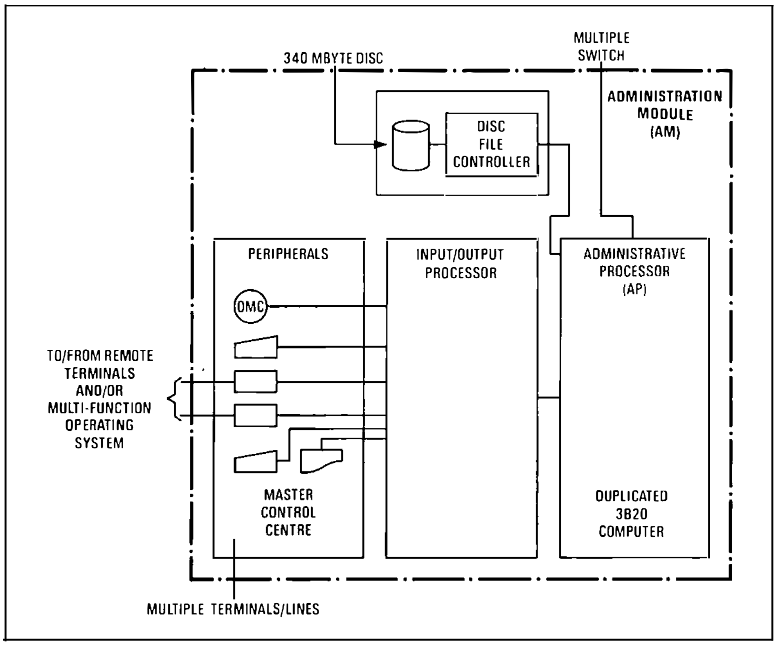


Figure 9—Administration module units

Communications Module (CM)

Figure 8 shows the interconnection of the various major units within the CM.

Time-Multiplexed Switch

The time-multiplexed switch (TMS) is a time-multiplexed space switch which provides physical paths for digital signals carrying data and control signals between SMs and control data between SMs and the AM. The TMS is duplicated and operates an active stand-by basis with the stand-by being updated with current information to minimise switchover delay. The TMS is interconnected with the message switch (MSGS) via network control and timing (NCT) links, which are used for:

(*a*) passing control information to SMs,
(*b*) an 8 kHz clock lead used for TMS timing, and
(*c*) control and diagnostic access link used for TMS control.

Network Control and Timing (NCT) Links

The network control and timing (NCT) links are optical-fibre links with each link consisting of two fibres (go and return) terminated with Berg connectors at each end. Each NCT link has 256 time-slots. On NCT links between SMs and TMSs, 255 time-slots are used for data and one time-slot for control purposes. On NCT links between the TMS and the MSGS, up to 252 time-slots are used (two per SM within the exchange), all for control purposes. The remaining four time-slots are used for signalling to the TMS.

Message Switch

The MSGS switches control, maintenance and administrative messages between the AM and SMs, between SMs, and between the AM and the TMS. It also provides system timing and synchronisation for the 5ESS-PRX exchange. The MSGS is a duplex unit which provides two separate paths of communication between the AM and the TMS. The message transfer load may therefore be shared between the two halves of the MSGS. If one half should fail, the other half is capable of handling the full load.

Administration Module (AM)

The administration module (AM) performs those functions that cannot be practically or economically performed by distributed processors. This includes global (exchange wide) fault detection, diagnostics and fault recovery, and global resource allocation such as allocation and release of TMS time-slots. The AM also processes administration data and provides access to external data links and disc storage. The AM may be considered to consist of three main units; Figure 9 shows the interconnection between them.

Administration Processor

The administration processor (AP) consists of a duplex 3B20D computer. The two sides of the AP work in an active/stand-by mode. In normal operation, the active AP has control and, at the same time, keeps the stand-by processor up-to-date. This allows switchover without loss of data.

Backing Storage

The AP interfaces with its backing storage via a duplicated disc file controller. The disc file controllers give access to up to eight disc drives, each having a capacity of 340 Mbyte. However, only drives 0 and 1 are initially being provided.

Input/Output Processor

The duplicated input/output processor interfaces the AP with various terminals and modem links. These include:

(*a*) video terminals and keyboards,
(*b*) receive-only printers,
(*c*) modems with a V.24 interface, and
(*d*) a 9600 baud synchronous link for connection to the operations and maintenance centre (OMC).

Video terminals and receive-only printers can be arranged to provide a master control centre (MCC), which will be the primary point for administering and maintaining the system. The MCC could be remotely sited at an OMC and serviced by a modem link.

Power Requirements

The 5ESS-PRX can operate from a wide variety of power plants which basically consist of AC mains to DC low-voltage rectification equipment and stand-by batteries. The DC voltage at the exchange SM, CM and AM cabinets may be from −46·25 to −52·5 V.

The DDSSC equipment can be powered either from the existing centralised power plant (CPP) within the building or from rack-mounted power plant (RMPP) equipment, which has been specially designed and built by the contractor AT&T and Philips Telecommunications for the 5ESS-PRX environment. Each RMPP consists of up to two modular cabinets and can produce a maximum of 200 A on full load.

SWITCHING CENTRE DESIGN CRITERIA

Traffic Levels

The initial order of hardware for the Phase 0 and 1 sites is based on a commercial marketing traffic forecast produced within BT. This forecast has been considered together with such aspects as SP signalling needs, network modernisation plans, analogue-to-digital changeover plans and switchblock architecture to determine the exact hardware configuration at each DDSSC. In consequence, each DDSSC will have a mandatory provision of one CM and one AM, but the number of SMs will vary from site to site.

Additionally, the units within each SM will vary on a site basis depending on SP termination requirements and the number of incoming/outgoing routes to other switching nodes. Each DDSSC will contain at least one GDSU and one MMSU.

The SM GDXLUs will be provided with a 4:1 concentration ratio which will allow for a maximum of 256 × 2-wire lines or SP circuits per unit.

Three categories of SP were identified when the ADSN was designed: low user (LU), medium user (MU) and high user (HU). Each user had a notional maximum number of circuits and this dictated where they were terminated within the analogue switch; that is, 2/10 or 11/- final selectors.

Similar rules will exist within the digital switch except that SPs with small circuit quantities will be terminated on line units whilst larger quantities may be connected by 2 Mbit/s TS16 highways direct to the switch.

Traffic Recording

Traffic recording facilities will be provided as an inherent part of the 5ESS-PRX switch generic. Typical parameters such as call attempts, route occupancy and calls lost due to congestion can be recorded, together with a vast range of 'peg counts' which totalise other data about the switch.

Commands to start, stop, schedule and output traffic recording data are input to the exchange via a man–machine interface point, namely a visual display unit (VDU) using man–machine language (MML) commands.

Distribution Frames

There are two types of interface frame associated with the 5ESS-PRX switch:

(*a*) analogue termination frame (ATF), and
(*b*) digital distribution frame (DDF).

All connections to and from the switch must pass through one of these two frames.

Analogue Termination Frame

The ATF is where all physical circuits to, from and associated with the switch are jumpered. The frame may be a free standing unit or several units bolted together to form a suite. It is double sided with capability for back-to-back jumpering.

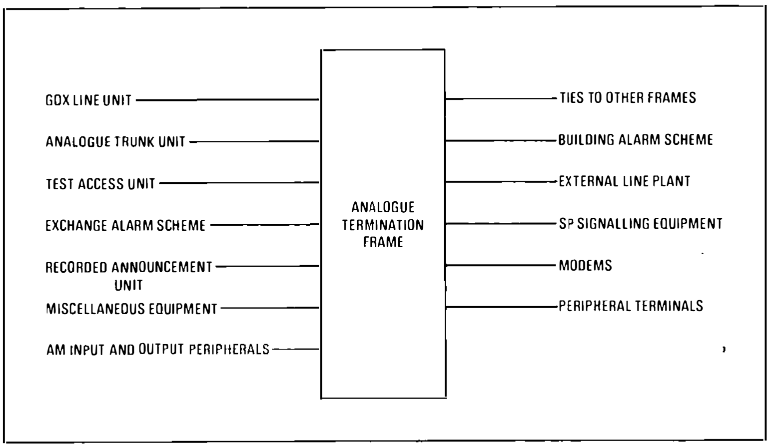
All terminations on the frame are via Connectors No. 237, which are 20-way insulation displacement connectors suitable for 10 × 2-wire circuits. A maximum of 176 connectors can be mounted on each side of a single frame unit.

Cross-connection to and from the switch and any building exchange alarm extension scheme is also via the ATF.

Tie cables are provided from the ATF to other frames within the building to permit maximum flexibility. Certain SP signalling system equipment can be terminated on the frame; that is, SSAC15A, SSAC15C and SSAC15E as required locally in order to make available urgently required space on other frames for use during the analogue-to-digital change-over period.

The ATF connector also serves as a test access point where interception testing can take place. Figure 10 shows typical frame connections.

Figure 10
Typical frame connections



GDX: Gated diode crosspoint AM: Administration module SP: Service provider

Digital Distribution Frame

The DDF is similar in concept to the ATF except that it is used as a test and patch point for all 2 Mbit/s paths to the switch. All connections to and from the frame are via coaxial cable using BT Connector No. 43. Coaxial tie cables to other parts of the building, including the repeater station, are provided from the DDF. All SM DLTU DFI ports are connected via the DDF.

Power Plant

As mentioned earlier, the DDSSC operates from a nominal −50 V DC supply. The source of this supply can be either the CPP or the specially designed RMPP.

Centralised Power Plant (CPP)

Some buildings housing DDSSCs have spare capacity within the CPP already provided, and so the opportunity has been taken to use this to power the switch.

In these situations, the switch will be provided with a power control and distribution frame cabinet(s) through which the supply from the CPP will be fused and distributed to the individual cabinets which compose the switch.

The power control and distribution frame houses fuses for each of its distribution supplies, together with associated alarm control and DC smoothing circuitry.

Rack-Mounted Power Plant (RMPP)

Each RMPP set consists of two cabinets:

(*a*) the main cabinet, which contains two battery sets, four rectifiers, alarm control equipment and module control equipment; and

(*b*) the secondary cabinet, which contains two battery sets and five rectifiers.

The main cabinet can work in the stand-alone mode without the secondary cabinet, but the secondary cabinet must be associated with a master for alarm and control purposes. Each pair of cabinets is designed to have a maximum nominal output of 10 kW (200 A at 50 V nominal).

SIGNALLING SYSTEMS

A limited range of signalling systems will be available at Phase 0 which will permit basic interworking with the existing analogue network. Additional signalling system capabilities are being developed for Phase 1 of the network.

Network Signalling System Phase 0

All MSUs will be connected to their home DDSSC, and all DDSSCs fully interconnected, via a PCM 2 Mbit/s TS16 signalling link. SPs can be accessed from DDSSCs by either DDI principles or DEL signalling conditions; for example, AC ringing/loop answering/loop calling/earth calling. If SPs are located within 2-wire unamplified range, then they can be directly connected to 2-wire subscriber line interfaces in the DDSSC. The subscriber line interface is the 2-wire interface within the SM GDXLU.

In situations where the DEL SP is outside the DDSSC unamplified signalling range, then SSAC15C, SSAC15E or PCM multiplex (using L7/1 and K7/1 signalling cards) can be used. If the SP requires earth calling conditions to interface with equipment, then SSAC15E or L7/K7 must be used. HU SPs requiring DDI can be served by PCM 2 Mbit/s TS16 signalling via the SM DFI in the DDSSC, terminating on a signalling unit B1/1 at the SPs' premises. MU and LU SPs requiring DDI, located outside unamplified range, use SSAC15A signalling which is connected to a 2-wire port on the SM ATU within the DDSSC.

Network Signalling Systems Phase 1

All DDSSCs will be interconnected to each other and associated digital main switching units (DMSUs) by using common-channel Signalling System CCITT† No. 7 (BT), which is capable of providing signalling facilities for a number of telecommunications services in separate or integrated networks.

† CCITT—International Telegraph and Telephone Consultative Committee

Information generated by users is passed between signalling points (that is, DDSSCs) over common signalling links in labelled user part messages. The message transfer part (MTP) is a group of functions responsible for accepting, routing and delivering data between signalling points. The MTP acts as a transparent carrier for user part message information. It is concerned only with that information required to identify the correct signalling point.

The user part messages are generated by the national user part, which contains the functions required to convert signals into signalling information fields suitable for transmission by the MTP and vice versa. The national user part also contains the protocol which determines the selection and sequence of signals to be exchanged during call control and the functions required to exchange signalling control information with the MTP.

In addition to the SP signalling systems mentioned for Phase 0 sites, Phase 1 will support SSAC15A and SSAC15E directly as 4-wire terminations without the need for a main exchange-end analogue signalling unit. The 4-wire switch termination will be given by a one-voice-frequency converter unit which is being developed for Phase 1 implementation. SSAC15A provides DDI to SPs that are outside 2-wire unamplified signalling range. SSAC15E provides earth calling and disconnect clear facilities to those SPs requiring amplified 4-wire circuits to the DDSSC.

Additionally, HU SPs can be connected to the DDSSC via a 2 Mbit/s SM DFI with TS16 signalling. PCM K7/1 signalling units would be used at the SP end if AC ringing with loop/earth calling is required. PCM B1/1 signalling unit will continue to be used for SPs requiring DDI facilities.

TRANSMISSION STANDARDS

Analogue Transmission Plan

The ADSN was designed to operate within the 1960 analogue transmission plan[2], which allowed for a maximum end-to-end (telephone-to-telephone) loss of 42·5 dB. This maximum end-to-end loss meant that most SPs required connection to their home ADSSC via dedicated links with a maximum loss of 3 dB.

Digital Transmission Plan

The wholly digital environment represents the optimum situation whereby the maximum loss on a call between the point of entry and exit from the digital network, that is, at the 2-wire point, will not exceed 7 dB.

SP lines have a maximum loss of 10 dB at 1600 Hz. This results in a maximum end-to-end call loss of 27 dB. Calls which are routed to a SP via a digital local exchange should not experience a higher loss provided that the call routing does not encounter any analogue switching points.

Calls which are passed through an SP's own PBX can experience a higher end-to-end loss because of the nature of the switching system used. Figure 11 shows the network transmission plan.

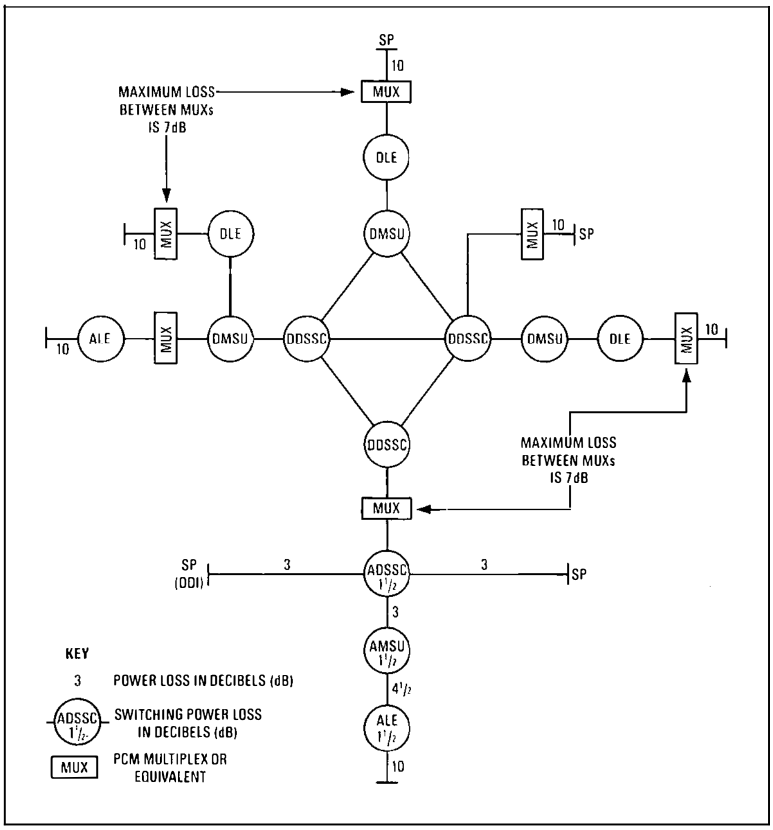


Figure 11
Transmission plan

Analogue/Digital Interworking Strategy

The transition from the 1960 analogue transmission plan standard to the digital standard will result in a mixed network environment during the progressive change-over period. During this period, the maximum end-to-end loss which will be encountered on any call should not exceed 42·5 dB.

SP circuits will continue to be provided to the analogue network transmission standards; that is, maximum link loss of 3 dB until all ADSSCs have been removed from the network.

The early introduction of DDSSCs, which will interwork with ADSSCs until full digital overlay/replacement is achieved, will result in analogue/digital interfaces with their inherent degradation of transmission being present for a short time.

NETWORK NUMBERING

National Number Group Codes

Six national number group (NNG) codes have been reserved for service on the derived services network (DSN) (see Table 1).

The format of the SP numbers will gener-

TABLE 1

National Number Group Codes for the DSN

National Number Group	Service	Charge to Caller
800	Freephone	Free
345	Economyphone	Local
891	Premium	a
894	Premium	b1
897	Premium	b
898	Premium	d

ally be the same as for the analogue network. SP numbers will be nine digits in length, excluding the prefix '0', and commence with the appropriate NNG code. The use of variable length numbers is under investigation.

The 5ESS-PRX uses a code conversion format of translation and converts all valid SP numbers to a 10-digit service provider network code (SPNC). Code conversion tables are part of the ODD information held on the switch database at each DDSSC.

The first three digits (ABC) of the SPNC identify the network, that is, the DSN, and the next three digits (DEF) identify the network node and the 10 000-line number block; that is, DDSSC and number block. The final four digits (GHJK) identify the actual SP (station code) on the terminating DDSSC within a specified 10 000-line number group. (See Figure 12.)

A DDSSC may have more than one DEF combination allocated to it since each combination identifies a 10 000-line station code group. Typically, the same DE digits are used with varying F digits. Each ADSSC also has a dedicated DE digit combination.

Once the originating DDSSC has converted the SP number to the SPNC, it utilises the ABCDE digit combination to select the required route to a distant DSSC. In the case of a distant DDSSC, on receipt of the ABCDE digits, it determines whether the call is to be terminated or tandem routed to a further ADSSC.

In circumstances where the ABCDE digit combination identifies a distant or the co-located ADSSC, then, from the F digit onwards, the code length varies between 1 and 12 digits to align with the analogue routing required to access the specific SP (see Figure 13). This will result in any call to an SP served by an ADSSC having the number fully examined for routing purposes within the DDSN.

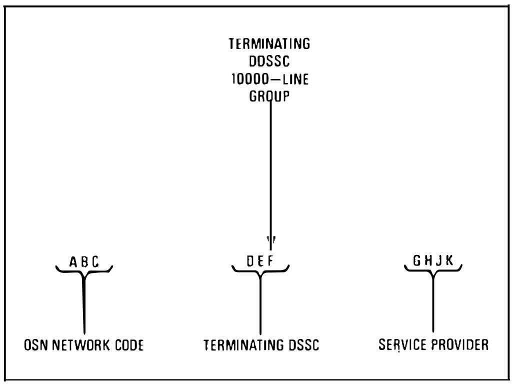


Figure 12
Typical DDSSC SPNC digits

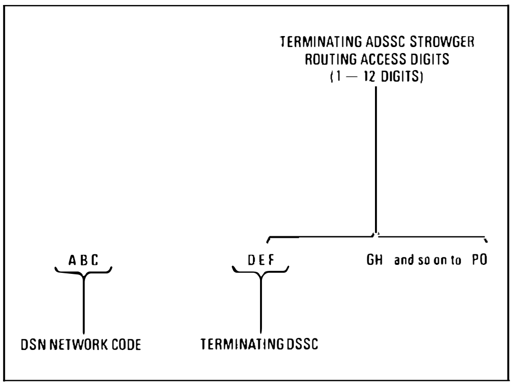


Figure 13
Typical SPNC digits for ADSN interworking

Universal Access Numbers

An HU SP can have several individual answer points, up to one per DMSU catchment area, all associated with the same number. The digits dialled to access the appropriate SP answer point are known as a *universal access number* (UAN). This is achieved by examining the HU number at the home DDSSC, by the site dependent ODD, and routing the caller to the SP answer point.

An SP may wish to have two regional answer points, situated at London and Manchester, both served by a UAN; for example, 345 110110. Calling customers served by the DDSSC at Bristol, Cambridge, London and Guildford can be routed to the London answer point, whilst those served by Birmingham, Glasgow, Leeds and Manchester can be routed to the Manchester answer point.

DDI Access

As with the ADSN, all DDI SPs will be defined as HUs. They will have 9-digit numbers excluding the initial '0' and be arranged so that the FGHJ, GHJ or HJ digits are repeated depending on whether the SP has a 10 000-, 1000- or 100-line number block, respectively.

MAIN NETWORK SWITCHING UNIT REQUIREMENTS

Each analogue main switching unit (AMSU) and DMSU will reside within a DDSSC catchment area and will have access via a single link main network route to its home DDSSC.

DMSU

Each DMSU will have a minimum of one 2 Mbit/s TS16 route consisting of 30 circuits to its home DDSSC. As mentioned earlier, the DMSU sends the full 9-digit number plus the prefix '0' to the home DDSSC for processing.

AMSU

The AMSU access will be from selector levels or, in the case of crossbar units, from router switch B, office route switch or junction route switch outlets.

Strowger Route Configuration

Each AMSU will have two access points from its switchblock to the DDSSC route. These access points, known as *main* and *peak routes*, are made up of circuits which form the access to the DDSSC. In the case of a Strowger unit having 30 circuits to its DDSSC, the main route will consist of 20 circuits for the specific main route usage and the peak route will consist of 10 circuits shared with the main route.

In order to facilitate the above, it is necessary to have two levels allocated at each Strowger unit, one for the main and one for the peak. The main level will have access to all circuits on the route to the DDSSC. The second level allocated to the peak route will be graded with the specified number of outlets tied to the 'back end' of the main level.

Crossbar Route Configuration

In crossbar units, it is not possible to directly tee outlets and therefore the configuration of the route differs from the Strowger variant.

In the crossbar situation, the main route is allocated a specified number of circuits to the DDSSC which are connected to discrete switch outlets in the crossbar exchange. The peak route is allocated its own number of outlets in a similar fashion to the main. The main route is then allowed to 'alternative route' to the peak route, and thus allow the main to access all circuits on the route to the DDSSC.

Derived Services Network Route Access Control Facility

The routing configurations described above allow implementation of the DSN route access control facility. If a particular SP generates very high levels of traffic, it may cause access problems to all other SPs.

In consequence, it is necessary to try and restrict this type of traffic to improve network resilience. By expanding the appropriate NNG code (800, 345 or 898) to 5th-digit expansion at the MSU, it is possible to route specific ABCDE digit combinations to either the main or peak access points.

Thus, if particular SP traffic is causing congestion or other access problems to all other traffic from a particular unit, then the ABCDE code for that SP is translated to route via the peak access point to allow an improved grade of service to those codes still routing via the main access point.

3–6 Minute Timeout at AMSUs

On a Freephone ADSN call, no supervisory answer condition is returned to the originating register-translator unit. Therefore, the *called subscriber answer* condition, even though the call has been successful, would not reach the originating AMSU switching equipment, and it would time out and release after 3–6 minutes. It has been necessary to modify all AMSUs such that the time-out facility for unanswered calls is removed.

SERVICE PROVIDER AND NETWORK FACILITIES

Each directly connected non-DDI SP can terminate on a GDXLU at Phase 0 or a GDXLU/integrated services line unit at Phase 1 within the DDSSC. Initially, the SPs will be configured as OUTGOING SERVICE DENIED. On lifting the receiver, an SP connected to a DDSSC is connected to a confidence tone (inverted ringing tone), confirming continuity of the connection to the DDSSC.

Network Facilities

The PSTN, and to a lesser extent the ADSN, offer various customer facilities. The DDSN will offer enhanced facilities to that already provided by the ADSN. These facilities will undergo major enhancement during the Phase 0 to Phase 1 upgrade process. Typical SP facilities at Phase 1 will be:

(*a*) *Call Diversion* Calls are diverted to an alternative destination prior to answer. This may be applied to all calls, on receipt of busy tone, or when there is no reply after a time period which can be specified by the SP. SPs can activate and deactivate the diversion from their own premises by using a suitable telephone instrument (multi-frequency type). SP specified numbers for diversion, up to a maximum of 32, can be programmed into the switch by BT so that the SP can activate or deactivate the service as required.

(*b*) *Call Queueing* Calls are held at the DDSSC when all lines to a SP are busy waiting for one to become available. Calls are connected on a first-in/first-out basis. BT is able to specify, based on a SP request, a limit to the number of calls which can be queued at any one time for a particular group of lines. SPs can choose for callers to hear a standard announcement and then ringing tone until the call is answered, or ringing tone for the complete period. Call charging starts when the call is answered.

(*c*) *Night Services*

(*i*) *Night Busying* This facility allows an SP to limit the number of calls received by busying out a block of lines. The SP decides which lines are to be busied so that BT can program the DDSSC equipment in advance. SPs can then activate and deactivate the service facility from their own premises by using a suitable telephone (multi-frequency type).

(*ii*) *Night Interception* This facility allows calls to be intercepted and transferred to a BT operator. The SP decides in advance which lines are to be intercepted. SPs can then activate and deactivate the service facility from their own premises by using a suitable telephone (multi-frequency type).

(*iii*) *Night Service Number* A special number is allocated to an SP, which will hunt for a free line in a sub-group of the main group. It overrides any active night interception or busying on those lines.

(*iv*) *Termination Bypass Number* A special number is allocated to the SP which is routed to one particular line in the main group and overrides any active interception or diversion on that line.

(*d*) *Dual Parenting* The SP can define two possible destinations, together with the desired percentage split of traffic, for calls to be answered from each DDSSC.

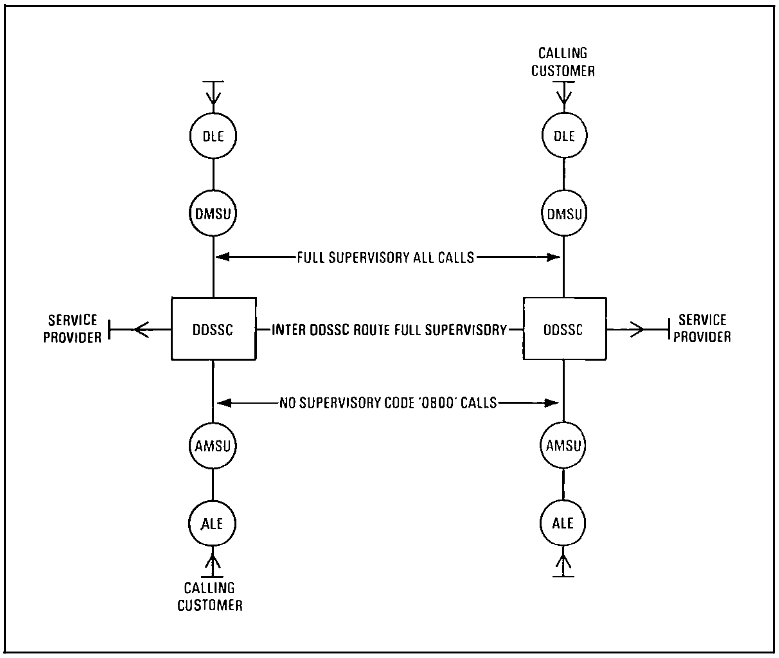
The DDSN will also offer enhanced call routing facilities in that it will be possible to associate any existing customer's telephone line with any DSN number, and thereby allow customers to receive PSTN traffic and DSN traffic at the same answer point. This facility will reduce the cost of service provision and increase the speed by which service can be given to an SP. The full implementation of this facility depends on the modernisation of the PSTN.

Improved SP billing information will be available and this is mentioned in the next section.

Testing Arrangements

Each DDSSC will have an associated trunk line and works station (TLWS) and a test access unit (TAU) to enable access to SPs' lines and trunks for testing purposes. The TLWS will be a function of the MCC, which will be sited at the DDSSC local control point. A supplementary trunk line and work station (STLWS) will be provided at the network management centre.

Figure 14
Principles of call charging



CALL CHARGING AND BILLING

Call charging can be divided into two main areas:

(*a*) calling customer charging, and
(*b*) service provider charging.

Calling Customer Charging

Analogue Principles

Normal Strowger call answer supervisory conditions, for example, line polarity reversal on answer, will be used at any analogue interface point to the DDSN, except in the case of AMSU-originated calls to the DDSN where charging must be inhibited to the caller on 0800 traffic.

If the call is free to the calling customer, and it originates via an AMSU parented on the DDSSC, then the home DDSSC suppresses repetition of the answering supervisory signal to the AMSU, the 3–6 minute time-out facility having been removed at the AMSU. The calling customer is not charged for the call.

If the call requires charging at the calling customer end, Economyphone or Premium service traffic, then the answering supervisory signal is repeated to the originating AMSU from the home DDSSC. The AMSU then applies the appropriate metering rate to the caller as determined by the register-translator at the unit.

Digital Principles

PCM 2 Mbit/s TS16 answer supervisory conditions will be used between all nodes employing 2 Mbit/s routes and the answer signal will always be provided as in the PSTN.

If the call originates via a DMSU parented on a DDSSC, then the home DDSSC repeats the answering supervisory signal to the originating DMSU. The digital network then inhibits, as necessary, charging from being passed onto the calling customer. Figure 14 shows the basic principles of call charging.

Service Provider Charging

Phase 0

Call logging facilities are provided as part of the 5ESS-PRX and, unlike the ADSSCs, no additional call logging equipment is required. Call record information produced by the DDSSC is stored on magnetic tape. This tape is sent directly from the DDSSC to the call record processing system. These call records will contain the same data as those produced by the ADSSCs to minimise the initial impact of the introduction of the DDSSCs on the charging and billing of calls.

Phase 1

The advent of new customer services such as call diversion and night interception in 1987, with a significant enhancement later in 1988 involving the introduction of centralised databases to provide customer-controlled call routing facilities, requires several new types of call record to be produced by the DDSSC. The new call records use a time stamp principle to record events rather than recording chargeable duration. Call durations are calculated off line.

The DDSSC will continue to produce call records for basic calls as previously, but, where a call uses supplementary services, such as diversion, information relating to the use of the service will be included in the call record. This will enable supplementary service usage to be charged for on a per call basis.

These new call records will be transferred from the DDSSCs by tape as before or via private circuits using secure X.25 protocols to a data collector and enhanced call raising system. This system will have the ability to poll for data and store it prior to processing, a function performed previously on the ADSN by the data collection centre at Oswestry.

DDSSCs have sufficient capacity to store call logging data for up to three days, in case a network or system failure prevents the collection of data. As additional security, the facility to output call records onto magnetic tape will be retained permanently.

The call raising system is being developed to cater for the new call supplementary service record format. This will enable the system to price, not just call transport charges, but also for the use of the supplementary services. Once all records have been priced and sorted according to billing number, they will be dispatched on tape to the national billing system or Customer Services System (CSS).

OPERATION AND MAINTENANCE FACILITIES

All switch maintenance functions can be performed from local terminals. They can also be performed from remote terminals. An allocation of specific tasks to specific terminals is possible to increase the effectiveness of maintenance personnel. Data links will be provided to OMCs.

Master Control Centre (MCC)

The MCC displays system status and alarm information and provides system control functions. Together with the exchange alarms, the MCC offers access to a complete set of switch and terminal maintenance features. The MCC provides trunk and line maintenance access facilities.

The MCC consists of a colour VDU with keyboard, a printer, a press-button telephone and a TAU. The top two lines of the screen of the VDU are reserved for continuous display of the system status and alarm conditions. Control and display pages can be selected for specific functions. Each page shows the operation condition and a menu of possible input commands for a particular subsystem. A command is executed by entering the command number displayed on the screen. It is also possible to enter MML messages.

Alarms

Fault conditions are brought to the attention of maintenance personnel in a variety of ways, either audibly or visual. Three alarm levels are provided:

(*a*) critical,
(*b*) major, and
(*c*) minor.

Trunk and Line Maintenance

The maintenance features included in the 5ESS-PRX are based on CCITT and CEPT† work on test and measurement.

All trunk and line features can be implemented from either the MCC in the TLWS mode or the optional STLWS.

Trunk and Line Works Station

The TLWS is arranged to control the following functions:

(*a*) testing SP lines,
(*b*) testing trunks,
(*c*) transmission testing of trunks to other DDSSCs,
(*d*) removing trunks and lines from service, and
(*e*) restoring trunks and lines to service.

Any function is initiated by an input command entered at the TLWS keyboard. After the built-in 5ESS-PRX diagnostic facilities have completed their tests, the results are displayed on the VDU and the printer. Access to lines can also be gained via the TAU utilising the MMSU located in the SM.

Automatic Progression Testing

Automatic progression testing periodically performs routines of all outgoing trunks (typically, once a day). When a trunk fails a test, an output message is printed at the TLWS, and the trunk is taken out of service. This enhanced facility is available only on inter-DDSSC trunk routes.

† CEPT—Conference of European Post and Telecommunications Administrations

Database Administration

The 5ESS-PRX stores exchange data (ODD) in a relation database. Data change and retrieval requests can be made from the MCC or an optional recent-change and verify (RC/V) terminal.

Recent-Change and Verify Terminal

The optional RC/V terminal, consisting of a VDU and a printer, serves as a device for adding, changing, deleting and retrieving exchange data.

Recent-Change and Verify Procedures

The MCC and RC/V terminal use a two-stage menu selection with forms for recent change (adding, changing and deleting data) and verify (retrieving data) requests. Two examples of the available forms are the telephone number form, and the trunk group form. The selected forms which identify all permissible data items, subscriber facilities and options, are displayed on the VDU. To ensure that any additions or alterations are error free the system performs range, syntax and integrity checks when the data is entered.

INTERWORKING AND CHANGE-OVER STRATEGY

The connection of SPs to, and the utilisation of, the three Phase 0 DDSSCs will depend upon the exhaustion of ADSSC switching capacity and the needs of the individual customer. This area is constantly under review and plans may be revised according to operational requirements.

Change-over Principles

Ideally, change-over from the ADSN to the DDSN will begin only when the full provision of DDSSCs and digital line plant is available. This will be achieved at Phase 1 of the modernisation programme. Route changeover to the digital units will be carried out in two stages. Firstly, a bothway interworking PCM route will be provided between the DDSSCs and the co-located ADSSC. Secondly, routes from exchanges parented on ADSSCs will be transferred onto their respective DDSSCs, interfacing 2 Mbit/s at the DDSSC. On completion of these stages, all ADSSCs will remain fully interconnected.

Network Interworking

After the route changeover phase, with all DDSSCs interconnected, traffic destined for SPs parented on ADSSCs will pass over the DDSN to locate the required ADSSC serving the SP. In this case, the required ADSSC is accessed over the DDSSC–ADSSC interworking route.

The final stage of the changeover will require transferring SPs from ADSSCs onto their parented DDSSCs. HU SPs will be transferred as required. However, MUs and LUs may be transferred in blocks of DEF digits to simplify digit decode work at the respective DDSSCs.

NETWORK EVOLUTION

The DSN is being progressively introduced into the BT network, commencing with the analogue network which opened during 1985. It is intended that the DSN should be enhanced both in hardware and facilities in keeping with BT's modernisation programme.

Six Phases (0–5) have been identified as milestones related to the modernisation of the DSN. These phases relate to a planned programme of activities which will enable BT to provide additional facilities whilst progressively enhancing the network. Each phase will be accepted from the contractor after rigorous joint testing prior to introduction into public service.

Phase 0

The Phase 0 sites were accepted from the contractor during November 1986. The sites are functionally for extended network testing (Network Acceptance and Proving Phase 0 (NAPP0)), maintenance familiarisation, and, with the exception of the model at Baynard House, for unplanned growth. The NAPP0 trial commenced shortly after the three sites were accepted. The early London unit will also be used as a PSTN gateway exchange to the 5ESS Centrex exchange (a United States domestic version of the 5ESS switch), which is being provided in the City of London. Consideration is also being given to the introduction of a local 0800 service, similar to that under trial on the analogue network, switched by the Phase 0 sites.

Phase 1

It is planned to bring the Phase 1 sites into service towards the end of 1987. Phase 1 will involve the extension of the three operational Phase 0 sites and the introduction of the remaining six sites.

Connections between the DDSSCs and links to DMSUs will utilise Signalling System CCITT No. 7 (BT). The Phase 0 sites will undergo retrofit to enhance them to the same standard and capability as the Phase 1 sites during 1987.

Phase 2/3

Phases 2 and 3 have now been combined so that the enhancements planned for Phase 3 will now be introduced under Phase 2. It is planned to introduce Phase 2 during late-1988.

Phase 2 will involve the introduction of a database at Oswestry, known as *multi-function operating system* (MFOS), to provide a network operations and maintenance centre in addition to the introduction of databases at London and Manchester, known as *network control points* (NCP). The NCPs will interwork with the user support system (USS) which will be provided at Oswestry.

Network Control Point (NCP)

Each NCP will normally handle 50% of the total NCP traffic but would be capable of handling 100% of the load should the other NCP fail.

The NCPs will provide a centralised database for holding routing, translations and other call handling information for a low percentage of DDSN traffic. This traffic will be destined for certain designated SPs known as *advanced feature SPs* (AFSPs). DDSSCs will still handle the majority of the traffic as in Phase 1 but will communicate with the NCP for AFSP-destined traffic.

The NCP will enable BT to keep an up-to-date record of information on current state of call counts and SP lines in service for the AFSP, and will allow the rapid alteration of AFSP routing information in response to commercial and network requirements.

Each NCP will be located in an exchange environment similar to that used for the DDSSCs. It will be linked with its host DDSSC (London or Manchester) and the other NCP via a 56 kbit/s data link using common-channel signalling. The NCPs will also be connected to the USS and MFOS via 9·6 kbit/s data links.

User Support System (USS)

The USS provides a user friendly interface between BT and the NCP. It supports an operations system for service provision, non-call-related billing data and other related functions.

USS hardware consists of three processor units with associated disc drive units and terminals/consoles housed in a computer room environment. BT will access the USS via a permanent V.24 data links. The data links between the USS and the NCP will operate at 9·6 kbit/s.

Multi-Function Operating System (MFOS)

The MFOS will give on-line access to the 5ESS-PRX switch for alarm processing, switch maintenance and switch database administration purposes. This will also include modification to exchange dependent routing data as required.

The MFOS will be sited at Oswestry in an office environment and it will be linked to each DDSSC and NCP via 9·6 kbit/s data links.

Network Services Complex

Two network services complexes (NSCs) will be provided under Phase 3. They will be sited at London and Manchester in a similar arrangement to the NCPs. The NSCs will provide customised announcements and interactive call facilities, using Signalling System Multi-Frequency No. 4, for calls destined for AFSPs.

The NSCs will be connected to their host DDSSCs via 2 Mbit/s speech links and a 64 kbit/s signalling link. Access from other DDSSCs will be obtained via the NSC host DSSC. The NSC will be connected to the MFOS via 1·2 kbit/s data links using the V.24 asynchronous protocol.

Additional enhancements are planned for the databases mentioned (NCP/MFOS/USS/NSC) which will allow the provision of extra facilities:

(*a*) To allow certain AFSPs to access the USS, using V.24 protocol, over a dial up/dial back facility via the PSTN. This facility will, for example, enable the SP:

(*i*) to alter the routing parameters of calls incoming to the SP without the assistance of BT, for example, if the SP has more than one location, in order to redistribute the calls between those locations; and

(*ii*) to start and cease service incoming to the SP.

(*b*) The barring of calls incoming to SPs depending upon calling line identity or partial calling line identity.

(*c*) The provision of standard and customised call announcements for calls destined for busy, out of hours or otherwise unavailable AFSPs. Also, in response to announcements, to provide an interactive call facility between the system and the calling customer, using a suitable telephone (multi-frequency type), to enable the caller to dynamically communicate in order to obtain access to various supplementary services provided by the SP.

'Call gapping' will be introduced as part of Phase 2. This is a facility which will allow the DDSSCs to regulate traffic flow to particular routes or SPs by diverting a predetermined ratio of calls (for example, 1 in 4) to a recorded announcement or busy tone. This will be an additional management tool to control traffic flow and subsequent possible congestion within the network.

Phase 4

Phase 4 involves the specification of a protocol with the aim of allowing flexible implementation of features in future phases of the DDSN.

Phase 5

Phase 5 will involve further advanced facilities implemented either on the databases or in the DDSSCs. These facilities have yet to be defined.

ACKNOWLEDGEMENT

The author wishes to express his thanks to AT&T and Philips Telecommunications for its assistance in the preparation of this article.

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Biography

Gerry Roberts joined the then British Post Office in 1968 direct from full-time education when he undertook a three-year apprenticeship. On completion of his initial training, he then worked on customer apparatus and trunk exchange maintenance. During February 1978, he moved to Telecommunications Headquarters to deal with the production of direct labour documents. He worked on the full national introduction of international direct dialling. He joined the DSN project team when it was established during April 1983. He dealt with most engineering aspects of the analogue network with specific interest in adaptive engineering. He now deals primarily with the commissioning and acceptance standards of the digital DSN with a continuing minor involvement in the analogue DSN.

APPENDIX

Glossary of Terms

ADSN	Analogue derived services network
ADSSC	Analogue derived services switching centre
AFSP	Advanced feature service provider
ALE	Analogue local exchange
AM	Administration module
AMC	Auto-manual centre
AMSU	Analogue main switching unit
AP	Administration processor
APT	AT&T and Philips Telecommunications
ATF	Analogue termination frame
ATU	Analogue trunk unit
CPP	Centralised power plant
CM	Communication module
DDF	Digital distribution frame
DDI	Direct dialling in
DDSSC	Digital derived services switching centre
DDSN	Digital derived services network
DEL	Direct exchange line
DFI	Digital facility interface
DLE	Digital local exchange
DLTU	Digital line and trunk unit
DMSU	Digital main switching unit
DSN	Derived services network
DSSC	Derived services switching centre
GDSU	Global digital service unit
GDX	Gated diode crosspoint
GDXLU	Gated diode crosspoint line unit
HU	High user
ISC	International switching centre
LU	Low user
MCC	Master control centre
MFOS	Multi-function operating system
MML	Man–machine language
MMSU	Module metallic service unit
MSGS	Message switch
MSU	Main switching unit
MTP	Message transfer part
MU	Medium user
NCP	Network control point
NCT	Network control and timing link
NNG	National number group
NSC	Network services complex
ODD	Office dependent data
OMC	Operations and maintenance centre
PCM	Pulse-code modulation
PRX	Processor (controlled) reed exchange
PSTN	Public switched telephone network
RC/V	Recent change and verify terminal
RMPP	Rack-mounted power plant
SM	Switching module
SP	Service provider
SPNC	Service provider network code
STLWS	Supplementary trunk line work station
TAU	Test access unit
TLWS	Trunk line workstation
TMS	Time multiplexed switch
UAN	Universal access number
USS	User support system
VDU	Visual display unit

Tester 351B—A New Performance Tester for the Digital Transmission Network

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UDC 621.394.4 : 681.327.8 : 621.317.08

British Telecom has introduced a new tester for upgrading the performance measurement, primarily for circuit-provision commissioning purposes, of 2, 8 and 34 Mbit/s links in the digital transmission network. A new design of tester was needed to overcome the shortcomings of earlier techniques in measuring performance as perceived by the end user, and to meet the latest CCITT Recommendations on error performance measurement. This article reviews the considerations which led to the development of the new tester, and describes its functional operation and the error performance measurements it provides.*

INTRODUCTION

The British Telecom (BT) network is being modernised by the replacement of analogue plant with digital switching and transmission systems[1]. Local and trunk analogue exchanges are being replaced by System X and other types of digital exchange, while the junction and trunk transmission network is being enhanced by digital transmission systems which conform to the CCITT* European hierarchical digital rates of 2·048, 8·448, 34·368 and 139·264 Mbit/s. These are generally referred to as 2, 8, 34 and 140 Mbit/s systems.

The progressive modernisation of BT's network during the early-1980s brought two new requirements for higher-order digital circuit-provision test equipment.

First, the high rate of diffusion of digital systems created a need for a widely-available digital circuit-provision tester capable of proving the continuity and measuring the error performance of 2, 8 and 34 Mbit/s digital links. Existing test equipment was expensive and thus not widely available. The cost of the new tester had to be kept to a minimum commensurate with the facilities required for circuit-provision work. The tester should be cheaper (about one quarter of the cost of currently available testers, which have facilities not required for circuit provision), integrated and portable.

Second, the new, more sophisticated, services becoming available as a result of telecommunications network modernisation around the world revealed the need for an improved standard of error performance measurement. At the time of development of the tester, this new standard was being specified by the CCITT as Recommendation G.821. Recommendation G.821 would more accurately reflect the performance of digital links as perceived by the end-user, and it was considered to be highly desirable that circuit-provision test equipment should have this capability.

† Trunk Network Operations, British Telecom UK Communications

* CCITT—International Telegraph and Telephone Consultative Committee

DIGITAL TRANSMISSION SYSTEMS

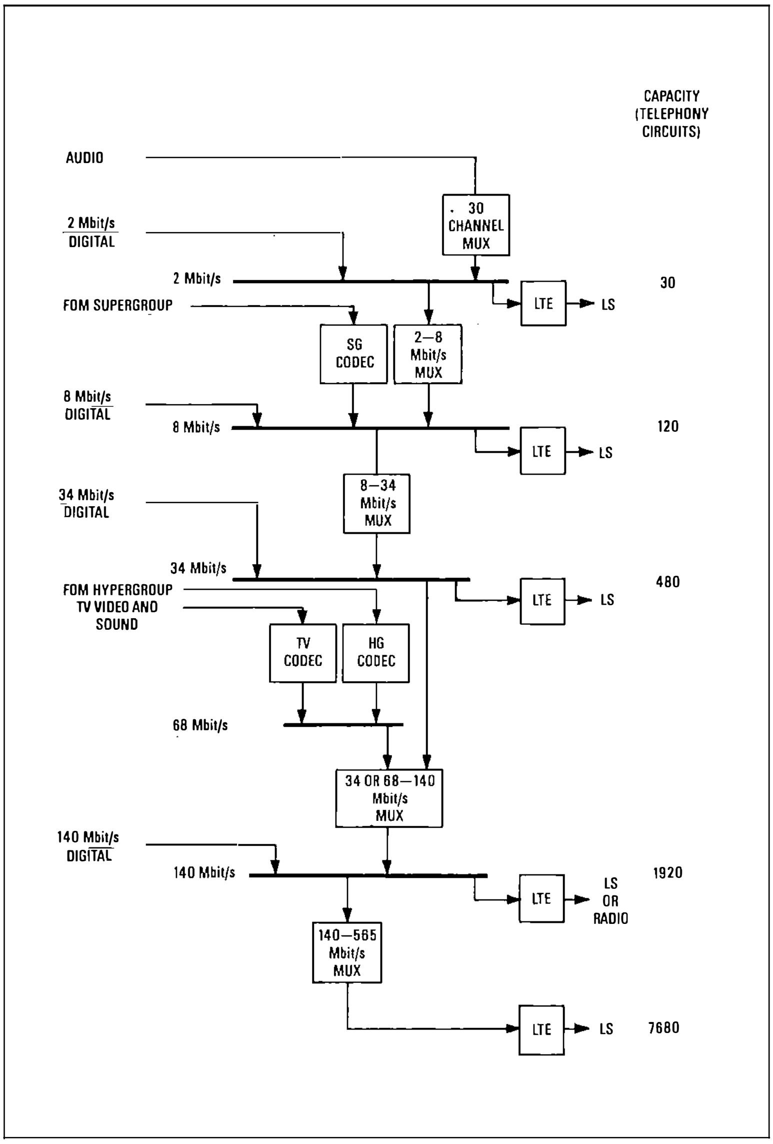
The BT network encompasses a wide range of digital transmission systems and higher-order multiplexing, coding and terminating equipment. The 2 Mbit/s digital systems are used extensively for 30-channel pulse-code modulation (PCM) systems[2] in the junction network, and demand has increased for 2 Mbit/s systems extending to customers' premises to provide point-to-point private circuits[3].

The digital circuit links for the main network use 140 Mbit/s systems[4]. The digital transmission mediums used include coaxial cable[4], optical-fibre cables[5,6] and microwave radio-relay systems[7]. It is expected that future transmission systems will operate at higher bit-rates and use optical-fibre cable[8].

Figure 1 illustrates the main types of circuit provided by the digital transmission network and shows the time-division multiplex (TDM) hierarchy, digital multiplexing, and telephone circuit capacities involved. Figure 2 shows the various types of digital links and their interconnection.

CIRCUIT PROVISION TESTING OF DIGITAL LINKS

Circuit provision involves the utilisation of installed systems and equipment to meet the demand for increased telephone and data capacity and the needs of BT's customers. The systems and equipment concerned undergo rigorous commissioning tests using sophisticated test equipment as part of the installation



FDM: frequency-division multiplex
HG: hypergroup
LS: line system
LTE: line terminal equipment
MUX: multiplexor/demultiplexor
SG: supergroup

Figure 1—Types of circuit provided by the digital transmission network

and commissioning procedure.

The provision of a new digital link requires the interconnection of equipment in accordance with a circuit order. The circuit-provision testing which follows this interconnection can be considered in two parts:

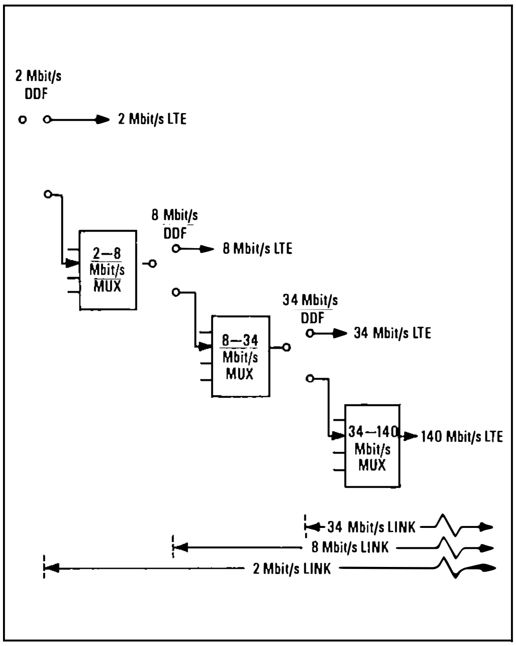
(*a*) a continuity check to prove transmission between the two terminal stations, and

(*b*) an error performance measurement to confirm that the digital link is operating within acceptable limits.

CCITT RECOMMENDATIONS ON ERROR PERFORMANCE

The traditional measure of error performance for digital links is the mean bit error rate (MBER). The adoption of the MBER was based on earlier studies which suggested that a significant proportion of error events arise as a result of random processes. This assumption has since been revised to take into account the fact that real error distributions can have intense error bursts [9].

Error performance studies have been conducted by the CCITT and their recommendations published in CCITT Recommendation G.821 [10]. This Recommendation defines three network performance objectives in the context of error performance, namely, *error free seconds*, *serverely errored seconds*, and *degraded minutes*, whose absolute values are apportioned over a Hypothetical Reference Connection (HRX) with respect to length and grade of digital section involved; that is, local, medium or high grade and is defined at the digital rate of 64 kbit/s. It is suggested that the error performance objectives given in Recommendation G.821 should be met by all transmission systems forming part of the HRX.



DDF: digital distribution frame
LTE: line terminal equipment
MUX: multiplexor/demultiplexor

Figure 2—Interconnection of various types of digital links

DIGITAL TESTER

In order to meet operational needs for circuit provision, BT has introduced a new tester—Tester 351B (see Figure 3). This tester also meets the requirements outlined in CCITT Recommendation G.821.

The tester is a combined pattern generator and error detector, capable of transmitting at bit rates of 2048, 8448 and 34 368 kbit/s. The test signal contains a pseudo-random binary

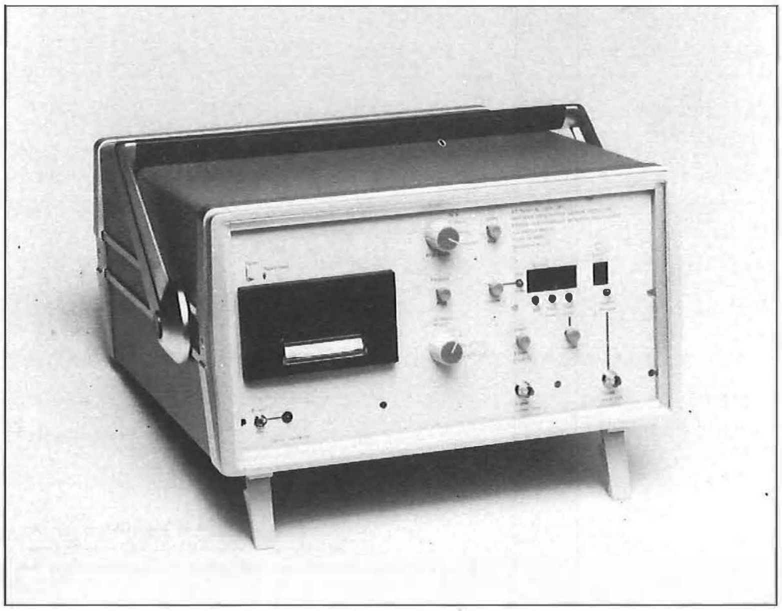


Figure 3—Tester 351B

Photograph courtesy of UPLEC Industries Ltd

sequence (PRBS) with a pattern length of $2^{15}-1$ bits at 2, 8 and 34 Mbit/s as well as a pattern length of $2^{23}-1$ bits at 34 Mbit/s[11]. A block diagram of the tester is shown in Figure 4.

The transmitter provides, from the 75 Ω unbalanced source, a PRBS at the appropriate rate using the interface code high-density bipolar 3 (HDB3), while the receiver input is a terminated 75 Ω measurement connection. After the HDB3 signal has been decoded into binary, the receiving section recognises and locks onto the pattern sequence and compares this with an internally-generated PRBS to detect any binary errors. These errors are incremented in a counter and passed onto the error performance monitoring section. Loss of synchronisation inhibits counting while recovery of synchronisation enables counting to proceed.

The error input signal to the error performance monitoring section is fed alternately to one of two identical 19 bit counters via the counter-select control circuitry. While one counter accumulates a count of error pulses,

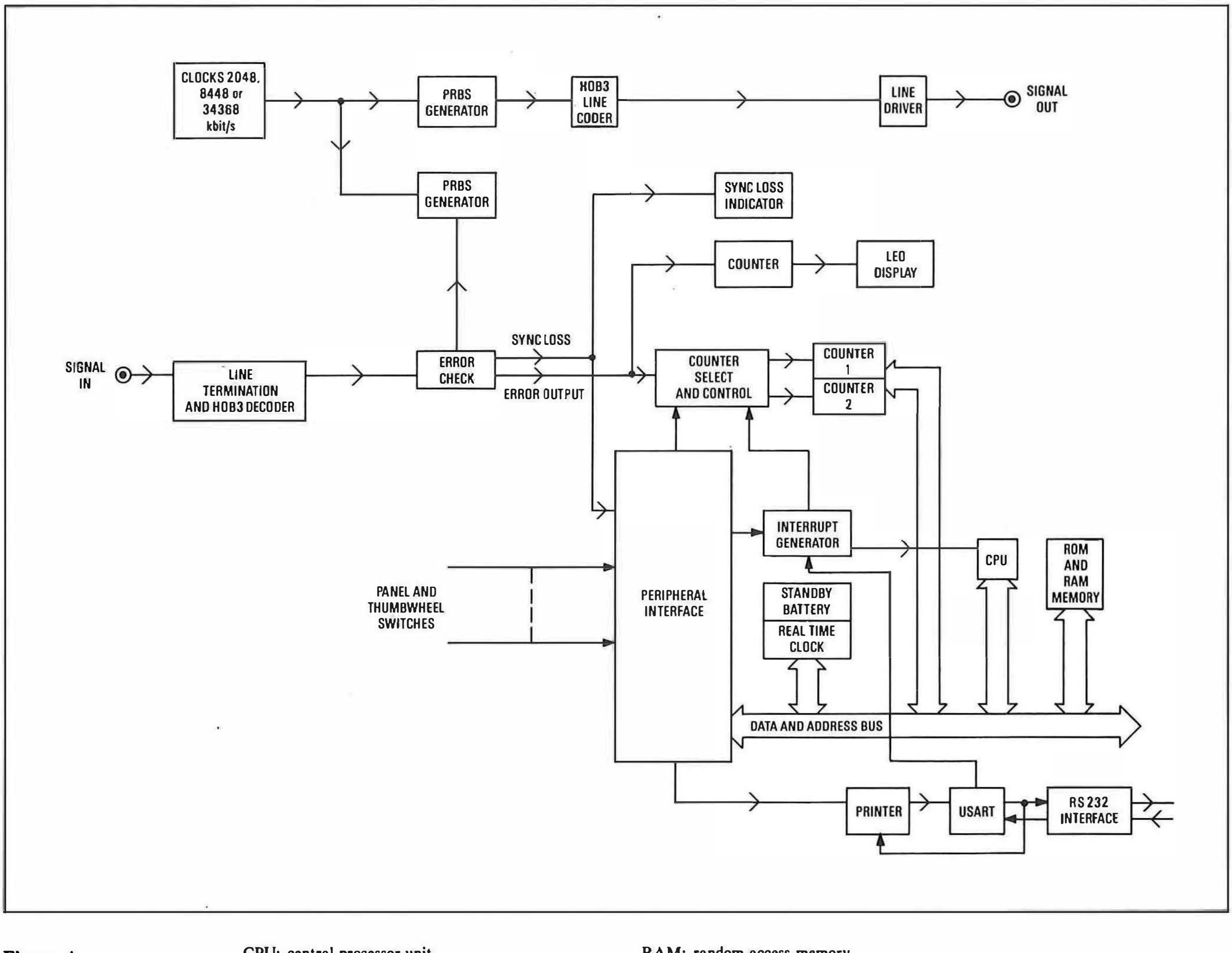


Figure 4
Block diagram of Tester 351B

CPU: central processor unit
HDB3: high density bipolar 3
LED: light-emitting diode
PRBS: psuedo-random binary sequence
RAM: random-access memory
ROM: read-only memory
SYNC: synchronisation
USART: universal synchronous/asynchronous receiver/transmitter

the other is available for reading by the microprocessor, and is then reset prior to the next counter alternation.

The peripheral interface permits the reception and distribution of control signals such as the status of the MODE switch, the line rate that is in operation, print request, synchronisation loss detector, and real-time clock settings.

The real-time clock circuit permits the time signature of result messages, facilitating the tracking of error events to their actual time of occurrence.

An 8 bit microprocessor is used to control the error performance measurement system and to process error-count values into the required results formats. Associated memory contains the operating program software in read-only memory (ROM), and data storage of the results in random-access memory (RAM).

In COMMAND mode, the microprocessor awaits command information from the thumbwheel input until a measurement sequence is initiated. Once in the MEASUREMENT mode, the processor is interrupted every 100 ms. At each interrupt, the error counters are alternated, the inactive counter being read and reset to zero. The idle period between the end of the interrupt service routine and the next interrupt is used to check the system status and, when required, to output the results information. Errors counted at each interrupt are compounded over 10 interrupt periods to produce error results on a second-by-second basis. Results of measurements are output to a parallel interface printer. They can also be output to a serial interface via an asynchronous interface device.

TESTER MEASUREMENT RESULTS

Measurement Definitions and Calculations

MEASUREMENT PERIOD This is the time of elapsed seconds from the start of the measurement to the time of printing the results.

ERROR FREE SECONDS (EFS) This is the number of whole seconds during which no error is detected during the available period, where

$$\text{available period} = \begin{matrix}\text{measurement}\\ \text{period}\\ \text{in seconds}\end{matrix} - \begin{matrix}\text{total seconds}\\ \text{of}\\ \text{unavailability}\end{matrix}$$

ERRORS Errors are counted in each errored second during the available period, and given as the value of cumulative errors.

E_{TOTAL} = the total number of errors during the measurement period excluding those errors in each errored second where the bit error ratio (BER) is greater than 1×10^{-3}.

If the error ratio in the errored second is greater than 1×10^{-3}, then this errored second is said to be *severely errored*. The total of severely errored seconds = S_{SEVERE}.

BIT ERROR RATE (BER) of minutes better than 1×10^{-n} This is expressed as a percentage and is given by:

$$\begin{matrix}\text{\% of whole}\\ \text{minutes when}\\ \text{BER} < 1 \times 10^{-n}\end{matrix} = \frac{\text{number of 60} \times \text{one second periods when BER} < 1 \times 10^{-n}}{\text{available period as expressed in whole minutes}}$$

where n = 6 or 7

AVAILABLE OR UNAVAILABLE TIME Unavailable periods commence when the BER for each second exceeds 1×10^{-3} for 10 consecutive seconds, these 10 seconds forming part of the unavailable time. Availability is re-established when the BER is better than 1×10^{-3} for a period of 10 consecutive seconds, these 10 seconds being considered as part of the available time (see Figure 5).

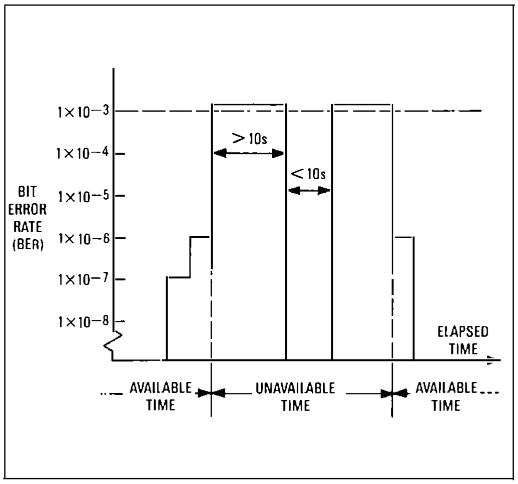


Figure 5—Example of available and unavailable time

Thus

$$S_{AVAIL} = S_{TOTAL} - S_{UNAVAIL},$$

where S_{AVAIL} = available seconds, and
S_{TOTAL} = measurement period in seconds.

Also

$$M_{AVAIL} = \frac{S_{AVAIL} - S_{SEVERE}}{60},$$

where M_{AVAIL} = available minutes.

Therefore,

$$\text{\% available time} = \frac{S_{AVAIL}}{S_{TOTAL}} \times 100\%.$$

Having determined the available time, the remaining values can now be calculated:

S_{ERROR} = number of seconds containing one or more errors

Thus,

$$S_{ERROR\ FREE} = S_{AVAIL} - S_{ERROR},$$

and

$$\text{EFS} = \frac{S_{ERROR\ FREE}}{S_{AVAIL}} \times 100\%,$$

If

S_{SEVERE} = the number of severely errored seconds, then

$$S_{\text{NON SEVERE}} = S_{\text{AVAIL}} - S_{\text{SEVERE}},$$

and

$$\begin{matrix}\text{\% of seconds} \\ \text{when BER} \\ <1 \times 10^{-3}\end{matrix} = \frac{S_{\text{NON SEVERE}}}{S_{\text{AVAIL}}} \times 100\%.$$

LONG TERM MEAN ERROR RATIO (LTMER) The LTMER is calculated by excluding the severely errored seconds.
Thus:

$$\text{LTMER} = \frac{E_{\text{TOTAL}}}{\text{bit rate} \times S_{\text{NON SEVERE}}},$$

where

E_{TOTAL} = total number of errors within $S_{\text{NON SEVERE}}$.

$S_{\text{NON SEVERE}}$ is now grouped into packets of 60 seconds and each packet is checked for BER to give:

$$\begin{matrix}\text{\% whole} \\ \text{minutes} \\ \text{with BER} \\ <1 \times 10^{-n}\end{matrix} = \frac{\begin{matrix}\text{number of packets of 60} \\ \text{seconds where the BER} \\ <1 \times 10^{-n}\end{matrix}}{M_{\text{AVAIL}}} \times 100\%,$$

where n is 6 or 7.

Results

The results output to the printer (see Figure 6) depend on the selected mode of the tester. These are given in Table 1.

TABLE 1
Error Performance Measurement Modes

Mode	Function
1 24 hourly G.821	Prints a list of G.821 values since measurement start plus a value for total errors since start, total errors since last print, and total seconds of synchronisation loss. Prints occur at 60, 120, 180 seconds, 24 hours and then at 24 hour intervals from measurement start.
2 Hourly G.821	As for mode 1 except that prints occur at 60, 120, 180 seconds, 1 hour and then at 1 hour intervals from measurement start.
3 5 minute G.821 plus errors	As for modes 1 and 2 except that prints occur at 5 minute intervals from measurement start, and includes a chronological list of one second error values over the measured 5 minute period.
4 Computer mode	Output is via a serial V.24 interface with a string of values representing a histogram of events over 100 ms periods plus a chronological list of one second error values.

In modes 1 and 2, where there is a long period between the programmed result messages, a facility is included to request a print of results for the period from measurement start to the time at which the print request is received. The request is permitted at any time except during the 2 minute period prior to the time at which a results print is normally due. The results are printed in the following format:

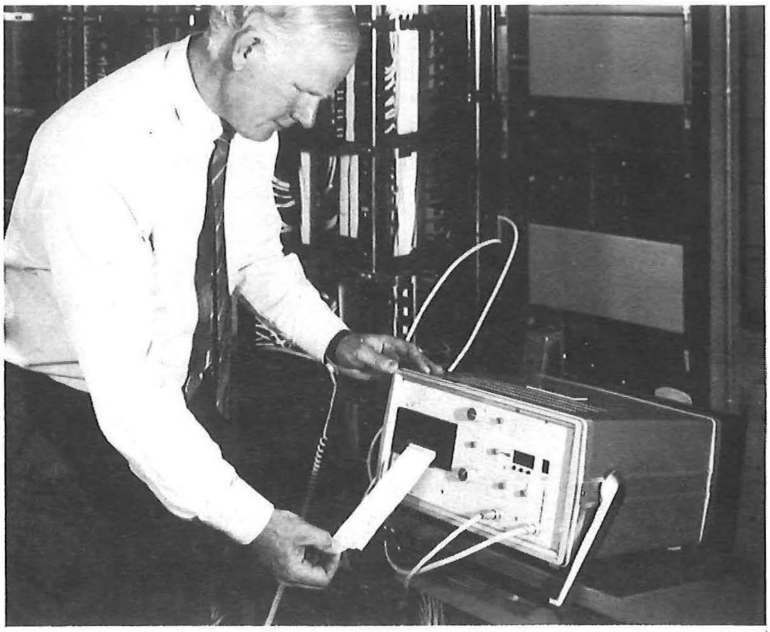


Figure 6
Tester 351B in operation

MODE 1–3

Time ON
Date
a, b, c, d, e, f, g, h, i, j, ///
Number of errors since measurement start in seconds with a BER $<1 \times 10^{-3}$
Number of errors this measurement period which have occurred in seconds with a BER $<1 \times 10^{-3}$
Number of consecutive seconds with a BER $>1 \times 10^{-3}$ for which availability is undetermined at this time
Number of elapsed seconds
List
%EFS
%minutes with a BER $<1 \times 10^{-7}$
%minutes with a BER $<1 \times 10^{-6}$
LTMER
%seconds with a BER $<1 \times 10^{-3}$
%available time
Number of seconds of synchronisation loss

Where a = number of seconds elapsed
b = number of available seconds
c = number of seconds which may be unavailable, but are as yet undecided, at the time of this message
d = number of error free seconds
e = number of seconds where BER $>1 \times 10^{-3}$
f = number of minutes where BER $<1 \times 10^{-6}$
g = number of minutes where BER $<1 \times 10^{-7}$

h = number of minutes available
i = number of errors during available time but excluding errors from whole seconds when BER $>1 \times 10^{-3}$
j = number of 100 ms periods when synchronisation loss is registered

List is a chronological list of error events on a second-by-second basis during the period since the previous message and is only used in Mode 3. The list contains a mixture of the following as appropriate:

number of consecutive seconds error free
number of errors in this second
number of consecutive seconds with error value $>2^{20}$ (error overflow)

For example:

68 seconds error free
10 errors
3 errors
210 seconds error free
6 seconds error overflow
14 seconds error free

Note: the total number of seconds monitored is 68+1+1+210+6+14 = 300 seconds.

An example of Mode 3 results is shown in Figure 7. Note that the readout from the printer starts at the bottom.

Figure 7
Typical mode 3 printout

```
X                X                X
Osecs Synch Loss
100% Available
100% sec better E3
LTMER = 2.51252E-9
100% min better E6
100% min better E7
99.48544% EFS

70 Secs error free
1 Errors
48 Secs error free
1 Errors
64 Secs error free
1 Errors
98 Secs error free
1 Errors
 16 secs error free
61800 Elapsed secs
4 errs this time
318 errs since start
30.1030,1030,318,0,///
61800,61800,0,61482,0,10

TUESDAY 11/11/1986
07:16:19 ON
```

Mode 4

Time ON
Date
a, b, c, d, e, f, g, h, i, j, ///
$n_1, n_2, n_3, \ldots\ldots n_{77}$
List, ?, *N*, #

Where n_1, n_2, up to a maximum of n_{77} are bins 1–77 of a histogram giving details of the number of error events in each 100 ms period during the period since the previous message.

List is as for Modes 1–3, but values are as follows:

Sn = number of consecutive seconds error free
En = number of errors in this second
On = number of consecutive seconds with error value $>2^{20}$

For example:

S68, E10, E3, S210, O6, S14

N is the number of 100 ms periods during which synchronisation loss occurred since the previous message.

In the event of a mains power failure while a measurement is in progress, the tester will retain previous measurement values in standby memory. On resumption of mains power, the tester will print a resumé of the previous measurement in the normal form for Modes 1 and 2 and will then initiate a new measurement automatically.

CONCLUSIONS

BT now has a cost-effective tester capable of proving the continuity of 2, 8 and 34 Mbit/s digital links and measuring their error performance to CCITT Recommendation G.821 standards. The general availability of this tester will result in a further improvement in the standard of the digital transmission network and the quality of service offered to BT's customers.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of Peter May of BT Research Laboratories and their colleagues in the test equipment and network performance standards groups of the Trunk Network Operations Planning Division.

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5 MUIR, A. W. Optical-Fibre Transmission Systems in the British Telecom Network: System Design. *ibid.*, Oct. 1983, **2**, p. 180.
6 BERRY, R. W. and RAVENSCROFT, I. A. Optical

h = number of minutes available
i = number of errors during available time but excluding errors from whole seconds when BER $>1 \times 10^{-3}$
j = number of 100 ms periods when synchronisation loss is registered

List is a chronological list of error events on a second-by-second basis during the period since the previous message and is only used in Mode 3. The list contains a mixture of the following as appropriate:

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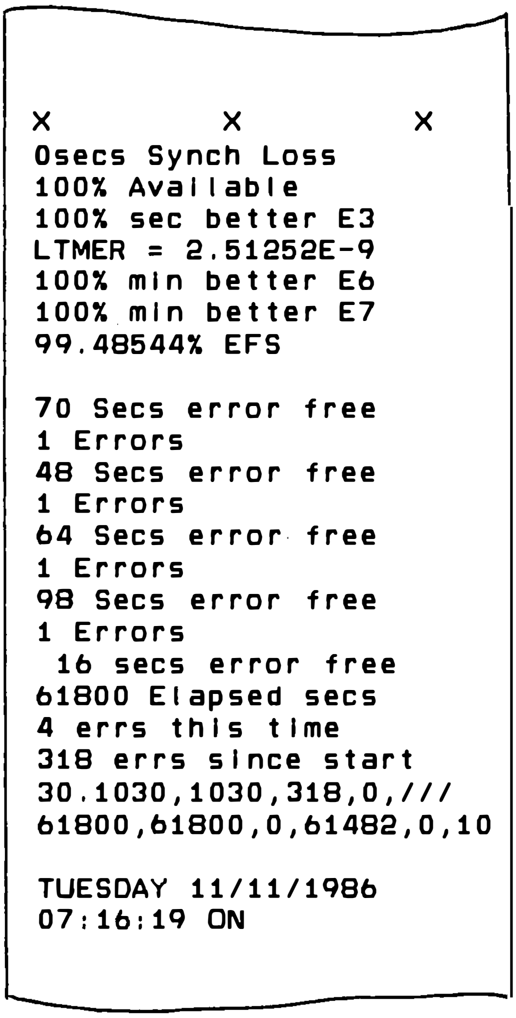
Figure 7
Typical mode 3 printout



Mode 4

Time ON
Date
a, b, c, d, e, f, g, h, i, j, ///
$n_1, n_2, n_3, \ldots\ldots n_{77}$
List, ?, *N*, #

Where n_1, n_2, up to a maximum of n_{77} are bins 1–77 of a histogram giving details of the number of error events in each 100 ms period during the period since the previous message.

List is as for Modes 1–3, but values are as follows:

S*n* = number of consecutive seconds error free
E*n* = number of errors in this second
O*n* = number of consecutive seconds with error value $>2^{20}$

For example:

S68, E10, E3, S210, O6, S14

N is the number of 100 ms periods during which synchronisation loss occurred since the previous message.

In the event of a mains power failure while a measurement is in progress, the tester will retain previous measurement values in stand-by memory. On resumption of mains power, the tester will print a resumé of the previous measurement in the normal form for Modes 1 and 2 and will then initiate a new measurement automatically.

CONCLUSIONS

BT now has a cost-effective tester capable of proving the continuity of 2, 8 and 34 Mbit/s digital links and measuring their error performance to CCITT Recommendation G.821 standards. The general availability of this tester will result in a further improvement in the standard of the digital transmission network and the quality of service offered to BT's customers.

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A New Reliability Tool for Designers

D. S. UBHI, M.SC.†

UDC 621.38.004.6

This article presents some discussion on the role of design engineers in achieving specified reliability requirements with the aid of appropriate tools. Highly reliable products can be manufactured only through effective quality control, reliability planning and design reviews right from the initial design stage. To enable the reliability of electronic equipment to be estimated, with the object of enhancing the usefulness of the product, a new database in the form of a handbook, the Handbook of Reliability Data*, *fourth edition, has been compiled by British Telecom. The purpose of the handbook is to provide a common basis for system/product reliability predictions in civil applications, especially telecommunications. This article also describes how the data for the handbook was collected and analysed, and discusses the application of two models for predicting reliability.*

INTRODUCTION

The *Handbook of Reliability Data* (*HRD*) contains a list, presented in an easily used format, of estimates of the generic failure rates for components used in telecommunications systems. These base failure rates of components are estimated figures at 60% upper confidence level, and have been updated to take into account advances in technology which have markedly improved the reliability of some components, especially integrated circuits (ICs). The list of component types has been extended to include 17 major categories, which are further divided into 174 sub-categories. The failure-rate data covers a wide range of components including optical-fibre and microwave components.

The handbook is a useful tool for telecommunications engineers, especially for those with a direct interest in equipment design. Several data sources have been used to compile this issue of the handbook. Many other databases such as MIL-HDBK-217D, CNET, BELL, NTT, INSPEC, MOD, British Gas and STACK have been compared where possible.

DATA COLLECTION

Field performance is the ideal source of data, since it represents component operations in the actual environment in which the component is to be used. Service data was collected largely from the performance of a wide variety of equipment installed in the UK inland telecommunications network. The compiling of data required pooling of failure information from different systems, sources and equipment operating under different conditions and environments. Before combining such information, statistical tests were carried out to identify if any significant differences occurred in the failure rates of components from different environments and applications.

The data collection was organised by the Materials and Components Centre (MCC) of British Telecom (BT) based at Birmingham. This was a large and difficult task which involved a great deal of effort by staff from the MCC and various repair centres throughout the country. A huge amount of data had been collected for the third edition of the handbook (*HRD3*) which was further validated and included in the fourth edition, *HRD4*. New data was gathered from various telecommunications systems installed by BT in the UK. Service data from the German Post Office was also included in this study for comparison with failure-rate data of similar components operating under similar conditions. This gave a wider spread of product and equipment types from a variety of applications and environments and included many new types of components which were not covered in the previous editions of the handbook.

It is essential that the data collected must have the attributes of accuracy and completeness, as well as utility and balance. This involves the field maintenance staff in considerable effort filling the fault dockets. These dockets give details of the location of components on the circuit board, fault symptom, fault date and the cause/effect of a failure etc. It is also necessary to collect information on the relevant population of components.

The database management system has been established on a mainframe computer. The database, called *CARE* (*C*omponent *A*nalysis and *R*eliability *E*valuation), was first set up in 1982 and now contains failure data for over 200 000 components collected from a number of systems. The replaced components are returned to the MCC at Birmingham from repair centres, telephone exchanges and equipment manufacturers with a fault docket containing the relevant details, which are sub-

† Materials and Components Centre, British Telecom Materials Executive

* The *Handbook of Reliability Data* is available from London Information (Rowse Muir) Ltd., Index House, Ascot, Berkshire SL5 7EU.

sequently recorded onto the computer database. Components identified as presenting significant in-service failures are analysed by BT laboratories to ascertain the cause and effect of a failure. Then, failure analysis data is added to the CARE database and is used to aid the prediction of component failure rates.

DATA ANALYSIS

Some difficulties were encountered with the data which was gathered from different sources. The underlying problem hinged on the acquisition of a representative sample in order to assess the effects of inter-relationships of the various factors and parameters. In some cases, particularly with the new technology components, the amount of data required to be statistically significant was not available from the field return information. Even in those cases where a reasonable amount of data was available, it was of limited use because of biasing and sampling errors.

As a result, the analysis was restricted to a few standard statistical techniques. At the time of compiling data for *HRD4*, most of the components returned were either very new or of the 'custom/semi-custom' type. As such, these components were low-population and low-usage parts, and the development of a statistically large and significant database became impossible.

The first step in the preparation of data was to perform a failure analysis on the returned components in order to determine *fault not found* (FNF) components and to positively identify the failure mechanisms of the failed components. An electrical test was performed and typically about 50% of those tested were found to be within their electrical specifications. These are classed as *right when tested* (RWT) components. This does not necessarily mean that the RWT components did not cause system failures; for example, a memory component with poor data retention could be RWT and still cause system failures. Further tests were carried out on individual components to establish the cause and effect of a particular failure.

The aim of the handbook is to give the generic failure rate that represents the intrinsic reliability of a component relating to its design and manufacturing process. This implies that failures due to other causes such as inadequate derating, mishandling, accidental damage and wrong application, etc., are not taken into account. The results of failure analysis highlighting such causes were taken into consideration while the base (generic) failure rate of a component was being calculated.

The next step was to examine the data statistically and to carry out data analysis. In order to analyse the failure data using standard statistical techniques, it was necessary to divide the data into different subsets. For the field data, the information on precise start-up and fault dates was not available. This problem arises when groups of equipment are brought into service at different times, and due to the size of the population which is changing all the time.

Several software packages for statistical estimation were used to enable time-dependent failure rates to be predicted even if the historical data for the individual circuit boards was unknown. The field data was expressed as grouped data; that is, at each maintenance visit, the number of faults that had occurred since the last visit was recorded without the knowledge of precise failure times. If the individual dates of failures are recorded and a service profile of a system is available, the component failure rate as a function of time can be estimated by using maximum likelihood estimation (MLE) techniques. The log-normal and Weibull distribution functions had been successfully applied where a sufficient amount of data was available. Where only the failure totals for the individual component types were given, crude failure-rate averages had to suffice.

As the failure rates have been derived from service data, it has been assumed that the equipment and the components in it are within their normal working lives. Only the maintenance failures subsequent to BT taking possession of the equipment concerned have been analysed for the handbook. Commissioning failures and those caused by the servicing of the operational plant have been excluded. The early-life failures during the infant mortality period have been excluded on the assumption that these failures would have been eliminated by equipment burn-in and screening etc. As the wear-out failures are minimised by replacing short-life components before they wear out, these have been completely ignored. Most emphasis has been placed upon estimating the base failure rates during the useful life of the components. The hazard rate or the instantaneous failure rate during the useful life is assumed to follow an exponential distribution.

APPLICATION OF *HRD* DATA

The application of quantitative reliability assessment during product planning, design, development, production and operation is becoming increasingly important. The handbook is a unique tool providing a useful basis for determining product requirements, comparing alternative designs and selecting the final product. Reliability predictions based on *HRD* data, if correctly carried out, can provide a useful measure for:

(*a*) comparing one design against another and design trade-off options,

(*b*) inputting to the reliability analysis of a complex system,

(*c*) selecting components and highlighting those which could be critical, (*d*) setting test standards for accept/reject criteria,

(*e*) planning maintenance strategy and logistic support,

(*f*) setting achievable in-service performance targets against which to judge the actual performance and stimulate corrective action,

(*g*) improving reliability at the design stage,

(*h*) estimating life cycle costs,

(*i*) providing a basis for negotiating contractual requirements.

RELIABILITY PREDICTIONS BASED ON *HRD* DATA

The two most commonly used models for predicting reliability of a product based on the component failure-rate† information given in *HRD* are described below.

Parts Count Model

The parts count model is applicable in the early design phase of a product when the list of parts to be used becomes available. This model assumes that all the components are connected in series with perfect connections. It also assumes that the failure of one part is statistically independent of the failure of another. This implies that the model does not take into account the effects of inter-reaction between components. It also assumes that the component failure rate remains constant during its useful life.

This simple model involves multiplying the base failure rate of a component by the appropriate environmental, quality, and complexity factors and the quantity of each component type and then adding the result. This model is concerned with the behaviour of the components themselves and the effects of quality, complexity and environmental conditions. The model does not take into account any product design faults and systematic failures due to any associated software errors.

The following information is required to apply the parts count model:

(*a*) *Parts list.* The most up-to-date parts list supplied by the product designers should be used for reliability prediction.

(*b*) *The generic failure rates of all the parts.* This information is given in Table 1 of the *HRD*. For the ICs not listed in this table, it is recommended that the mathematical models described in the appendices should be used to predict base failure rates.

(*c*) *The component quality factors.* These are tabulated in *HRD* for three different quality levels of components used. The quality levels are defined in Appendix A1.3 of the *HRD*.

† Failure rate is a measure of reliability of a device and is defined as the number of device failures per unit operating time. A widely used *F*ailure rate un*IT*, called the *FIT*, is the number of failures in 10^9 device-hours.

(*d*) *The component complexity and technology.* These are listed in Table A.1 of the *HRD*, and are based on device codes.

(*e*) *The environmental factors.* These factors are derived from the conditions in which the devices will operate. These factors are given in Table A7 of the *HRD.*

(*f*) *The numbers of different generic types of parts as given in the parts list.*

Parts Stress Count Model

The parts stress count model requires additional information about the components including stress levels, temperature weighting factors, power dissipation, thermal resistance, ambient temperature, the number of pins, and the type of package in the case of an IC. The parts stress count model requires more time and effort to carry out reliability predictions from the component data. The parts count prediction results are further multiplied by the relevant stress factors to take account of temperature, power dissipation and the number of pins etc.

This analysis is more suitable for application in the later stages of the design process when the required detailed information becomes available. It assists the designer by highlighting over-stressed components and marginal stress levels.

Basis of Parts Count and Parts Stress Count Models

Assume that n statistically independent components are connected in series. The reliability of a total system, R_s, is given by the product law of probabilities of success (reliabilities):

$$R_s = R_1 \times R_3 \times R_3 \times ..... \times R_i \times ..... \times R_n,$$

where R_i is the reliability of the ith component in the series system.

Assuming exponential distribution,

$$R_i = \exp(-\lambda_i t),$$

where λ_i is the constant failure rate of the ith component.

The above expression can be written as:

$$\exp(-\lambda_s t) = \exp\{-(\lambda_1 + \lambda_2 + \lambda_3 + ... + \lambda_i + ... + \lambda_n)t\},$$

or $$\exp(-\lambda_s t) = \exp(-\sum_{i=1}^{n} \lambda_i t),$$

which implies $$\lambda_s = \sum_{i=1}^{n} \lambda_i.$$

Hence, the predicted failure rate of a system of components all connected in series is the sum of the constant failure rates of all the components.

This forms the basis of the above models which can be expressed mathematically as:

$$\lambda_s = \sum_{i=1}^{n} N_i \lambda_i,$$

where $\lambda_i = \lambda_b \pi_T \pi_q \pi_e \pi_c$,

N_i = the quantity of the ith part; and

λ_b = the base failure rate for the ith part,

π_T = the temperature weighting factor for the ith part,

π_q = the quality factor for the ith part,

π_e = the environmental factor,

π_c = the complexity factor for the ith part.

An example based on *HRD4* data illustrating the application of the above models is given to demonstrate the effect of component quality on the long-term reliability of a product. A hypothetical board made up of a number of device types is specified. An example of reliability prediction in terms of mean time to failures (MTTF) for this board, based on *HRD4* quality level 2 data, is given in Figure 1. Figure 2 shows the difference in the reliability function of the board for three quality levels of components. This demonstrates how significant is the effect of component quality on the long-term reliability of the board.

† FRATE (*F*ailure *RATE*) is a computer program written by the Systems Reliability Consultancy, British Telecom Research Laboratories. It contains all the component failure-rate data and models used in *HRD4*. This enables the user to produce tabulated reliability predictions quickly and efficiently, even for large systems. The program is flexible, allowing global changes to be made to component quality, environment and temperature in order that the effect of each may readily be appreciated. Also, the user is able to tailor the output table to suit his particular requirements. The program runs on an IBM PC XT or compatible with 512 Kbyte of main memory and offers the option of using a mouse to aid data entry and program control.

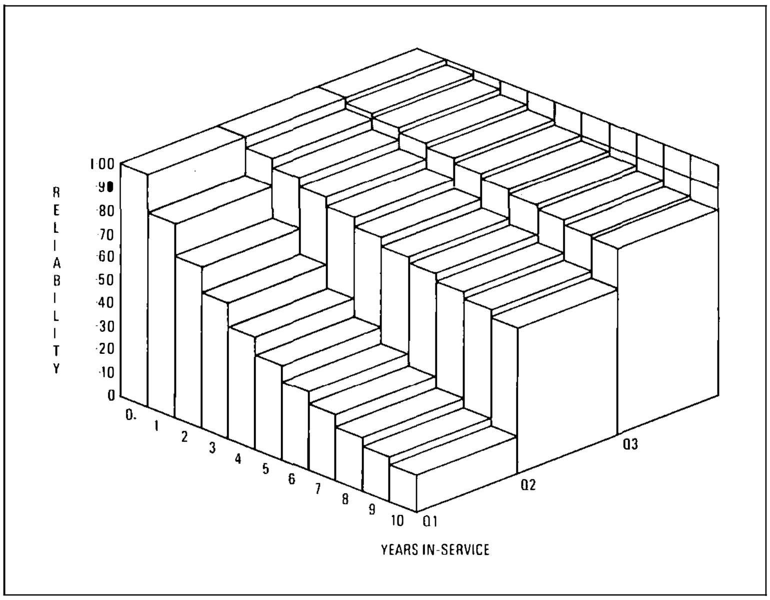


Figure 2
Reliability function of the example in Figure 1 for three quality levels of components

MTTF is normally defined as the total operating time divided by the total number of failures during that time. The practical significance of MTTF is that, after a time period equal to the MTTF, only about 37% of devices of the same kind would still be operating, whereas about 63% would have failed during the MTTF. This is true for any item or system where the failures occur randomly and follow an exponential distribution. It is important to realise that the reliability prediction of a product based on *HRD* data gives only the intrinsic reliability under ideal conditions, whereas the actual reliability of the product in service will be many times worse owing to the failures contributed by external causes.

For predicting the reliability of large and

Figure 1
An example of a reliability prediction using BT's FRATE† computer program

HRD4 Catgry	Description	Comp. Identity	----- Thermal Junc. Temp.°C	Power (mW)	Details ----- Package	Pins	No. of Elements	Qual. Level	Appl. Factor	Comp. FITS	No. Off	Total FITS	% of Total
1.3.1	Bipolar Digital Logic TTL	IC1	56		Plastic		10000G	2	5	275	1	275	14.8
16.2.1	850 nm LED Fibre Driver	F2						2	1	200	1	200	10.8
1.3.2	Bipolar Linear	IC4	56		Plastic		10000G	3	2	183	1	183	9.9
1.3.4	MOS Linear	IC8	56		Plastic		10000G	2	1	183	1	183	9.9
1.3.1	Bipolar Digital Logic	IC2	56		Hermetic		10000G	3	1	173.5	1	173.5	9.4
1.3.3	MOS Digital Logic	IC6	56		Hermetic		1000G	2	1	123	1	123	6.6
1.3.9	Bipolar ROM	IC16	56		Plastic		100000G	2	1	102	1	102	5.5
16.1	Fibre Connector	F1						2	1	100	1	100	5.4
1.3.3	MOS Digital Logic	IC5	56		Plastic		100G	2	1	65	1	65	3.5
1.3.9	Bipolar PROM	IC14	56		Plastic		1000G	2	1	30	2	60	3.2
12.3	Liquid Crystal Display	D1-2						2	1	30	2	60	3.2
1.3.9	Bipolar ROM	IC15	56		Plastic		10000G	2	1	55	1	55	3.0
1.3.7	MOS EPROM	IC11	56		Plastic		10000G	2	1	13	4	52	2.8
5.2	Mercury Wetted Reed Relay	RR1						2	1	50	1	50	2.7
14.3.1	Standard Toggle Switch	SW1						2	1	30	1	30	1.6
1.3.4	MOS Linear	IC7	56		Plastic		100G	2	1	26.3	1	26.3	1.4
1.3.2	Bipolar Linear	IC3	56		Plastic		100G	2	1	26.3	1	26.3	1.4
6.1	Power Transformer	T1						2	1	25	1	25	1.3
1.3.7	MOS EEPROM	IC12	56		Plastic		100000G	2	1	23.9	1	23.9	1.3
1.3.9	Bipolar RAM	IC13	56		Plastic		100G	2	1	16.6	1	16.6	0.9
2.5	Polystyrene Foil Capacitor	C1-20						2	1	0.5	20	10	0.5
1.3.7	MOS CCD	IC10	56		Plastic		1000G	2	1	7.1	1	7.1	0.4
1.3.7	MOS DRAM	IC9	56		Plastic		100G	2	1	3.8	1	3.8	0.2
3.2	Carbon Film Resistor	R1-12						2	1	0.2	12	2.4	0.1

Total failure rate = 1852.9 FITS
Mean time to failure = 61.6 Years

Environment: Ground benign—nearly zero environmental stress
Air temperature: 30°C

Quality: See individual components
Level 2—Components produced to an agreed specification
Level 3—Components subjected to 100% testing and burn-in

complex systems without the use of a computer, the above models could become very tedious and time consuming. A software package based on *HRD* data has been developed to carry out parts count and parts stress count analysis.

SUMMARY AND CONCLUSIONS

This article has presented an appraisal of some basic requirements of the reliability data for the components used in the telecommunications industry. The guidance and rationale provided in the *Handbook of Reliability Data* is intended to serve as a tool for the aid of designers to build reliability into the product at the design stage. Increased emphasis has been placed on the credibility of field performance data. A sharp distinction has been drawn between the intrinsic reliability of a device and its failure due to external causes. The main concern of this article has been to emphasise the need for a statistically significant database compiled from the knowledge of the physical causes of failures and for this information to be built into the failure-rate prediction models.

Finally, there is a great need to collect service data from different sources, applications and environments to obtain representative samples for every category of components. The effective reliability predictions should be tailored to fit the needs of design, operation, and maintenance support, and the data and models given in the *HRD* should be carefully applied.

Biography

Denis Ubhi received his M.Sc. degree in Industrial Mathematics and Statistics from the University of Aston, Birmingham, in 1970. Since joining BT in 1967, he has worked on technical adjudications and progress of TXE4 and System X contracts. He moved to the MCC in 1982 and has been involved in reliability analysis of components and systems. Currently, he is a reliability manager responsible for the development of BT's *Handbook of Reliability Data*.

Automatic Scanner for Monitoring Traffic Overflow Meters—TOMAS

J. M. HALTON, and P. J. GOODWIN†

UDC 621.395.31 : 621.395.66

TOMAS (traffic overflow meter automatic scanner) is a microprocessor-controlled scanner which is located remotely at an exchange; it is designed to monitor traffic meters, and has internal storage to retain their readings. The results are read by clerical staff using a computer terminal at the planning office to access an exchange telephone number equipped with a standard 1200 baud asynchronous modem. The results are printed in a familiar format (Form A441) with an option to print only exceptions which have exceeded a preset limit.

INTRODUCTION

In any sensibly-planned telephone switching network, economics dictate that a proportion of calls be allowed to fail to mature at peak times owing to congestion of switching or line plant, but this must be within clearly defined limits acceptable to the customer; this is referred to as *grade-of-service* (GOS). Clearly, it is important that these peak-hour lost calls are accurately monitored so that a satisfactory GOS can be maintained. In the analogue network, this is effected by physical meters, called *traffic meters*, located at the exchange and used to count the lost calls or the length of time all circuits in a group are in use.

As large exchanges need hundreds of traffic meters (see Figure 1), the process of reading them is tedious, time consuming and labour intensive, and involves several stages of handling, copying, and circulating between exchange staff, managers and trunking-and-grading offices for remedial action.

The traffic overflow meter automatic scanner (TOMAS) was conceived, designed and developed by Manchester District Project Group as a means of automating the process of reading traffic meters. In addition, it would improve reliability, afford new facilities and speed up greatly the acquisition of the lost-call data at much reduced cost.

MAIN DEVELOPMENTS

A prototype unit was installed at Stepping Hill crossbar exchange for a field trial to test the reliability and accuracy of the recorded results. The production of the initial unit required a good deal of hand wiring on the back-plane. Connections to the four 50-way D-type sockets mounted at the rear were particularly difficult and could have led to faults in the future.

The remote terminal had little in the way of sophisticated software to control or print the recorded results into a suitable printed form. However, this field trial did prove that the basic elements of the system worked satisfactorily, though it was clear that a good deal of development work would be needed to bring the project into an acceptable form for use by network planning groups. The following list of facilities was identified as being necessary, and development work was started to provide these.

Software features:

(*a*) Print-out data in the familiar Form A441 format.

(*b*) Print option for routes exceeding 50% critical figure.

(*c*) Menu-driven terminal programs for ease of use. System must be capable of being used by clerical staff with the minimum of training.

(*d*) Auto-dial access to the public switched telephone network (PSTN) from the terminal program.

(*e*) Enhanced noise immunity of scanner software.

(*f*) Password security protection.

(*g*) Checksum generation to guard against line noise.

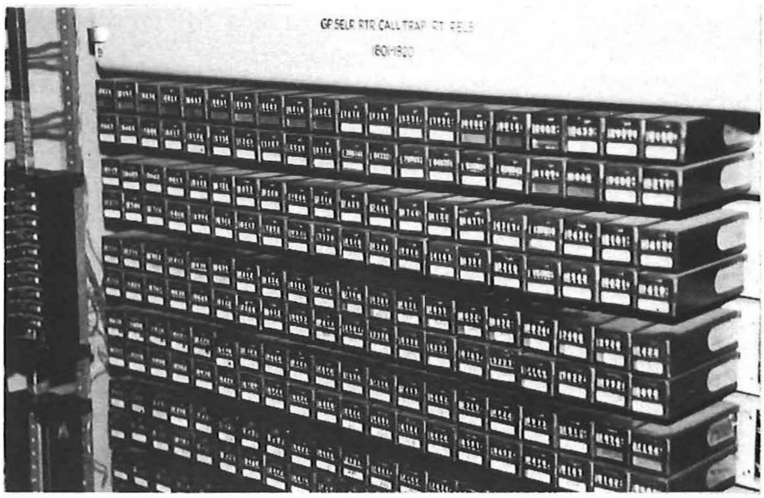


Figure 1
Typical traffic meters

† Manchester District, British Telecom UK Communications Division

Some hardware improvements:

(*h*) Double-sided printed-circuit board with plated-through hole connections to replace all the back-plane wiring.

(*i*) Epoxy-cased switch-mode power supply mounted on new backplane.

(*j*) Suitably robust case for the 19 inch rack.

(*k*) Insulation displacement termination (IDT) connectors for 50-wire cable plugs to simplify cabling to the meters.

UNIT. GRP. LEV:	MR/WYT	MACC'O'ORD	MR/DAL
NO OF TRUNKS:	15	73	62
TYPE OF METER:	GOTM	GOTM	GOTM
DURATION:	2.3	2.9	2.3
TRAFFIC CAPY TABLE:	PE12/.013	PE12/.013	PE12/.03
CRITICAL READING:	702	702	1620
METER NO:	F09-06	F09-09	F09-15
21/04/87	75	69	37
29/04/87	54	25	62
05/05/87	21	5	1385
11/05/87	101	105	882
18/05/87	71	151	2
26/05/87	181	789	176
01/06/87	363	875	1120

Figure 2—Exceptions report showing three routes > 50% critical

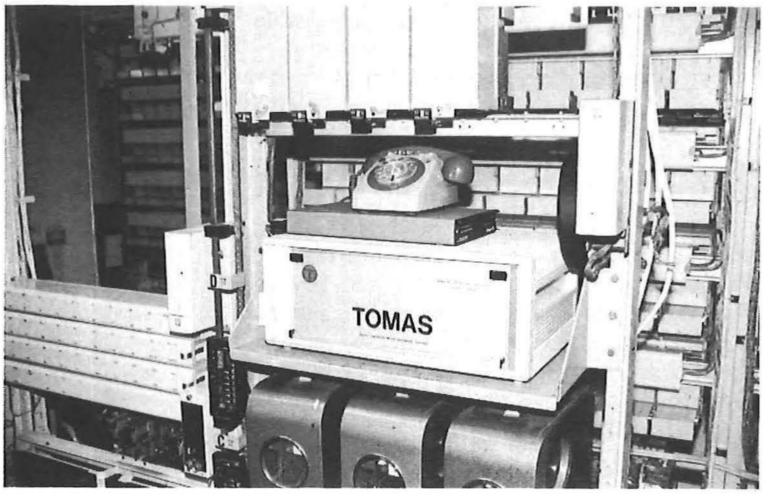


Figure 3—The installation at Manchester tandem exchange

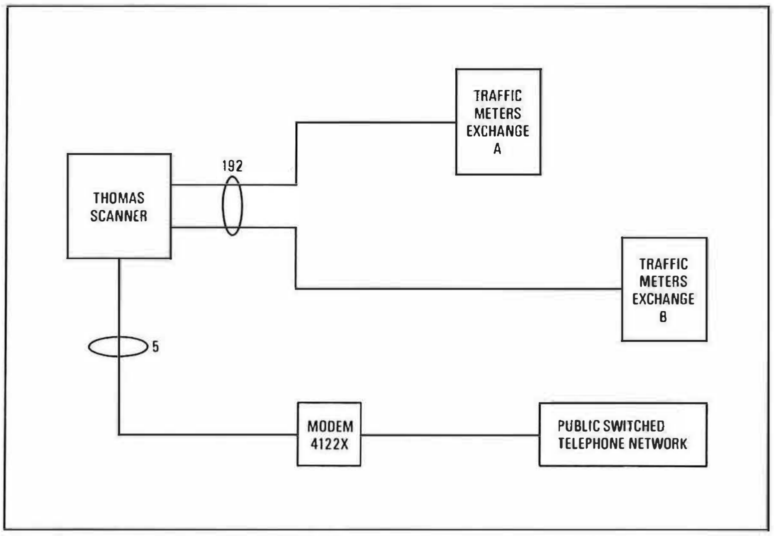


Figure 4—Block diagram of exchange installation

The addition of these features has turned TOMAS into a reliable unit which is easy to install. The unit removes the tedious task of meter reading from the hands of maintenance staff, and saves operational costs both at the exchange and in the planning office. An exceptions report showing only routes which exceed a preset limit is produced weekly for each exchange by the clerical assistant who used to duplicate A441 readings from the circulating copy to the office file. The information in this more concentrated form is then sent to maintenance and planning groups for action. The example in Figure 2 illustrates a typical print-out. This procedure has saved much time, a great deal of paper and photocopying costs.

The quarterly congestion committee proposed that 25 such units should be installed at exchanges throughout the Manchester District. Exchange overflow and group occupancy readings could be taken when and as often as required. Future quality targets set for 'plant engaged' would be difficult to achieve and the speedy acquisition of this data would be essential.

Initially, exchanges which had a relatively long service life remaining were connected, since a minimum of two years was considered to justify the initial outlay. Most common-control director exchanges and the main tandem exchange (see Figure 3) were chosen. Later, it was found that sufficient capacity existed on some TOMAS units to connect meters at co-located Strowger exchanges.

An IBM PC XT was selected as the most suitable computer for the terminal, particularly because several of these machines were being networked within planning offices at the District Headquarters.

SYSTEM DESCRIPTION

The equipment used for the TOMAS system falls naturally into two parts; the exchange equipment and the planning office equipment.

Exchange Equipment

The TOMAS equipment installed in the exchange (see Figure 4) is a microprocessor-based scanning system that utilises an 8085 processor together with input multiplexing and communications circuitry. The input multiplexing allows the system to read up to 192 inputs, while the communications board carries an RS232 interface, which allows a modem to be connected. Typically, a Modem 27B or 4122 would be used, and this allows data-transfer rates of 1200 baud.

Inputs to the system are via four 50-way IEEE-type connectors, which have the advantage that conventional cable can be run to the meter rack and terminated there on a tag-block, while it can be terminated in the IEEE connector at the scanner end by using an insulation-displacement technique. The IEEE connectors appear to be the only type that presently allow insulation-displacement connection, with its enormous speed advantage, to be used with conventional, that is, non-ribbon, cable.

The TOMAS scanner consists of a 4U 19 inch rack housing seven circuit boards, together with a switch-mode power supply, which generates a 5 V supply for the logic circuitry from the exchange 50 V supply. The seven boards comprise four input multiplexor boards each carrying 48 earth-detecting inputs, an address decoder board, the communications board, and the central processing unit (CPU) board. The CPU board carries the 8085 processor together with two 8755 electrically-programmable read-only memories (EPROMs) and a 6264 random-access memory (RAM); these give a capacity of 8 Kbyte of RAM and 4 Kbyte of ROM. The CPU card also carries a programmable timer, which is used to generate an interrupt to the CPU every 50 ms; this initiates a sequential scan of all the 192 inputs. Since the typical meter pulse is of the order of 200 ms, a pulse is available for detection for several successive scans. This gives a high degree of noise immunity, since, because a noise spike is generally present for only one scan, the software can be written so that only conditions present for more than one scan are counted as being genuine.

The software can be thought of as a set of 192 four-digit resetable meters which can be read remotely, together with several housekeeping functions such as a reset facility, a real-time clock which records elapsed time since last reset, and various internal self-checks, such as an over-run real-time test. The meter reset facility is normally used only on installation, after which the meters are allowed to increment cumulatively like their hardware counterparts. Subtraction of each week's reading is performed in the office-end software. This allows more than one set of readings to be taken from the same scanner without interaction between them, so that the same scanner can be read weekly in the normal programme of readings, and, for example, read at hourly intervals during the course of a day as part of a separate study of a particular exchange or route.

The scanner software was written in 8085 assembly language and occupies some 2 Kbyte of EPROM space.

Scanner Operation

The organisation of the seven circuit boards for TOMAS is given in Figure 5. A scan is initiated every 50 ms when the programmable timer on the CPU board generates an interrupt to the CPU. The CPU responds by sending the address of the first input of the first multiplexor to the address decoder board. As its name implies, the function of this board is to decode the address supplied by the CPU into an *enable* signal for a particular multiplexor board, and an address code corresponding to one input from the 48 carried by that board. Thus, one input from the possible 192 is selected. The condition of that particular input at that instant (that is, earth present or not present) is output by the multiplexor onto the common data lead from the multiplexor boards to the CPU, which can thus read the data.

The CPU records the state of each input, since the action taken at this point depends on the result of previous scans together with the current scan. If an input which had no earth present is seen to have an earth present for two successive scans, and no pulse has been recorded against that input, then a pulse is added to the total for that input, and that

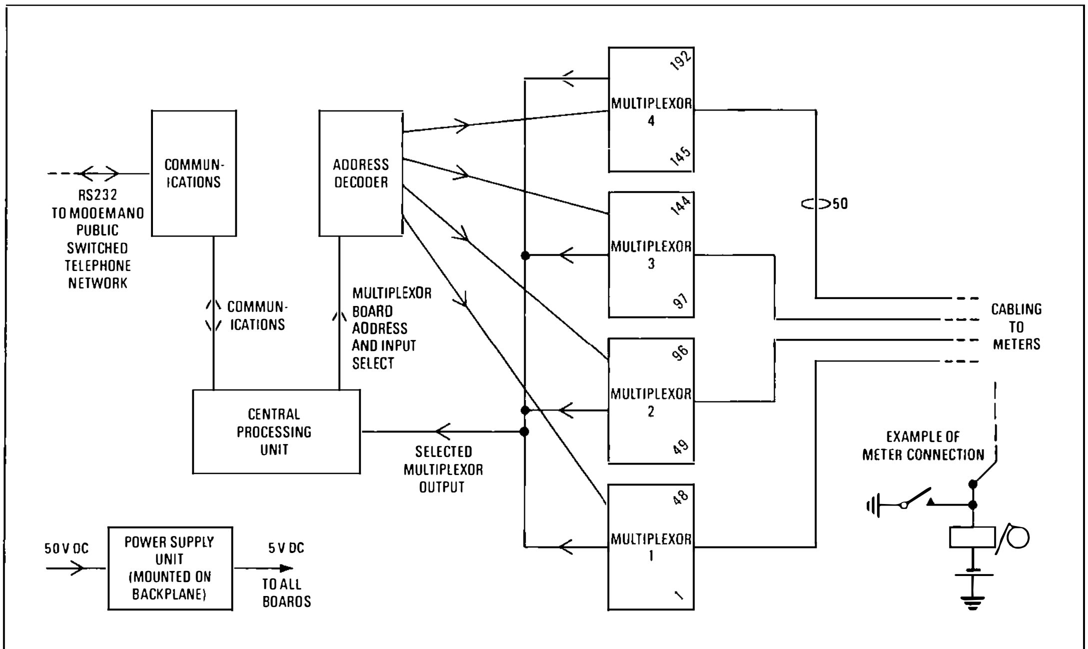


Figure 5
TOMAS scanner schematic

fact is noted. Thus, while the earth remains on the input, no further action is taken. One byte of RAM per input is used as a flag byte, to keep track of the various events occurring on that input. The operation of the software can also be understood as a state-variable system, with the flag byte functioning as a state table for each input.

This process is repeated for all 192 of the inputs, every 50 ms.

On completion of each scan, the processor updates the lapsed-time clock, checks it has completed the scan correctly without over-running real time, (that is, started a new scan before completion of the previous one), and then returns to its background tasks. These include monitoring the communications system ready for any incoming communications activity.

If the communications board indicates that data has been received over the RS232 interface, the CPU responds by sending a *password request* message. Further input is checked, but no further response is generated until the correct password sequence has been received in its entirety. A *sign-on* message is then transmitted, followed by a command prompt. If the *data message request* command is received, scanning of inputs is inhibited while the data is transmitted, to prevent anomalies arising from the data changing while it is being transmitted. The data is transmitted in the form of 48 lines of four readings each, with the meter number preceding each reading and a checksum for the line appended to each line.

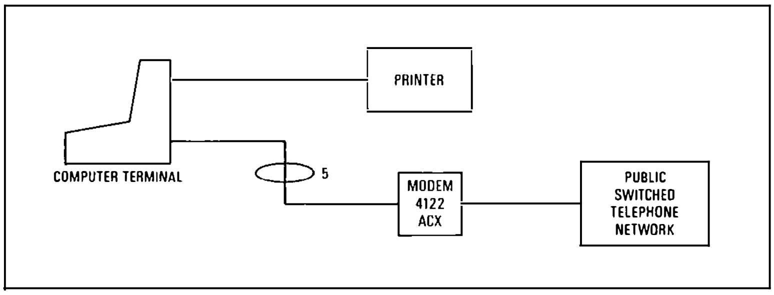
The system returns to pre-password status automatically if the carrier is lost; the system is therefore secure against a follow-on call picking up where a legitimate one left off.

The communications system has worked extremely well in practice, and no problems have been encountered.

Office Equipment

Equipment required for the planning office end of the TOMAS system consists of an IBM XT or equivalent, such as the Merlin 5000, Amstrad etc., equipped with a hard-disc system, a serial or parallel interface and 132-column printer, and serial interface and modem (see Figure 6). Generally, all of these, except, perhaps, the additional interface and modem will be available within the office environment already; thus cost is minimised.

Figure 6
Block schematic of office equipment



The modem recommended for the latest version of the TOMAS system is the 4122ACX, which offers an auto-dial facility, and allows complete automation of the system.

The software for the office machine was written in IBM BASICA and compiled under BASCOM86. It offers a comprehensive range of facilities, selectable from a number of menus, and maximum consideration was given to making the system as user-friendly and natural to use as possible, so that the system can be used with the minimum of familiarisation. Comprehensive input validation is employed to ensure that the information is reliable. Facilities are provided to compile and edit a list of exchange names and numbers for the auto-dial facility, and to edit and compile the column heading information for the print-out of results. This information can be entered by clerical staff from existing paperwork for the old system, after which it remains on disc. Once the system has been installed and this information has been entered, a single command entered once per week causes the system to dial up sequentially and extract meter information from all the TOMAS scanners in the control list, and print out either all overflow results, or only those whose readings exceed half the critical figure for the route. For the ultimate in automation, use of a scheduling program such as TIPTOK would make even this minimal degree of intervention unnecessary and reduce routine human intervention to just collecting the print-out.

Facilities are also provided to allow various degrees of manual running of the system, such as accessing a single exchange or requesting a specific print-out. A terminal emulator program is also provided, for direct access to the scanners etc.

An installation menu is also provided, which allows printer control strings and so forth for a particular installation to be set up.

The system is made secure by a password system controlling access to the scanners, while corruption of data in transit between the two modems is checked for by a system of checksums generated by the scanner software and transmitted with the data. The checksums are also generated by the receiving-end software, and the data is accepted only when these correspond. The failure of a checksum results initially in a further data request, with correct data replacing the corrupted data. Should checksum failures recur, the software assumes that the PSTN connection is too poor for data to be transferred reliably and automatically re-dials. Should this attempt fail, a message is displayed to this effect at the end of the run.

The last twenty readings from each exchange are held in individual disc files in the office machine, and the calculation of differences between successive weeks is performed when records are requested. The advantage of this technique is that the data is kept in its

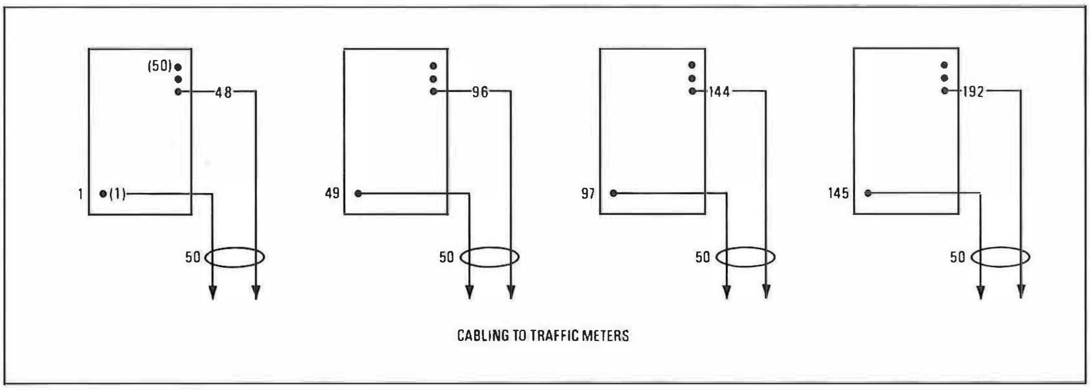


Figure 7
Rear view of cabling connections on scanner

raw form, and thus is available for processing in any way that may arise in the future.

During the first twenty weeks, each week's readings are appended to the file. As the twenty-first week's readings are added, the first week's readings are removed, so the file always contains the most recent twenty readings.

Although the hard disc units on the IBM machines are very reliable, as with any computer system, consideration should be given to data back-up procedures. The file structure used for the TOMAS software is standard in every way, and presents no problems to conventional back-up techniques.

INSTALLATION

The following notes will be helpful in considering a particular application.

The 50-wire cabling used for connecting the meters to TOMAS can be of any length provided that the signal seen by the scanner is of full earth potential. In practice, this should allow cabling to other exchange units on different floors within the same building.

The TOMAS scanner is mounted on a shelf type TP5227 or similar, as can be seen in Figure 3. The modem can be positioned quite safely on top of the case if space is at a premium, but, on the other hand, it does not need to be particularly close. An RS232 lead can be made up locally to connect the modem to the scanner, and the length of this and the siting of the modem can suit the individual requirements. The only mains power required is for the modem, and a suitable site can be selected to avoid use of temporary power extension leads.

In the case of TXE4RD exchanges, one possibility is to make use of the old TXE4 traffic recorder shelf because fully mechanised traffic recording (FMTR) has now replaced it. This shelf is already equipped with mains power.

When connections to the 50-way IDT plugs which will fit to the sockets on the rear of TOMAS are made, it should be noted that each socket corresponds to 48 input ports; therefore, there are two spare wires per cable.

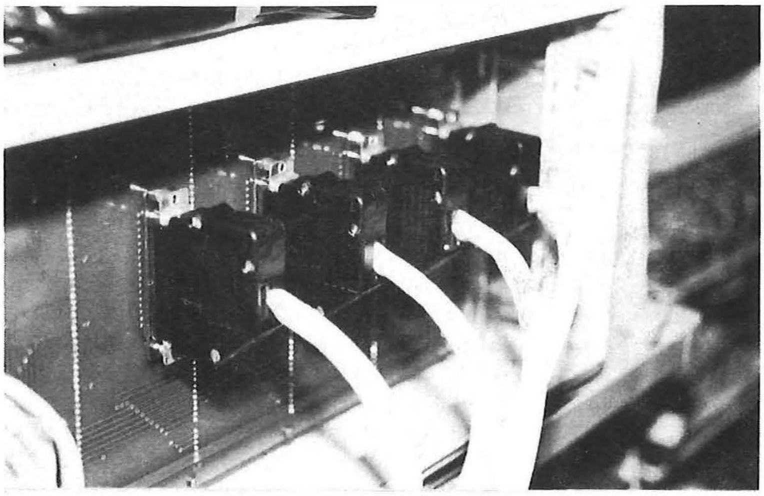


Figure 8
Cabling at the rear of TOMAS

The connections are numbered as follows:

1–48, 49–96, 97–144, 145–192.

Figures 7 and 8 clearly show these connections. The connectors used on more recent units are slightly different.

It will be useful too, if the meters are allocated in a similar order to their appearance on the existing A441 schedule for the exchange.

A schedule of connections for meters can be made by acquiring a photocopy of the A441s from the trunking and data group. Then, as the meters are wired the port number should be marked against the heading data. This will be used later by the clerical assistant to enter the heading data into the computer file for this exchange.

FUTURE APPLICATIONS

A further point of interest in the system is that its use is not confined to overflow meters only. Since the TOMAS scanner is essentially an earth-pulse monitoring device, the same hardware with different software could be used for many other applications, for example, intelligent prompt alarm monitoring etc., as well as other applications in the traffic measurement field.

CONCLUSION

The system has now been in operation for two years, and in every respect has proved to be a bonus for both the District's planning and exchange maintenance staff. The idea has aroused considerable national interest and several Districts have already placed orders. The benefits of adopting this system have given the District greater overall efficiency and have contributed to improved performance.

ACKNOWLEDGEMENTS

Grateful thanks must be conveyed to Mr. D. N. Clegg, Executive Engineer (Network Management), for encouraging the development of the original concept into a field trial unit at Stepping Hill Telephone Exchange, and for his continual support and assistance in formulating ideas. Mr. Clegg also contributed the introductory comment to this article. Thanks also go to Mr. P. N. Kirkpatrick, T2A, for his valuable work assembling the prototype.

FURTHER ENQUIRIES

Enquiries relating to the provision and system application of TOMAS should be addressed to Mr. J. M. Halton, and those relating to the technical aspects and software to the designer, Mr. P. J. Goodwin. Both can be obtained on Telecom Gold SYS 82 TMN262 or through the Manchester District Network Equipment Group by telephoning 061–600 0600.

Biographies

John Halton is Assistant Executive Engineer in the trunking and data office at Manchester District. He joined British Telecom (BT) in 1957 as an apprentice and his work experience has been in the network switching group. His current responsibilities include traffic recording liaison, STAR and in-service data management but, in addition, he is product manager for TOMAS and is responsible for its manufacture, installation and application.

Peter Goodwin joined BT as an apprentice in 1969. He spent several years as a Technical Officer on exchange maintenance, including installation and maintenance of RT13 (digital register/translator) equipment in Strowger exchanges. In 1981, he transferred to the special fault investigation group, with responsibility for 'special projects', the most recent of which was the hardware and software development of TOMAS. Since 1986, he has been a temporary level 1 on computer support for the junction network planning group, with continuing responsibility for the technical aspects of TOMAS.

Duct Laid Across the River Weaver

J. C. HOUGH†

INTRODUCTION

The River Weaver which flows from Runcorn to Frodsham was once a busy river route down to the Mersey and Liverpool docks. Although the traffic along the river has now substantially declined, the river itself remains a natural obstacle to British Telecom's (BT's) main underground/junction cable route between Warrington and Chester. Previously, 18 subaqueous cables had been buried under the river. These had been laid in two groups of nine: one group contained coaxial, audio and carrier cables, while the other had spare lengths of pressurised cable as an insurance against the possibility of damage caused by dredging or general faults occurring in the working cables.

DUCT VERSUS BURIED CABLE

In 1953, and again in 1965–66, the laying of duct across the river was contemplated but rejected for engineering and financial reasons. However, the idea was revived again in 1986 when an optical-fibre cable route was proposed for the junction and main network between Runcorn East and Frodsham.

BT's Central Marine depot undertook to estimate the costs of laying two subaqueous lengths of eight and twelve fibre cables across the 27 m river and into the duct network on either bank. Also, estimates for laying ducting across the river were obtained from four contractors. As a result, it was judged that it would be more economic to lay duct, and one contractor—Z & W Wades Ltd. of Whalley Bridge who had completed similar work in the Manchester District—was chosen to undertake the work.

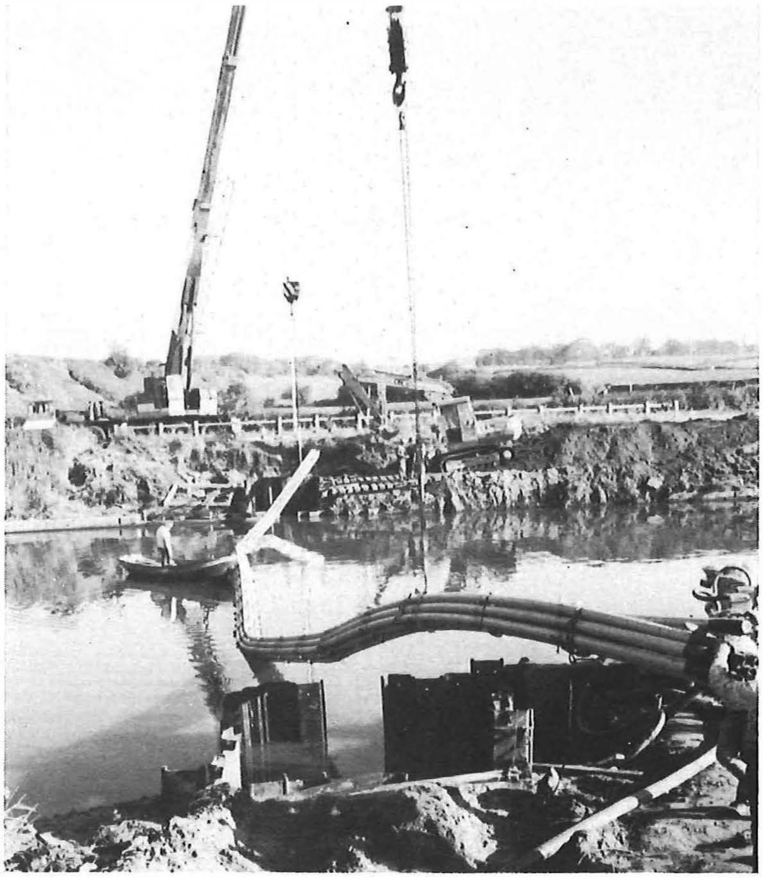
ON SITE

Work began in October 1986 with the construction of temporary coffer dams on both banks of the river at the water's edge. These were made of interlocking sheet steel that was then pile driven into the ground to form a water tight compartment; the earth inside them was then excavated so that they formed reception chambers for the duct.

Meanwhile, the British Waterway's dredger *Willow II* had begun excavating a trench across the bed of the river between the coffer dams; simultaneously 6 m lengths of polyvinyl chloride (PVC) duct 54D were laid out on the river bank to be assembled in a 3 × 3 × 3 formation in a shape that allowed for changes in the levels of the trench near each bank. Stakes driven into the ground on either side of the ducts were used to form the shape required; sharper bending was provided by the use of short lengths of duct 54D that had been manufactured with a slow bend in it. The individual sections of duct were glued together to form nine lengths, and then assembled into a nine-way configuration by using wooden formers and steel bands.

When this work had been completed, cranes on either side of the river banks withdrew a section piling from both of the coffer dams to allow the excavated areas to flood, and to provide entry points for the ducts (see Figure 1). The preformed nine-way duct formation was then attached to both cranes and hoisted out over the river and lowered so that it floated with the ends positioned in the coffer dams. Originally, it was hoped that the ducts would be installed with all their bores free

Figure 1
Lifting the pre-formed ductway into place
(note the temporary coffer dam, with a section of piling removed to allow duct entry, in the foreground)



† Liverpool District, British Telecom UK Communications

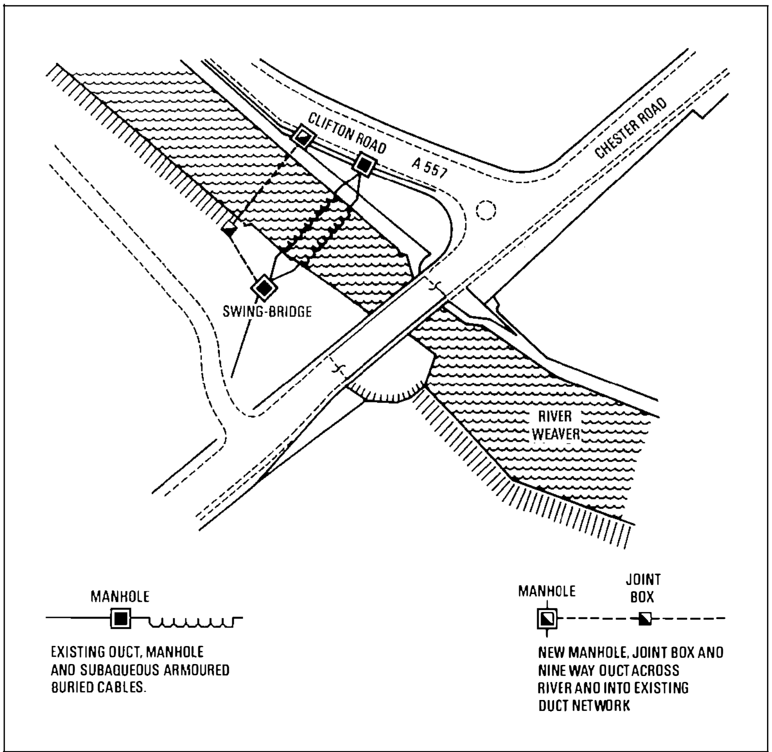


Figure 2
Locality

of water; but the air-filled pipes were very buoyant and eventually had to be flooded to enable them to be lowered into the trench that had been dredged across the river. The duct was then tested by pulling a brush and mandrel through each bore. Bags of dry lean mixture of sand and cement were placed on top of the ducts to form an anchorage, and the trench was then back-filled to return the bed of the river to its original state.

COMPLETION

A second contractor was employed to lead the river ducting into the existing network. On the Runcorn bank, the duct route was extended up to the road and a manhole was constructed on the existing track. A joint box was built on the end of the duct on the Frodsham side to provide a 45° bend, and the nine-way duct was extended into an existing manhole some 30 m away (see Figure 2).

ACKNOWLEDGEMENT

The author wishes to thank Mike Fahey, Liverpool District, for providing Figure 1.

BIOGRAPHY

John Hough joined the then Post Office in 1954 as an apprentice Y2YC. After completing his apprenticeship and two years national service in the Royal Signals, he spent some years as a T2A and Technical Officer on external works and main cable testing. He transferred to external planning in 1968, and was promoted to Assistant Executive Engineer in 1980 on miscellaneous and local line planning. In 1983, he moved over to main underground/cable junction planning.

Video Map and Imaging System

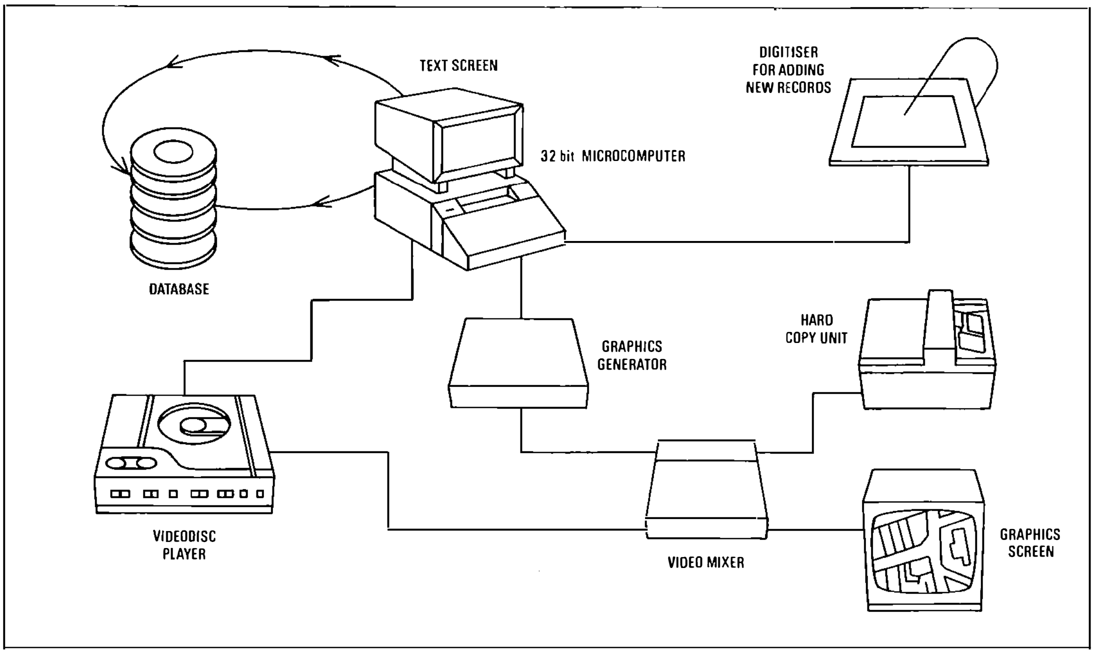
BRITISH TELECOM PRESS NOTICE

British Telecom (BT) has introduced an advanced videodisc system for displaying maps, plans, or photographs on a monitor screen and overlaying extra details by computer. The new product, known as *video map and imaging system* (VMIS), will offer local authorities, public utilities, emergency services and businesses a powerful and flexible aid to planning and operations.

VMIS enables users to call up maps or other images easily and quickly on to a monitor screen and superimposes additional graphics to show, for example, the location of specific plant, equipment or resources. Images are stored as still pictures on videodiscs. They are cross-linked to graphics and data held in a database on a supermicrocomputer.

VMIS is a revolutionary system, the keynotes of which are simplicity and accuracy. It requires no special drafting skills, and little technical knowledge is needed to operate it. Mapping information can be updated with minimum delay when changes result from development, or new building on green field sites. VMIS offers enormous power and flexibility as an aid to planners, and network and service operators of all kinds. It can also be of great help to civil authorities in dealing with emergencies by assisting them in displaying their resources rapidly to best effect. The system is highly cost-effective, requires much less computer storage and power than digital mapping systems, while being superior in flexibility, speed of up-date and ease of use.

VMIS was developed by BT's Research Laboratories with the co-operation of the Ordnance Survey. It is made and marketed by BT's International Product Division, and will be sold primarily by BT's National Account Managers. A typical main work station, consisting of videodisc player, 32 bit microcomputer with visual display unit (VDU), digitiser tablet, graphics generator, video mixer, monitor and hard copy printer, would cost less than £30 000, with a remote station at about half that.



Maps are displayed in colour on the monitor. Their videodisc images are precisely aligned with National Grid references in the computer. Maps can then be overlaid with graphics to show with great accuracy, for example, the routes of cables and pipes, or records of planning applications and the like. Associated data is displayed on the VDU.

Ordnance Survey maps are stored in a range from 1:625 000 to 1:1250, in order to allow users to 'zoom in' on an area of interest, from a view of a whole conurbation, such as Greater London, to a 100 m square. Graphics are overlaid on the 1:1250 scale map with an accuracy better than 50 cm, and a scale resolution of about 20 cm. The database correlates the Post Office's postal address file with national grid references, so that any postcode location can be pin-pointed with the same accuracy.

Images and their associated data and graphics can be transmitted easily and quickly in electronic form over communications networks. This could, therefore speed the exchange of information about underground services between public utility organisations, and avoid the need to transfer vast quantities of paper. In addition, the microcomputer supplied by BT for use with VMIS can simultaneously support standard software packages for office automation, such as word processing, spread sheets, and account ledgers.

VMIS is based on BT's M6000 series microcomputer, which uses a 32 bit high-speed Motorola MC 68020 microprocessor. The M6000 has been adopted by the company for in-house use on UNIX applications. To this basic M6000 unit, a VDU and keyboard is added, together with graphics generator and high-resolution colour display monitor, digitiser tablet, video mixer subsystem and videodisc unit.

The main computer is supplied with a variety of hard disc options for the storage of digital data and text. High-speed Winchester disc drives are used to ensure effective data retrieval. A 0·25 inch tape streaming back-up unit is used for security. Up to 16 Mbyte of random-access memory (RAM) is available, plus up to 2 Gbyte of hard-disc storage. The operating system is UNIX V.2 and the system software is written in 'C'. UNIX has become the *de facto* operating system for the new generation of supermicrocomputers. Informix structured query language (SQL), a relational database, controls the storage of text and graphics-related data.

Images are generated and controlled by a Phillips professional VP400 series Laservision videodisc player. Each disc has a capacity of 55 000 photographic images per side. Image retrieval time can be as short as 40 ms. The main capability of VMIS is its high-speed random selection of an image with the variable data associated with it. The data can take the form of symbols or text, and may be superimposed on the original images. To simplify this overlay, 64 different levels are available to the user, and these can be recalled in any desired combination. Each image can be shown at various scales and part of it selected by using the 'zoom' and 'pan' facilities of the system. The overlaid graphics are automatically increased or decreased in size in direct relationship to the scale of the displayed background image, at the same time maintaining their positional accuracy.

VMIS can be configured as a stand-alone system or networked. The network facility allows a number of workstations to be linked together, as well as giving the product an additional capability of acting as an intelligent terminal. Full X.25, SNA and Ethernet (TCP/IP) compatibility exists.

Book Reviews

International Dictionary of Telecommunication
Graham Langley
Pitman Publishing Ltd. xi + 402 pp. £24·95.

Do you know what *cable dancing* is? Or where to find a *spatially aligned bundle* or a *puff*? The author of this specialist dictionary, originally published in the USA as Telephony's Dictionary (2nd edition), does; in fact, he has provided around 16 000 definitions of telecommunications words and terms in this edition. Now an independent consultant, Graham Langley has served with British Army Signals, the overseas civil service in Singapore and Malaya and has been head of Cable and Wireless's telephone-related consultancy services.

The definitions in the book are arranged alphabetically, and technical terms take their place alongside the slang or buzzword, to make it a single compact source of knowledge for all readers. For example, on the same page as *public data network*, which the author defines as 'a network established and operated by a telecommunications administration, or a recognised private operating agency, for the purpose of providing data transmission services for the public', he places the term *puff*, the commonly accepted slang for picofarads and a nostalgic reminder of this reviewer's days as a Youth-in-Training in British Telecom.

The first 350 pages are definitions of words. Then follow another 46 of acronyms and abbreviations, and a couple of pages on SI units. The last is a useful chart of the electromagnetic spectrum—from kilohertz to terahertz and beyond, far into the regions of X-rays and gamma rays.

Except for those whose work is very specialised, or involves emerging standards where definitions take on almost legalistic import, this book will surely suffice for most people. Technicians, managers and writers will rarely need to look elsewhere.

S. Cockett

Introduction to Queueing Networks
E. Gelenbe, G. Pujolle, and J. C. C. Nelson.
John Wiley and Sons Ltd. xiv + 177 pp. £14·95.

The authors have written a useful book for the mathematically inclined engineer involved in designing or modelling communications systems or computers. It cannot, however, be recommended as an introductory text to anyone unaquainted with probability theory, Markov processes, and renewal theory, despite extensive examples at the end of most chapters. For those starting out in this field, the books by Kleinrock or Gross and Harris, for example, are better.

The topic coverage is fair, covering single-server queues as far as GI/GI/1, Jackson networks, BCMP networks, the diffusion approximation, etc. The two chapters on more recent developments in approximation methods, and on reversability and flows, are welcome. It is dissapointing, however, that no mention is made of simulation or of random access protocols (token rings, CSMA-CD systems etc.); and that the treatment of priority queues (and scheduling systems generally) is very brief. The treatment of single-server queues and Jackson networks is given a refreshingly novel slant: the authors, in each case, first develop a deterministic analysis (in the style of Buzen and Denning's operational analysis), and then develop an analogous stochastic analysis in a renewal process setting. They, of course, also present the standard Chapman-Kolmogorov approach.

The applications given are, as the authors observe, biased towards communications networks, and are mainly drawn from the field of protocols and packet networks. Numerical algorithms are given in pseudo-pascal for calculating the normalising constant of closed queueing networks. Finally, each chapter closes with a good bibliography.

M. J. Whitehead

Waves (2nd Edition)
F. R. Connor
Edward Arnold. viii + 128 pp. 75 ills. £5·50.

This book is one of a series introducing electronics and telecommunications. It is aimed at students studying for degree examinations, the examinations for HNC and HND and the Engineering Council examination. Its title is somewhat misleading, since it is really concerned with forms of line transmission. It contains sections on open and coaxial lines, strip line and micro strip, waveguides and optical fibres. It does not deal with antennas and the unguided propagation of electromagnetic waves.

The book cannot be described as an introductory text. Considerable basic knowledge is assumed on the part of the student. For example, in the section on Gunn diodes, a good understanding of the band theory of semiconductors is necessary. In some parts, the ONC- or OND-qualified reader might find the going tough. Certainly a good knowledge of calculus, including the solution of partial differential equations, is required.

On the other hand, the book has many good points. It is concise and written in a clear, direct and very readable style. There are numerous worked example problems scattered through the text, and 23 problems, together with answers, for readers. There is also a comprehensive list of further references on the subject.

The book cannot be recommended as an introductory text, but it does pack a great deal of information into a very small space. As examination time approaches, most students would find it an excellent means of drawing together their knowledge, gained from other sources, of line transmission.

R. T. Lamb

Databases in Theory and Practice
J. A. Jones
Kogan Page. 320 pp. 85 ills. £18·95.

This text provides a lucid and thorough account of databases generally, one that covers concepts, analysis, design and administration concisely but in detail. The reader is taken through a brief history of data management, and then the analysis and design of a database—illustrated with a working example and covering the most common problems that arise in this area; the maintenance and administration of the database are then dealt with and finally descriptions are given of some of the database systems available.

The presentation is good. The material is structured in a way to highlight points of major reference without the overall context of the book being lost. The style of writing is relaxed as well as informative and many useful figures and examples supplement the text.

The book is aimed particularly at the student, but will provide a helpful introduction to anyone unfamiliar with databases who wishes to learn. However, its value to those already adept in database skills is limited. It may provide a useful reference for those using CODASYL, IMS or DMSII systems; but it underplays the important role of the relational database in current data management, although the final chapter is devoted to purely relational database concepts.

The book can be recommended for the beginner, or anyone involved in one area of databases who wishes to gain an overall picture; however, its suitability for those at a more advanced level, especially if their work is within the field of relational databases, is doubtful.

A. COLLINS

Communication Network Protocols (Second Edition)
Brian W. Marsden
Chartwell-Bratt. 343 pp. £9·95.

This is the kind of book in which the author gradually pulls the reader from a position of technical innocence to one of substantial involvement. This is not limited to the techniques and principles of protocols, but also to the history of how protocols were developed—and where they fall short. Anyone in the arena of communications standards will support the importance of this kind of understanding; history and standards are interrelated and critical students should observe this fact.

Chapters 3 and 4 lay the foundations for a more detailed examination of high-level data link control (HDLC) and X.25, which follow in Chapters 7 and 8. These provide good introductions to the procedures and subtly introduce the concept of layering, which is of value when the reader reaches the Open Systems Interconnection (OSI) reference model in Chapter 14. Together with Chapter 15, which deals with the functions of the OSI Network and Transport layers in depth, a student should have enough grounding to be able to understand the actual standards and not feel intimidated. Similarly, Chapters 16 and 17 do a good job for the higher layers of OSI.

The final part of the book is devoted to local area networks (LANs); these chapters introduce the reader to the various LAN technologies, and the discussion includes not only the well-known LANs (Ethernet, Cambridge Ring etc.), but also mentions others in common use (Omninet, Econet, Clearway etc.). A chapter on the IEEE project 802 contains a discussion on the architecture and additional detail on each of the standard LAN protocols.

Throughout the book there is an emphasis on standards; an early chapter on the process of making standards is included, and, in many of the other issues discussed in the book, their relationship to standards is highlighted.

The book does, however, have some shortcomings. The author has adequately demolished the BSC protocols, but a similar critical examination of the faults in HDLC is missing. Some further elements of protocol theory could have been drawn out, especially from the Fundamental Concepts and HDLC chapters; for example, a discussion on 2-way versus 3-way handshaking is missing, Go-back-N is not mentioned, and the role of timers, and their strict disciplines in HDLC, is not discussed.

The suggestion that 'when designing protocols for LANs it is not necessary to conform to international standards' is particularly disturbing to read, and is also inconsistent with the general thrust expressed in favour of standardisation and the later discussion on LAN standards. More of the items mentioned could have had a reference to standards; for example, given the thorough discussion on BSC, no reference to the International Standards Organisation ISO 1745 (*et al*) nor the equivalent British Standard BS4505 can be found. In fact no reference to the British Standards Institute can be found in Chapter 6.

The author's personal views are evident in some places; on the process of making standards, an unsubstantiated statement is that draft proposals will fail 'especially if ANSI votes no.' His dislike of Cambridge Ring LANs is frequently evident, yet in spite of his prediction it is well on its way to becoming an ISO standard.

There are a few typographical errors; text is missing between pages 93 and 94 and there is an error in Figure 21.3.

On balance, this is a good book and it has a place on my bookshelf. It faces up to the Scylla and Charybdis of being up-to-date (and slightly amiss because the target is moving), and wholly correct (and missing new developments). It is clearly a book which will progress to subsequent editions. I would suggest that the material on ARPANET and the UK academic community protocols be dropped to make space for a more thorough examination of HDLC and the new standards for the provision of the OSI Network Service on LANs. The book is strongly recommended to those encountering the difficult business of protocols and communications standards for the first time.

A. SARSBY

Advanced Mathematics for Practising Engineers
Kurt Arbenz and Alfred Wohlhauser.
Artech House Inc. xiii + 291 pp. 116 ills. £60·00.

This book covers a useful range of mathematical topics. The style is concise and, in the easier sections at least, is clear. However, there is rather a high ratio of mathematical symbols to text which, together with the concise style, may make the more elaborate topics a little difficult for the beginner to grasp. It is not unknown for books of this kind to contain serious mathematical errors, which are usually due to unsuccessful attempts to simplify subtle mathematical points. This book is refreshingly free from such slips. Quite a few books which cover similar ground are published, and most of them suffer from two defects, which seem to be widespread in the teaching of mathematics to engineers.

While no-one doubts that mathematics is an essential tool for engineers, it is difficult to relate the formal symbols of mathematics to physical reality, and, if this is not done, it is difficult for engineers to make proper use of the mathematics that they have learned. Although many examples of applications are given in this book, very little advice is given which would help engineers to discover for themselves new applications of the techniques. Most of the methods described in this book were invented to describe physical reality, and many of the formulae and theorems have a direct physical interpretation. For example, in vector analysis, if the vector field **F** is thought of as a flow, then div **F** represents the rate at which material is created or destroyed at each point. When this is born in mind, the divergence theorem is nearly obvious, but if it is not, as in this book, the theorem can seem mysterious and difficult. There are very good reasons why mathematicians suppress the physical interpretation of the theories they study, but none of these apply to engineers; so why should books like this make it unnecessarily difficult to understand the significance of the mathematics? It is all very well to explain the purely mathematical structure of a technique, but surely it is more important to explain what it means and what it is for.

It is common knowledge that simple methods have snags, and this is no less true in mathematics than in real life. There are many mathematical techniques, particularly numerical methods, which are simple to explain and use, but which frequently go wrong when used on unsuitable data. More difficult techniques must then be used. While it is not to be expected that a book of this level should cover these advanced methods, it is sad to see that several techniques which give rise to this sort of trouble are described without any warnings about possible breakdowns. The method described for the least-squares solution of linear equations is a clear case. The iterative solution of an equation by the Newton-Raphson method depends critically on the starting point chosen, and without an a priori estimate of the root it is very difficult to find a good starting point. No discussion of the serious numerical difficulties which can arise with the iterated power method for eigenvalues is given. Much time and effort has been wasted and inaccurate results produced because of unawareness of these difficulties, particularly the three just mentioned.

The reviewer, who runs a mathematical consultancy group at British Telecom Research Laboratories, has had experience of the results of these defects, which he believes have quite serious consequences.Nevertheless, the book under review is by no means the worst example of these defects. The wide field covered should make this book useful to engineers who are prepared to work hard at coping with the sometimes rather drily mathematical explanations.

D. J. BOND

Optical Fibres
J. A. Geisler, J. P. Boutruche, and G. L. Beaven.
Pergammon Books Ltd. xiv + 635 pp. 536 ills. $150·00.

This book is one of a series produced by the European Patent Office. As such it does not fit into the usual style of educational or specialist review textbooks.

It covers the manufacture and materials of various types of optical fibre, together with connectors, fibre devices, receivers and transmitters. A significant omission is a section on optical-fibre cables, an area which is more closely related to fibre than devices.

The book is built around condensed descriptions of patents in each area; each section begins with a review of basics but then slides smoothly into a series of typically half-page descriptions of relevant patents, usually complete with diagrams. These are often used to illustrate the variety of options available; for example, for wavelength-division multiplexers, examples are given of prisms, interference filters and gratings.

Half of the book is concerned with transmitters and receivers, and most of this is aimed at the electronic circuitry required to linearise, stabilise, improve reliability and reduce impairments in transmitters and the automatic gain control, improved dynamic range and reliability on the receiver. This is a fair reflection of the engineering effort required external to the device itself.

The authors claim that they want to illustrate the present state of the art in optical fibres with the simplest examples of patents in the area, chosen from the many thousands available; and they have been successful. Although it is a book which requires close attention and is very detailed in its drawings and descriptions, it is surprisingly readable. However, even though the patent area should be five or six years ahead of the final development of its subject and act as a pointer to the future, the patent examples in the book are diverse and, because they are given equal emphasis, it is difficult to assess their practicality or likely application. Moreover, comment on the significance of the patents in the various areas would have been useful.

One salutary feature brought out by the list of patentees at the end of the book is the relatively very high proportion of Japanese patents in this area: a lesson that can be learned in Europe and the USA.

The book appears, to this reviewer, as an interesting curiosity; it neither gives confidence that any topic has been addressed fully, nor the feeling that it covers all the relevant patents in a given area, sufficient to make it less necessary to seek professional advice about patents. It does, however, certainly provide a mine of information that does not appear in conventional textbooks, and, as an additional reference book to an already well stocked collection on the subject of optical fibres, it could well prove useful.

PROFESSOR T. R. ROWBOTHAM

Telecommunication Systems
Pierre-Girard Fontolliet.
Artech House Inc. xii + 586 pp. 410 ills. £60·00.

'The Engineer is a guy who knows what to leave out'. Mr. Fontolliet's book begins with this quotation and, if length alone provides a means to judge, little has been left out. The text takes the reader from the basic requirements of communication, through specific techniques to overall systems.

The structure of the book is described in the Introduction as 'spiral' since the study of complex telecommunications systems cannot be covered in a linear sequence of chapters. In reality, the arrangement is logical, moving from overall objectives in the opening chapters to a middle section covering fundamental details of a wide variety of transmission media and transmission processes, both analogue and digital. The final chapters then draw upon the detail of the earlier parts of the book to explain and analyse complete systems such as microwave, satellite and optical links, together with networks and switching.

The treatment of the characteristics of transmission media and the process of analogue and digital transmission is thorough and sound. The diagrams, in particular, are well thought out and liberally provided. The approach adopted, which assumes some theoretical background, provides a useful transfer from the purely theoretical approach of a signal processing course to the more complex real world of communications. It is in this area that the strength and value of this book lies: it would form a useful text for a final-year option, or for an M.Sc. course in telecommunications.

For a book which purports to describe the generality of telecommunications systems, however, certain subjects receive only cursory treatment. This is especially evident in the area of switching, which is relegated to part of a single chapter; there is very little coverage of traffic calculations and none at all on the structure or design of switches, either space division or time division.

Despite its recent publication, there is a surprising lack of recent information in certain other areas of the book. This is amply demonstrated in the sections on optical fibre, where single-mode fibre scarcely receives a mention while attention is focused on multi-mode step index and graded-index fibre. The apparent discrepancy arises, however, because the book was originally published in French in 1983, and has only now been translated into English. This explains the delay, but it also gives rise to two other minor problems. Firstly, many of the references to fundamental material refer to French texts; secondly, there are several areas in which the translation gives rise to inelegant or unfamiliar English which can be disconcerting in the midst of a theoretical treatment which requires precision of meaning.

Overall the book makes a useful and readable introduction to telecommunications as a subject and to transmission in particular. It assumes much basic theory, however, and should therefore be seen as a 'conversion' text rather than a fundamental work. It would be valuable to a student of the subject but I fear the price will make it inaccessible to all but the most affluent students!

J. R. W. AMES

Product News

New Facsimile Machines

British Telecom (BT) has added two new MerlinFax facsimile machines to its range: the MerlinFax PC100, which combines a facsimile terminal and a personal computer (PC) to provide a wide range of features for the volume use of facsimile; and the MerlinFax HS20, a compact terminal with integral telephone that is particularly suited to small businesses or as a departmental terminal for large organisations.

Facsimile has grown in the UK at an average of 100% each year for the past six years, and currently over 90 000 terminals are in use; forecasts suggest that this will increase considerably. Now that the CCITT Group 3 standard is widespread, the speed and quality of document transfer means that more and more businesses are finding facsimile a cost effective and efficient means of exchanging information.

Examples of the use of facsimile abound in all spheres of business and public service: designers and copy-writers sending material for approval by clients, as facsimile is quicker and cheaper than courier; distributing weather reports to council offices so that winter road treatment keeps traffic moving; sending and receiving orders, both nationally and world-wide, since facsimile operates unattended and is unaffected by time zones.

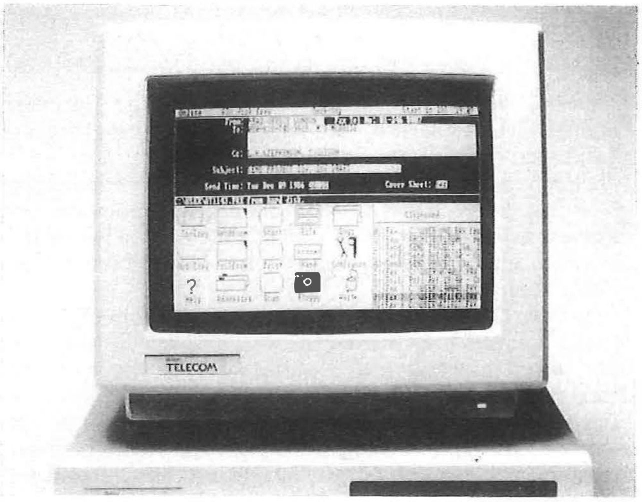
The MerlinFax PC100, with software developed by BT, provides store and forward features for facsimile linked with text processing. This means that facsimile documents can be received and combined with other prepared text, and forwarded on to other addresses as a single message. For example, a large organisation can collect various departmental reports sent from any Group 3 facsimile terminal to a central MerlinFax PC100. Other pages, such as header, index and distribution, can be prepared by using the word processing features and a complete document for retransmission collated from the separate elements.

MerlinFax PC100 is flexible in that individual pages in memory can be selected for retransmission; thus different pages of a single document can be sent to different addresses. For example, a distribution organisation can receive a total delivery listing for several different outlets and then retransmit relevant individual segments of the listing to each outlet. And any page stored in the memory can be viewed on the screen before sending or printing.

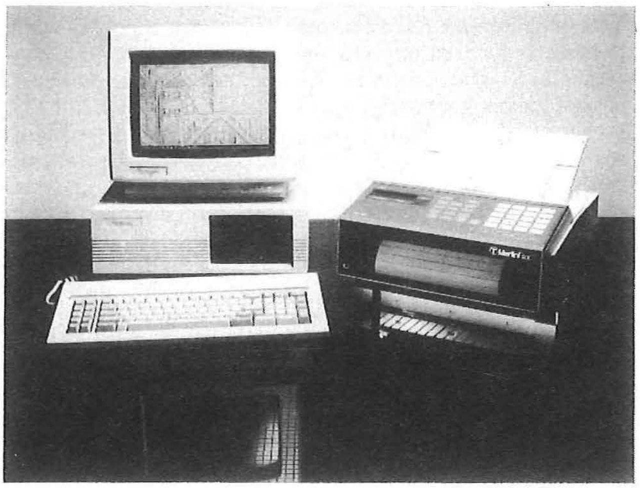
The system includes a delayed sending feature so that facsimile messages can be stored for sending at, say, cheap rate times. If the receiving terminal is busy, the PC100 makes up to four more attempts to connect. If the transmission fails part of the way through the message, the PC100 re-sends only those pages not successfully received.

Where messages are sent regularly to groups of addresses, distribution lists can be created and stored in MerlinFax PC100 so that sending is simplified. Up to 1500 addresses can be stored and these can be combined in up to 500 different groups. Once the group is selected by the operator, the message is automatically sent to each address in the group.

Operation of the MerlinFax PC100 is carried out by using the screen and keyboard of the microcomputer, and a simple icon-based menu presentation is used to provide ease of operation. In-tray and out-tray displays show immediately those documents that require attention or are being processed.



MerlinFax PC100 icon-based menu display



MerlinFax PC100

MerlinFax HS20

The growing use of facsimile for business communications has lead to an increasing demand for terminals to meet the needs of smaller businesses. BT's new MerlinFax HS20 terminal is a low-cost compact desk-top unit with integral telephone. Although small in size, the MerlinFax HS20 is well equipped with features. It works to CCITT Group 3 standards and provides compatibility with Group 2. Speed of sending is normally 9600 bit/s, and so an A4 page of print is transmitted in well under a minute. The terminal provides automatic fall back to lower speeds to ensure clear transmission in the event of a poor connection.

Single-button operation is provided for up to 20 stations, with abbreviated dialling for an additional 50. If the MerlinFax HS20 encounters a busy line, it automatically redials twice to attempt connection. An auto-timer allows the user to send a document at any pre-selected time.

The integral handset allows MerlinFax HS20 users to make ordinary telephone calls or to set up facsimile calls manually. However, if the terminal is unattended, it automatically switches to automatic operation if a call is received so that incoming facsimile messages are not delayed.

The HS20 incorporates an RS232C interface providing connection to PCs. This allows the terminal to be used as a printer and provides communication capability, via a built-in modem, to other PCs. The HS20 can also be used as a copier. Other features include polling to initiate sending from remote stations, log of all transmissions and receptions and automatic date, time and sender 'identity' entry at the top of each received page. The compact size and light weight of the MerlinFax HS20 make it easily transportable. All that is required for operation is a standard telephone socket and a 13 A power outlet.

Leopard Telex Terminal

A new Telex terminal, known as *Leopard*, is now available from British Telecom (BT). Leopard is British made and is a compact, cost-effective and flexible Telex terminal. It is modular, has modern styling and is designed so that anyone in the office can use it with ease. The new Telex terminal also replaces the successful Puma machine; it offers greater flexibility of operation together with improved features at a lower cost. The physical design separates processor unit, keyboard and printer to give flexibility in equipment layout and in choice of printer.

The keyboard incorporates a liquid-crystal display (LCD) of three lines of up to 80 characters. The display also indicates the functions of the 'soft' keys at each stage of use together with operational prompts. This makes Leopard easy to use and, if the user has difficulties, there are help features available at the touch of a key. In all, there are about 200 prompts that guide users stage by stage through each operation from message preparation and editing to sending.

Leopard can send and receive calls during message preparation. Sending can be delayed so that non-urgent calls are stored temporarily to leave the machine free for incoming calls. If the distant end is busy, Leopard will try again, several times if necessary. Multi-addressing allows the same message to be sent automatically to more than one address. Short-code dialling simplifies the calling of regularly used numbers and the optional answerback check ensures that messages do not get sent to the wrong destination.

All these features require memory, and Leopard offers flexibility here as well. Three capacities are available—24K, 56K or 88K—with upgrade capability from the lowest through to the highest. Even the smallest size is equivalent to about 4000 words of storage. To ensure that no messages are lost, the memory has battery back-up to safeguard against power failure.

Message-preparation features include a range of editing functions and, since upper and lower-case characters are available, memoranda and letters can be readily prepared on Leopard. A feature called *TelexLock* ensures that Telex messages can be prepared only in the correct format, although Leopard can also convert ordinary text to Telex format if necessary.

Leopard Telex terminal

The optional extras include a Mailbox. This allows other suitable office terminals to gain access to the Telex line either by direct connection or through dial-up telephone lines via modems. Furthermore, Mailbox allows conversational Telex operation; so, with a few simple commands, a user can have direct access from a desk-top computer keyboard to any of the 2 million or so Telex terminals around the world.

A large liquid-crystal display screen which provides up to 20 lines of 80 characters is also available. This makes message preparation easier by showing more of the message. When this option is fitted, the 'soft' key prompts and date and time are shown permanently on the keyboard LCD.

Notes and Comments

QUARTERLY REVIEW

On 26 March, a £5·7M contract was signed for an unrepeatered undersea optical-fibre communications cable running 135 km between Guernsey and the South Devon coast near Dartmouth. The contract was awarded jointly by British Telecom (BT) and the Telecommunications Authorities of Guernsey and Jersey to STC Submarine Systems. This cable is being provided under modernisation programmes which are bringing customers the benefits of digital services. The new cable will have six fibre pairs of which two will be in use immediately the cable comes into service. The system will operate at 140 Mbit/s and will use single-mode technology with high-performance lasers operating at 1·535 μm wavelength.

A contract for another long unrepeatered undersea fibre system was placed in early April for a link between the UK mainland and the Republic of Ireland. The cable will run 126 km between Holyhead, on the North Wales Island of Anglesey, and Port Marnock in the Republic. The contract has been awarded jointly by BT and Telecom Eireann to Submarcom. The cable will be laid by a BT cable ship using the company's submarine plough, which will bury the cable about 1 m below the sea bed to avoid risk of damage.

A contract worth more than £700 000 to upgrade one of BT's television earth terminals at the London Teleport in the Docklands has been awarded to Marconi Communication Systems. The equipment to be supplied, installed and commissioned by Marconi comprises three 14 GHz 2 kW HPAs, seven 14 GHz transmit systems, four 11 GHz receive systems, control and supervisory equipment, waveguide components and a test translator.

A new premium telephone information service, *Customcall*, was launched in April by BT. Customcall enables independent service providers to sell high-value information, consultancy or data to customers, with calls connected by BT's operator service and the telephone system. Most services will offer factual or advisory information, but in some instances recorded information will be supplied.

To make use of Customcall, customers dial 100 for the operator and ask for the service required by name. The operator then connects the caller to the appropriate service and arranges for the fee to be itemised separately in the customer's telephone bill. By providing access through the operator, a single set fee can be charged for each call, regardless of its duration.

The length, content and pricing of each call will be decided by the service provider. However, service providers will be required to adhere to the Code of Practice established for premium information services over the telephone. This Code is being extended to include live as well as recorded information services.

In-flight trials of the first world-wide satellite telephone service for air travellers will start this autumn. British Telecom International (BTI) and the telecommunications authorities in Norway and Singapore are to work towards providing global coverage for the 'phones on planes' service, which BTI will launch on transatlantic flights next year. BTI's Skyphone service will allow passengers to make their own telephone calls from aeroplanes and they will pay by credit card only. The service will also cater for telephone and data message facilities for airline operations.

Passengers will be able to use press-button telephones mounted on the walls or on seat-backs. Initially, it will not be possible to receive incoming calls. A special antenna mounted on the aircraft transmits the signals to the INMARSAT satellite, where they are downlinked to the earth station, and then automatically switched to the public telephone service. A dedicated earth station at Goonhilly Downs in Cornwall is available for the BTI Skyphone service, and similar new earth station facilities will be provided in Norway and Singapore.

BTI Skyphone is the result of a collaborative agreement between BTI, Racal-Decca and British Airways. In-flight tests of the new service are due to take place in October. Passenger trials on British Airways 747 transatlantic aircraft will begin next spring, with a service available to all airlines in December 1988.

In April, BT announced the introduction of 'talking' telephone bills for its blind and visually-impaired customers. This initiative from BT's Action for Disabled Customers in conjunction with the Royal National Institute for the Blind (RNIB) will help these customers gain greater independence. Instead of bills being sent through the post in the normal way, they will first be sent to one of BT's local area offices who will telephone the customer, give details of the bill and advise on the ways of paying it. The bill will then be forwarded to the customer by post.

BT is to open 60 new retail shops in Britain's major high streets and shopping precincts over the next three years. BT's retailing was previously developed under the *Phoneshop* banner, but most of the outlets were concessions in department stores, or as part of BT office premises, and often well away from where BT's customers normally shop. All the shops will be in thriving shopping areas serving a population of more than 100 000.

Each shop will provide the public with a wide-ranging service for their communications needs. The latest range of telephones will be on open 'live' display and will allow customers to listen to ringing tones and pre-recorded messages before they choose the product they would like to buy or rent. The shops will offer the full range of BT telephones, answer/record machines, accessories and DIY extension kits, as well as products from other leading manufactures. Customers will also be able to pay bills, and a service point will answer enquiries about all types of BT services.

Within the same premises, a business centre—aimed at the smaller end of the business market—will display a wide range of equipment such as small switch systems, Telex and facsimile machines, cellular telephones and radiopagers. An electronic point-of-sale system will ensure that central management is fully aware of each shop's performance and that stock availability meets customers' requirements.

BT has ordered a new £4·7M gateway Telex exchange for operation early next year. The new computer-controlled Eltex V exchange, to be supplied by STC Telecommunications, will be installed in the City of London. With 10 000 lines, it will be the world's second largest international Telex exchange, after British Telecom International's Keybridge

House installation. The existing international exchange at the St. Botolph's site, which will gradually be phased out, has 8000 lines. The capacity of Eltex V is made up of 7700 direct lines and 50 time-division multiplex systems, each of 46 lines.

BT is extending its international 0800 Freephone service to cover most of Western Europe. Finland, Italy, Norway, Belgium and Spain will join Denmark, France, the Netherlands, Sweden, West Germany, Switzerland, Australia and the USA, where the service is already available. Reciprocal arrangements will be available between the countries taking part, and it is intended that the service will ultimately be available across the whole of Western Europe and other major markets abroad. The participating countries are all members of the European Conference of Postal and Telecommunications Administrations (CEPT).

For businesses in the UK and abroad, who pay for incoming calls on their special Freephone numbers, the service offers novel marketing opportunities. Known in continental Europe as the *Green Number* service, International 0800 serves a wide variety of business needs including retail sales, travel and hotel reservations and easy telephone access for contacts and employees calling from overseas. Callers using the service dial locally-recognised Freephone telephone codes, such as 0800 in the UK, 05 in France and 06 in the Netherlands. No special equipment is needed to join the service. Companies are simply allocated special Freephone numbers in each of the countries where they wish to offer the service, and they can answer the calls on their existing telephone lines.

Any business with a personal computer will be able to send and receive Telex messages by using its own dedicated Telex number with a new service launched by BTI. TextDirect provides a link between the Telex network and most word processors and personal computers. The only additional equipment that users may need is a modem to enable terminals to communicate over the telephone network, and the appropriate communications software. Messages can be typed direct from the keyboard or prepared off-line in advance before being sent over ordinary telephone lines to the TextDirect computer in London. Messages are delivered to the Telex network via BTI's Telex Plus service, which provides store-and-forward facilities. Incoming messages are stored on the Text Direct computer to be retrieved by the user when convenient. A password system assures security.

BT is streamlining its major purchasing activities, currently worth about £1800M a year, to cut costs and improve efficiency. The former Procurement Executive has been replaced by a new Materials Executive which is responsible for the bulk of BT's purchasing for the company's operating divisions. It also provides national warehousing, distribution and other services, such as quality assurance and materials and components analysis. The Executive's purchasing activities will be carried out by a new unit—Materials Procurement—which brings together the procurement work of BT's two previous main purchasing units—the Materials Department and Major Systems Procurement.

Mr. Roy Peacock, formerly Deputy Director of Major Systems Procurement, has been appointed Director, Materials Procurement. He will be responsible for the supply of System X and AXE10 digital local exchanges, digital transmission systems and cable, computers and cable television equipment. Mr. Peacock's units will also provide technical service support, advice and assistance to other BT divisions for special procurement projects. The new nationwide warehousing and distribution unit, set up under the rationalisation within the Materials Executive, will, with its associated computing system, ensure that goods bought by BT arrive at the places where and when they are required. Overall responsibility for all BT procurement remains with Mr. David Pentecost, Chief Procurement Officer and head of the new Materials Executive.

Dr. John Spackman, who until 1 April was Director of Operational Strategy in the Department of Health and Social Security, joined BT on 1 July as Director of Computing. This is a new appointment in which Dr. Spackman will be responsible for BT's internal computing systems needs as a whole. He will formulate policies and progress the programme of commercial systems development. Dr. Spackman will also have line management responsibility for computing in BT's newly-formed UK Communications Division. Working to him will be the general managers responsible for systems development, including the Customer Services System (CSS) project, and computer operations and technical services.

Professor Eric Albert Ash, C.B.E., F.R.S., F.ENG., has been appointed as a non-executive Director of BT.

BT has been awarded a £130M Ministry of Defence contract to design and undertake the construction of a digital communications network for the RAF's project BOXER. Project BOXER will provide secure and fully protected fixed telecommunications links to more than 200 sites throughout the UK. It is the single biggest defence contract ever won by BT.

BT was selected, as a result of rigorous competitive tender, to undertake the initial project definition study and is now appointed prime contractor for the implementation of the optical-fibre and microwave radio transmission links which are major elements in the fixed telecommunications network. STC plc are appointed sub-contractors for the long-haul optical-fibre installations as part of the contract, which specifies maximum use of competitive tendering for other sub-contract work. In addition to linking RAF installations, project BOXER will also serve Royal Navy, NATO and other defence users with communications links.

Orders worth £4M have been won by BTI from two leading Japanese business houses. BTI is supplying private telecommunications networks to enable Matsushita Electric Trading Company and the Marubeni Corporation to speed up inter-office data and text communication between Tokyo, London and New York. The service, known as ***Primex Special***, gives these customers a private international packet-switched network for integrating facsimile, teleprinter, teletex and data transmissions. These networks incorporate use of a new technique which automatically converts Telex messages to facsimile format.

BT is to play a major role in the development of a Pan-European digital cellular radio network as a result of an agreement made in Bonn on 19 May between the UK, France, West Germany and Italy. Mr. Geoffrey Pattie, formerly Minister for Information Technology, who had responsibility for telecommunications in the UK, met with his counterparts from France, West Germany and Italy to endorse a narrowband standard for the new network. The four countries have now agreed to work towards a commercial service on the new network by 1991. This will allow customers to use their telephones wherever they are in each of the four countries.

In May, the Department of the Environment (DOE) announced its decision to list a further 400 telephone kiosks as being of special architectural and historic interest. The DOE and BT are to work with English Heritage to identify a representative sample of post-1939 kiosks worthy of preservation. The extension follows the DOE's recent decision that listing can be given to buildings 30 years old and more. Previously, only pre-1939 buildings qualified for listing.

LIVE-NET, the interactive video network developed jointly by BT and the University of London, was officially opened on 28 May 1987 by Her Royal Highness the Princess Anne, Chancellor of the University. The service will link seven of the University's sites across London to allow simultaneous lectures, tutorials and meetings. LIVE-NET uses equipment which was developed by BT for use in advanced cable television systems, such as the one being installed in the City of Westminster. British Telecom Vision, the division responsible for cable television applications, has helped develop the system to the specific needs of an organisation like the University.

The opening marked the end of the first significant stage of the project—the installation of optical-fibre links to the seven university sites, and of the computer-controlled switch at the centre of the system. Trial operations began last October and an intensive development phase is continuing, to devise the software and hardware to make LIVE-NET remotely controllable by all users without the need for any central studio control or local technical staff. This development work is a central part of the co-operative agreement between BT and the University. The intention is to develop a package that allows any organisation to take advantage of the flexibility of private switched-star video networks.

On June 11, the Gibralter Government announced that it is to set up a joint venture company with BT to run Gibralter's international telecommunications services. BT will have a 50% shareholding in the new company, which will be granted a 20-year licence to operate the services, commencing in January 1988.

FIRST STEP TO BECOMING A QUALIFIED ENGINEER

The Engineering Council, which sets relevant professional, educational and training standards for engineers and technicians, has started to register people who have gained either a degree, a Higher National Certificate or a National Certificate in engineering—the first step towards becoming a qualified engineer.

Previously, the Engineering Council, which has 300 000 Chartered Engineers, Technician Engineers and Engineering Technicians on its official Register, has registered engineers in those three categories only after they have completed three stages: achieved the exemplified academic standard (known as *Stage 1*), completed an approved training period (*Stage 2*), and gained acceptable experience and professional responsibility (*Stage 3*).

The Council's Board for Engineers' Registration has now approved the first list of candidates for registration at the Stage 1 academic level.

The Engineering Council urges people to register as soon as they have gained a recognised degree, Higher National Certificate or National Certificate qualification so that they can quickly proceed towards their objective of becoming qualified engineers in one of the Council's three categories. The Council and the professional engineering institutions will be able to advise and encourage young entrants.

The Council's titles and designatory letters of Chartered Engineer (C.ENG.), Technician Engineer (T.ENG.) and Engineering Technician (ENG.TECH.) are recognised guides to the competence and standards achieved by registered engineers, and denote qualifications recognised nationally and internationally.

PUBLICATION OF CORRESPONDENCE

A regular correspondence column would make a lively and interesting feature in the *Journal*. Readers are therefore invited to write to the editors on any engineering, technical or other aspects of articles published in the *Journal*, or on related topics. Letters of sufficient interest will be published under 'Notes and Comments'. Letters intended for publication should be sent to the Managing Editor at the address given below.

DISTRIBUTION OF THE JOURNAL

Many IBTE Members and other employees of British Telecom and the Post Office who subscribe to the *Journal* by deductions from pay have still not yet supplied their home addresses to the IBTE Administration Office so that copies of the *Journal* can be sent directly to their homes. Back issues of the *Journal* since October 1985, when this new method of distribution was started, are being held in store for these Members and readers until this information is received. Members and readers are asked to remind their colleagues to supply this information as soon as possible if they have not already done so; a form for this purpose was included with the April 1985 issue of the *Journal*. These Members and readers will then be sent the back issues and all future issues to their home address. Any enquires about this notice should be directed to The IBTE Administration Manager, Room 107 Intel House, 24 Southwark Bridge Road, London SE1 9HJ; Telephone: 01–928 8686 Extn. 2233.

CONTRIBUTIONS TO THE JOURNAL

Contributions of articles to *British Telecommunications Engineering* are always welcome. Anyone who feels that he or she could contribute an article (either short or long) of technical, managerial or general interest to engineers in British Telecom and the Post Office is invited to contact the Managing Editor at the address given below. The editors will always be pleased to give advice and try to arrange for help with the preparation of an article if needed.

Educational Papers

The Editors would like to hear from anyone who feels that they could contribute further papers in the series of educational papers published in the *Supplement* (for example, see the paper entitled *Digital Multiplexing*, included with the April 1986 issue of the *Supplement*. Papers could be revisions of British Telecom's series of *Educational Pamphlets* or, indeed, they could be completely new papers. It is intended that they would deal with telecommunications-related topics at a more basic level than would normally be covered by articles in the *Journal*. They would deal with, for example, established systems and technologies, and would therefore be of particular interest to newcomers to the telecommunications field, and would be useful as a source for revision and reference and for those researching new topics.

Intending authors should write to the Deputy Managing Editor, at the address given below, giving a brief synopsis of the material that they would like to prepare. An honorarium would be offered for suitable papers.

EDITORIAL OFFICE

All correspondence relating to editorial matters ('letters to the editor', submissions of articles and educational papers, requests for authors' notes etc.) should be sent to the Managing Editor or Deputy Managing Editor, as appropriate, at the following address: *British Telecommunications Engineering*, Room 107, Intel House, 24 Southwark Bridge Road, London SE1 9HJ. (Telephone: 01–928 8686 Extn. 2233.)

THE INSTITUTION OF BRITISH TELECOMMUNICATIONS ENGINEERS

(Founded as the Institution of Post Office Electrical Engineers in 1906)

General Secretary: Mr. J. H. Inchley, LNS2.1.1, Room 543, Williams National House, 11–13 Holborn Viaduct, London EC1A 2AT; Telephone: 01-356 9020.
(Membership and other enquiries ahould be directed to the appropriate Local-Centre Secretary as listed on p. 251 of the October 1986 issue.)

CHANGES OF ADDRESS—LOCAL-CENTRE SECRETARIES

Aberdeen

The new address for Mr. A. T. Mutch, Secretary of the Aberdeen Centre, is D2.1.6, New Telecom House, 73–77 College Street, Aberdeen, Scotland AB9 1AR.

Manchester

The new Secretary of the Manchester Centre is Mr. J. M. Asquith, NE20, Telecom House, 91 London Road, Manchester M60 1HQ. (Tel: 061–600 2947.)

Martlesham Heath

The new Secretary of the Martlesham Heath Centre is Mr. K. R. Rose, R18.1.1, British Telecom Research Laboratories, Martlesham Heath, Ipswich IP5 7RE. (Tel: 0473 642676.)

North Downs and Weald

The new Secretary of the North Downs and Weald Centre is Mr. N. Smith, NP4, Telephone House, Rheims Way, Canterbury, Kent CT1 3BA. (Tel: 0227 474594.)

Scotland East

The new Secretary of the Scotland East Centre is Mr. B. Curry, NJ3, Telephone House, 357 Gorgie Road, Edinburgh EH11 2RP. (Tel: 031 345 4218.)

CONSTITUTION OF THE COUNCIL FOR 1987–88

Chairman: Mr. J. Tippler.
Vice-Chairmen: Mr. A. B. Wherry, and Mr. A. F. Beardmore.
Honorary Treasurer: Mr. R. New.
President, Associate Section: Mr. A. G. Bealby.
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Mr. B. Fielder, South West.
Mr. R. D. Hooker, South East.
Mr. R. A. Fry, East.

AMENDMENTS TO THE RULES OF THE INSTITUTION

Rules 55–63:

All references to Area and Regional Liaison Officers shall be changed to District Liaison Officers.

All references to Regional Committees shall be changed to Inter-District Committees.

Additional Rule 63X:

The Associate Section National Executive Committee may at its discretion recommend to Council individuals who have rendered outstanding service to the Associate Section of the Institution for consideration for the award of Honorary Membership of the Associate Section of the Institution.

HONORARY MEMBERSHIP

Council has approved two nominees for Honorary Membership—Mr. J. F. Boag, and Mr. B. Farr.

For the four years prior to his retirement from British Telecom in April this year, John Boag served as Chairman of the Institution; during his period of office, he was largely responsible for introducing the recent large-scale organisational changes within the Institution. He was also responsible for establishing a much closer relationship between the *Journal* and the Institution, which culminated in a full-time membership secretary being established within the *Journal* office; this has enabled the home mailing of members' *Journals* to be introduced.

John joined the British Post Office in 1944 as a Youth-in-Training at Aberdeen. After service in the REME, he returned to repeater station maintenance in Aberdeen; this was followed by service as a demonstrator at the Regional Training School, Edinburgh, and, after promotion to Assistant Executive Engineer, on repeater station construction work at the TAT1 terminal, Oban. He moved to Telecommunications Headquarters in 1958 as an Executive Engineer engaged on systems engineering work connected with the US–Bermuda and COMPAC submarine cable systems; he was promoted to Senior Executive Engineer in 1965. During 1967–68, he was seconded to COMSAT, in Washington DC, where his systems engineering experience was put to good use on various INTELSAT satellite systems. Returning to the UK, he was promoted to Assistant Staff Engineer with responsibility for microwave radio-relay construction and then for network planning, a task which he continued as Head of Division. It was during this period that the plans for the digital trunk transmission network were formulated. In 1975, he began a period of consultancy work which led to the creation of British Telconsult in 1979 and to his appointment as General Manager of the new organisation. Under his guidance, consultancy work grew rapidly into a multi-million-pound business. He became

Director of the Overseas Liaison and Consultancy Department and then, in 1983, joined British Telecom National Networks as Chief Executive Trunk Services. He returned to the Overseas Division in 1986 and at his retirement was Chief Executive Consultancy and Network Investment Group.

John's successor as Chairman of the Institution is Mr. J. Tippler.

Brian Farr has served as Secretary/Treasurer of the *Journal* for the past 30 years; he has also recently retired from British Telecom and, at the time of his retirement, was Territorial Personnel Manager for the South of England and Wales. During this time, under several editors, the Journal organisation has produced some 120 issues of fine quality, which have been of enormous benefit to current and previous generations of engineers. For the time being, Brian continues serving the *Journal* as Secretary/Treasurer in his retirement.

RETIRED MEMBERS

The following Members have retained their membership of the Institution under Rules 10(*a*) and 13(*a*).

D. Archer	1 Cliff Road, Felixstowe, Suffolk IP11 9PP
J. G. Ashe	31 Pine Avenue, West Wickham, Kent BR4 0LN
K. F. Aubertin	57 Bishops Way, Egham, Surrey TW20 8EJ
G. Austin	38 Willow Crescent, Hatfield, Peverel, Chelmsford, Essex CM3 2LJ
A. R. Belson	23 Barby Lane, Rugby, Warwarkshire CV22 5QJ
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J. G. Brooks	3 Carr Manor Road, Leeds, West Yorkshire LS17 5AY
A. R. Brown	23 Treworder Road, Truro, Cornwall TR1 2JZ
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G. E. F. Clarke	17 Warden Court, Cuckfield, Haywards Heath, West Sussex RH17 5DN
K. H. Clarkston	18 Eltham Park Gardens, London SE1 1AW
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P. W. Constable	5 Albemarle Road, East Barnet, Hertfordshire EN4 8EQ
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B. Copping	Elmthorne, 61 Pettitts Lane, Dry Drayton, Cambridge, Cambridgeshire CB3 8BT
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G. H. Emmerson	Shereen, 25 Fairhaven Avenue, West Mercea, Colchester, Essex CO5 8EZ
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G. G. Johnson	7 Dunmail Avenue, Blackpool, Lancashire FY3 9PG

P. W. Lancaster	Bassington House, Smith Cutter Lane, Middleton Tyas, Richmond, North Yorkshire DL10 6QY
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E. J. Simpson	14 Mackenzie Street, Carnoustie, Angus DD7 7NR
J. Smith	18 Mayfield Court, Mayfield Road, Moseley, Birmingham, West Midlands B13 9HS
G. G. Stephens	54 Wendley Drive, New Haw, Weybridge, Surrey KT15 3TR
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D. Strachan	56 Gamekeepers Road, Edinburgh EH4 6LS
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G. A. Whiting	25 Obthorpe Lane, Thurlby, Bourne, Lincolnshire PE10 0ES
A. D. Williams	18 Broadacres, Leckwith, Cardiff, South Glamorgan CF1 8DD
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B. J. Woollett	9A Old Hill, Avening, Tetbury, Gloucestershire GL8 8NR
L. Wright	2 Conway Close, Whitefield, Manchester M25 7AZ

Members about to retire can secure life membership of the Institution at a once-and-for-all cost of £10·00 and so continue to enjoy the facilities provided, including a free copy of this *Journal*. Enquiries should be directed to appropriate Local-Centre Secretary.

THE INSTITUTION OF BRITISH TELECOMMUNICATIONS ENGINEERS

(formerly The Institution of Post Office Electrical Engineers)

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FITCE is an organisation with similar objects to IBTE and draws its members from the public telecommunications administrations of Belgium, Denmark, Eire, France, Greece, Italy, Luxembourg, the Netherlands, Spain, Portugal, the UK and West Germany. FITCE publishes a quarterly Journal from its Brussels headquarters, sponsors multi-national study groups (Commissions) to enquire into and report on problems of general interest, and each year organises a General Assembly/Congress in one of the member countries.

Full membership of FITCE in the UK is available only through IBTE. Members and Affiliated Members of IBTE who hold a University science degree or who are Chartered Engineers may join through the FITCE Group of IBTE. The annual subscription for 1987/8 is £5·00; this covers local administration expenses as well as the *per capita* contribution to FITCE funds, and thus ensures that no charge proper to FITCE affairs will fall upon the general membership of IBTE. Membership forms are available from your Local-Centre Secretary or direct from the Assistant Secretary (FITCE), Mr P. A. P. Joseph, OC1.3.1, Room 21, Cheyne House, Crown Court, Cheapside, London EC2V 6BE; Tel: 01-248 9073.

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