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THE BT TELECOMMUNICATIONS NETWORK

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CONTENTS

INTRODUCTION

This paper briefly describes the British Telecom telecommunications network which, at the end of 1988, served over 23 million exchange connections and is the fifth largest network in the world.

The paper will concentrate on the integrated digital network that is rapidly being deployed to replace the previous analogue network. BT is currently spending about £3M each day in modernising and expanding its basic telephone network. Two new local digital exchanges are being commissioned, on average, every working day and, by the end of March 1989, about 7 million lines of capacity were in service on nearly 3000 exchanges. The new digital trunk network, comprising 53 digital main switching units (DMSUs), is in place and carrying over 75% of trunk traffic and will be fully loaded in 1990.

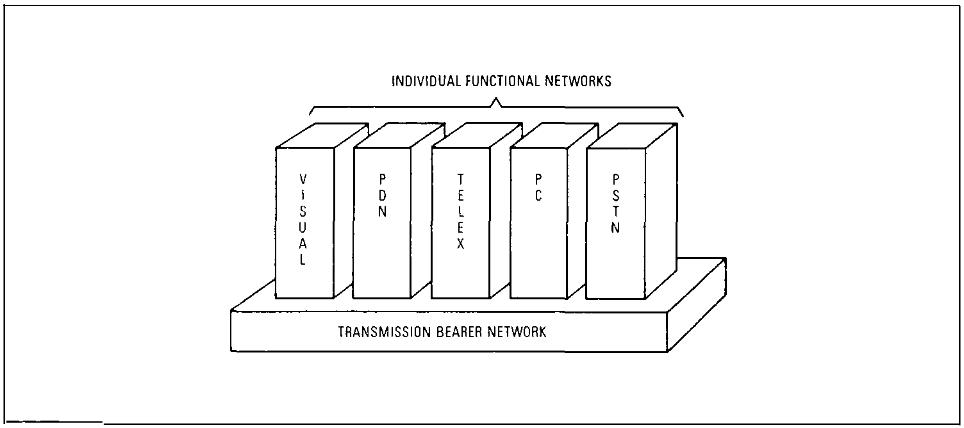
The decision to modernise the network stems from computer-assisted network studies undertaken in the 1960s, when it was recognised that the then analogue network could not economically provide for future requirements of customers. The results of the studies led BT to pioneer the development and use of digital switching and transmission systems in an integrated manner.

MODERNISED NETWORK

The modern telecommunications network is analogous to a Rubic Cube (see Figure 1). It can be considered as a series of layers in both the vertical and horizontal planes and, like the Rubic Cube, the two dimensions of planes have to be properly aligned to achieve a viable solution.

The BT network comprises a bearer transmission network which carries a number of separate functional networks each in turn supporting a number of network services.

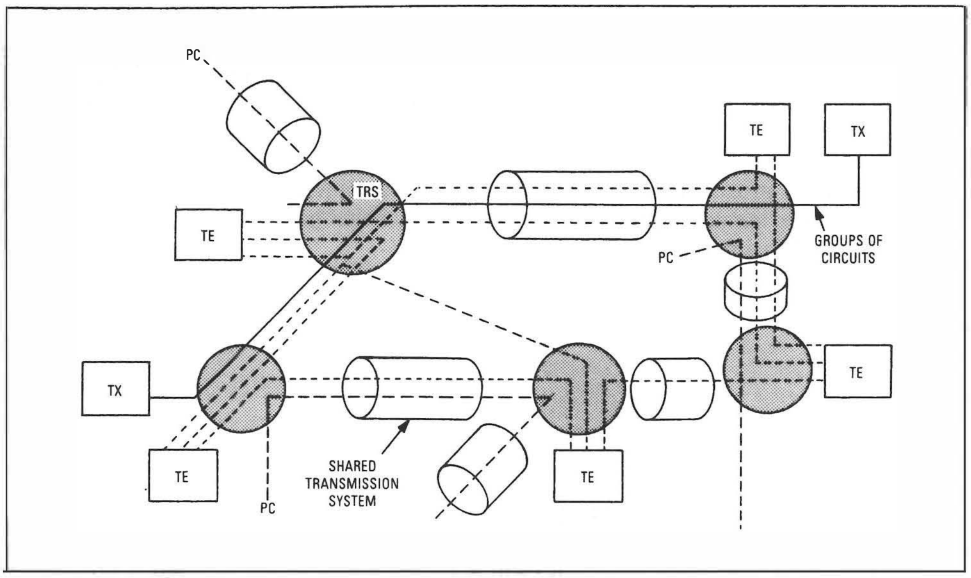
Figure 1
Bearer and functional networks



PSTN: Public switched telephone network PC: Private circuits PDN: Public data network

TRANSMISSION BEARER NETWORK

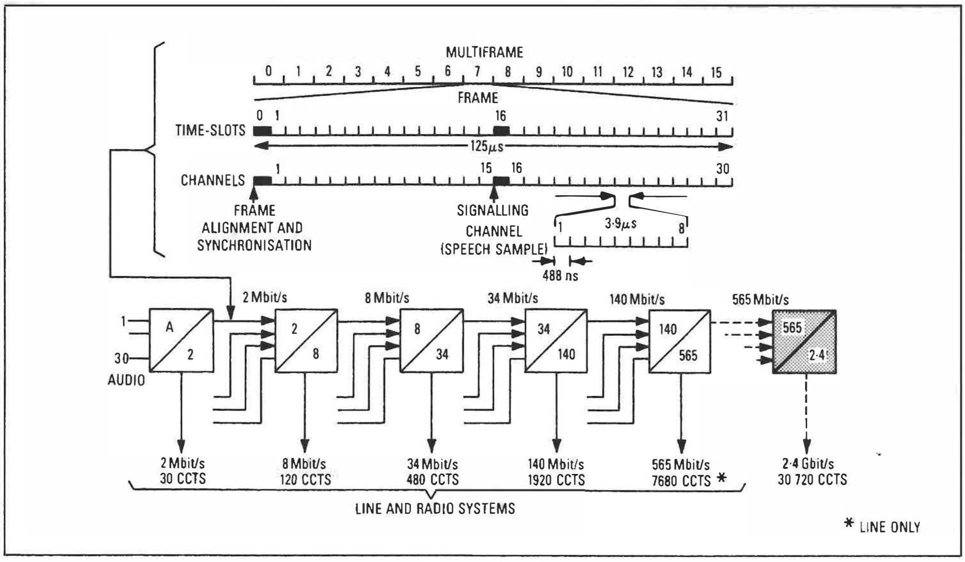
The transmission bearer network consists of a large number of transmission systems each carrying a large number of circuits used to interconnect the switching nodes of the various function networks. The systems are interconnected at flexibility nodes known as *repeater stations*. A highly meshed network of large capacity systems comprises the core which interconnects smaller systems fanning out at the periphery (see Figure 2).



TRS: Transmission repeater station   TE: Telephone exchange   TX: Telex exchange
PC: Private circuit

Figure 2
Shared capacity in the transmission bearer network

The introduction of digital transmission systems into the British Telecom network began during the 1960s with the installation of 24-channel PCM systems operating at 1·5 Mbit/s on existing deloaded audio cables. However, these systems have now been superseded by 2 Mbit/s systems to the CCITT recommended structure, carrying 30 telephony channels per system each with a bandwidth of 64 kbit/s. On larger transmission routes, economies of scale can be obtained by using higher capacity systems at bit rates of 8, 34, 140, and 565 Mbit/s. Figure 3 shows the multiplexing structure now being used in the BT network.



CCTS: Circuits

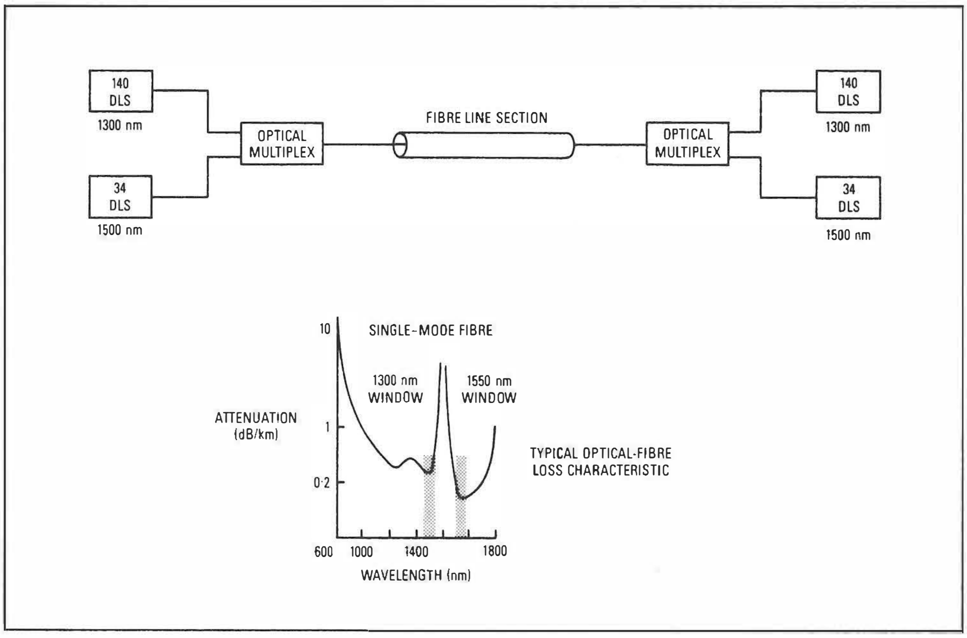
Figure 3
Digital multiplexing hierarchy

Initially, non-standard 120 Mbit/s and early 140 Mbit/s digital transmission systems were installed on existing coaxial cables, mainly small bore containing between 4 and 12 coaxial pairs, two pairs being required to provide a bothway system. Also, early 8 Mbit/s systems were installed on pair-type cables previously used for analogue carrier systems. However, the economic and other advantages of optical-fibre systems are now so significant that no new coaxial systems are being planned for the BT network.

Optical-fibre systems have a number of significant advantages for the transmission network. There are no buried regenerators, they have the potential for a vastly increased capacity without the need to introduce additional intermediate regenerators, and they are expected to have increased flexibility in terms of the spacing between surface regenerators. 140 Mbit/s single-mode optical-fibre systems are therefore being installed, mainly on 12 and 18 fibre cables, but latterly on 48 and 88 fibre cables. At the end of 1988, over 2000 such systems had been installed in the network.

To meet the increasing demand for capacity, the size of digital transmission systems is being increased to 565 Mbit/s, carrying 7680 channels. A number of such systems are already working in the network and others are on order. Systems with even higher capacities of 1·2 Gbit/s (15 360 channels) and 2·4 Gbit/s (30 720 channels) are expected to be introduced. Indeed, a trial 2·4 Gbit/s system has already been successfully demonstrated in the actual network. Other methods of exploiting the high bandwidth of fibre that have been trialled in the network are the use of bi-directional couplers to give two-way working on a single fibre and the use of wavelength-division multiplexing (WDM) to use simultaneously the two principle (low loss) operating windows of optical fibre at the 1300 and 1550 nm wavelengths. Figure 4 shows a current use of WDM in the trunk network.

Figure 4
Wavelength-division multiplexing



DLS: Digital line system

Radio Network

The BT microwave radio network comprises over 200 radio stations. The analogue systems are being replaced by digital systems operation in the 4, 6, 11 and 19 GHz frequency bands, each providing between six and eight bothway 140 Mbit/s channels. The 11 GHz band was first to be used for digital transmission, but systems currently being introduced utilise the radio spectrum more efficiently by using a modulation technique known as *64 QAM* (quadrature amplitude modulation). Even more efficient modulation methods (256 QAM) are being developed that will enable 565 Mbit/s channels to be carried on radio systems.

Because of the need to use existing radio stations originally provided for the analogue radio relay network, two complexities have had to be overcome.

Firstly, the relatively long hop lengths of the BT microwave network, many being more than 50 km, restrict system performance during periods of anomalous radio fading activity unless special countermeasures are adopted. Considerable use is made of both space diversity, that is, two aerials mounted in different positions on the radio tower so that there is usually a strong signal from one of them during fading conditions, and the use of adaptive transversal equalisers to correct for amplitude and phase distortion due to fading.

Secondly, the conversion from analogue to digital operation in the same frequency bands requires careful planning to avoid interference between co-frequency analogue and digital systems on converging or adjacent routes during the transitional phase.

These problems have been successfully overcome for 140 Mbit/s systems, but the economic and environmental considerations, in the geographically small, heavily meshed UK network, have precluded any significant extension to the microwave radio network.

Network Structure

Individual circuits or groups of circuits are routed through the trunk transmission network by combining them into 480-channel 34 Mbit/s blocks of capacity and interlinking them in line and radio systems to form end-to-end 34 Mbit/s blocks to meet the source-destination demand matrix (shown in Figures 5 and 6).

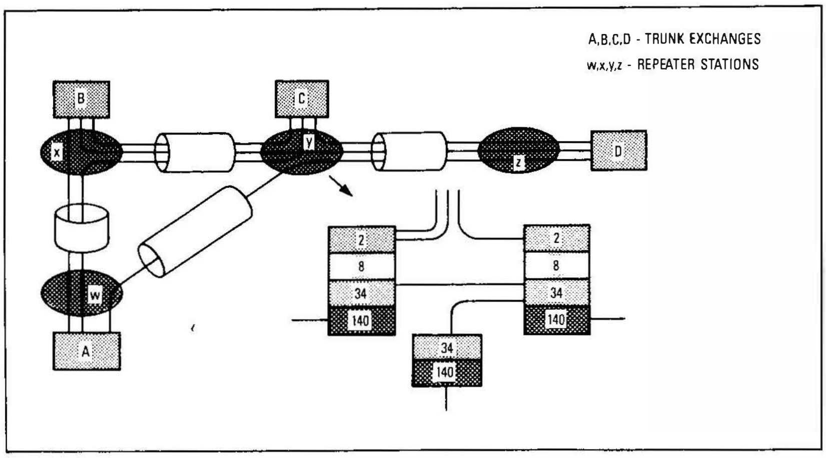


Figure 5—Routing of 34 Mbit/s blocks

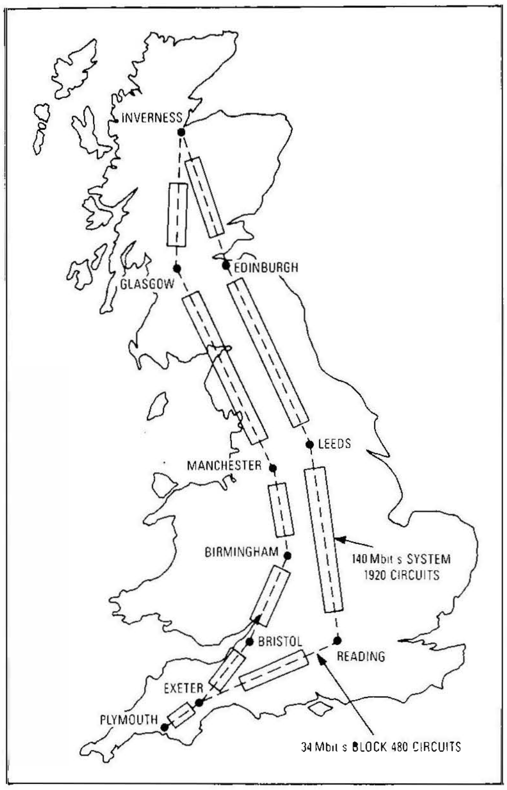


Figure 6—Diverse routing of 34 Mbit/s blocks from Plymouth to Inverness

Synchronous Multiplexing

The existing digital multiplexing hierarchy has a complex frame structure which, at each stage of multiplexing, has overhead bits added to maintain frame alignment and identify the tributaries. Hence, at the final 140 Mbit/s stage, it is impossible to identify any of the sixty-four 2 Mbit/s basic tributaries without demultiplexing all the way down the multiplexing chain.

The need to introduce stages of multiplexing in order to break out from or interconnect between transmission systems gives rise to additional network cost, the 'multiplex mountain', and fault liability.

This could be avoided if the higher capacity transmission systems operated synchronously instead of plesiochronously. The main capabilities of synchronous multiplexing are illustrated in Figure 7 and comprise 'jump multiplexing', that is, the direct multiplexing from 2 Mbit/s tributaries to the 155 Mbit/s module; 'drop and insert' where any 2 Mbit/s block can be extracted from or added to the 155 Mbit/s module; and the cross-connect facility through the HACE (higher order automatic cross-connect equipment) that allows interconnection of any 2 Mbit/s block between transmission systems without the need for demultiplexing.

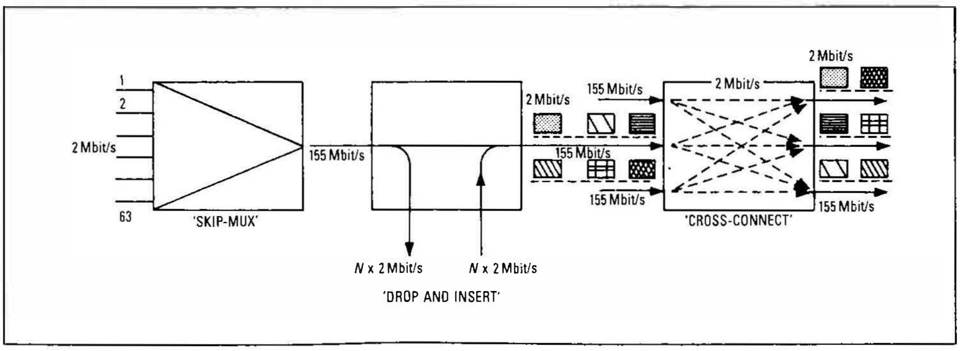


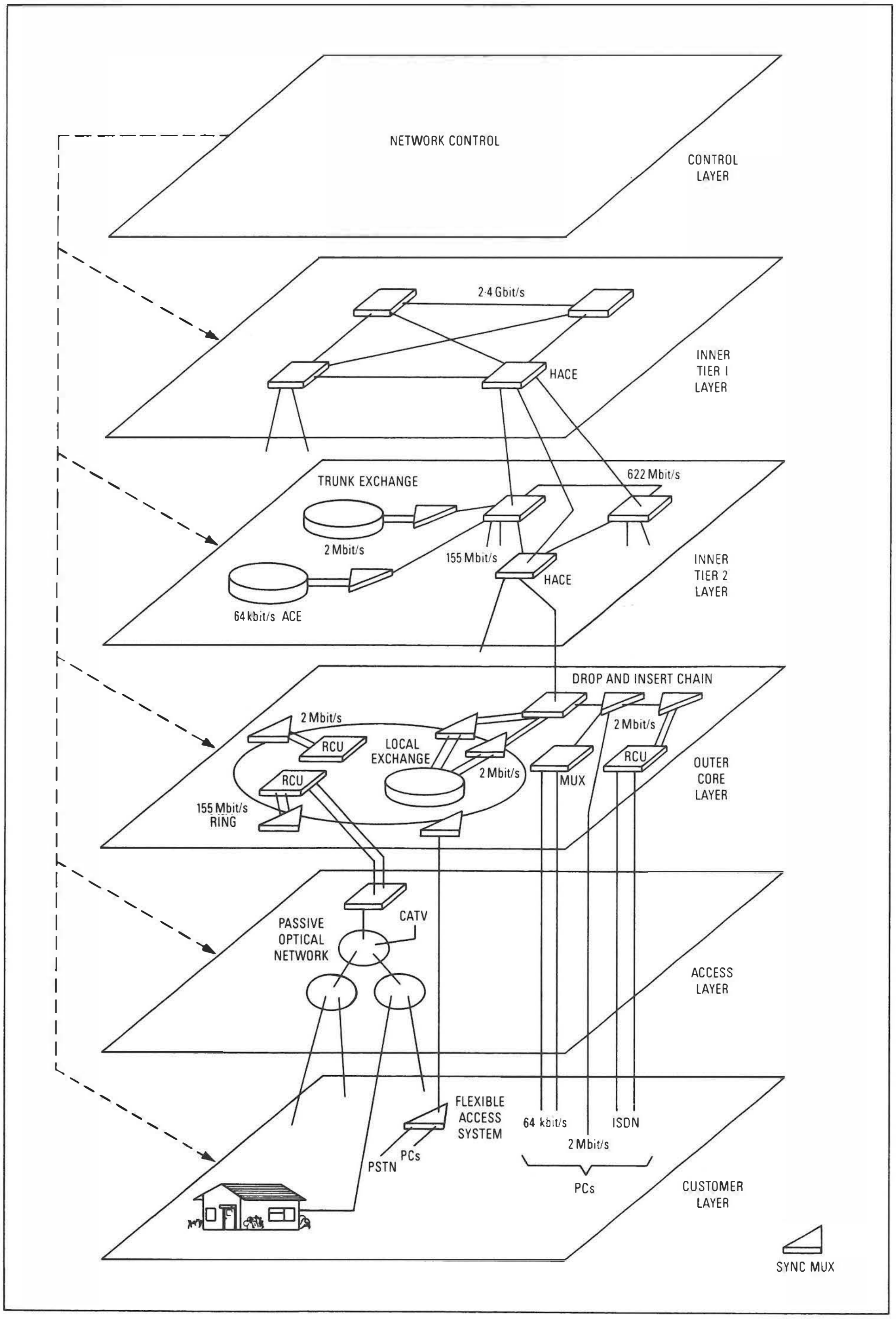
Figure 7
Principles of synchronous multiplexing

With appropriate control software, such a 'managed synchronous network' could provide hands-free operation allowing, for example, end-to-end 2 Mbit/s blocks to be set up from a single terminal, configuration of private networks to be under customer control and automatic reconfiguration of the network to make good failed transmission systems. Figure 8 is an example of how such a network could be structured.

CCITT, the international telecommunications standards body, has recently produced Recommendations (G.707, G.708 and G.709) for a new *synchronous digital hierarchy* (SDH), multiplexing structure, format and interfaces. The currently specified gross bit rates are 155·520 Mbit/s and 622·080 Mbit/s which contain a range of management features in addition to the payload of communication channels which can be subdivided into blocks at the 2 Mbit/s primary rate or at higher levels in the multiplexing hierarchy; for example, 34 Mbit/s.

The SDH standard is based on that originating in North America (SONET, synchronous optical network). But conversion to suit both North American and European networks

Figure 8
Possible managed synchronous network



and its adoption as a world standard was significantly influenced by BTUK Network Directorate staff.

The basic SDH signal is called the *synchronous transport module* (STM-1) with a bit rate of 155·52 Mbit/s. The frame structure repeats every 125 µs. A particular 8 bit byte can be uniquely identified by its time position within a frame of sequential time-slots. The sequential time positioning of bytes can alternatively be considered as a matrix of rows and columns where individual bytes are identified by their position in the matrix (that is, by row and column number), reading, as in a book, from top left hand to the bottom right hand byte (see Figure 9).

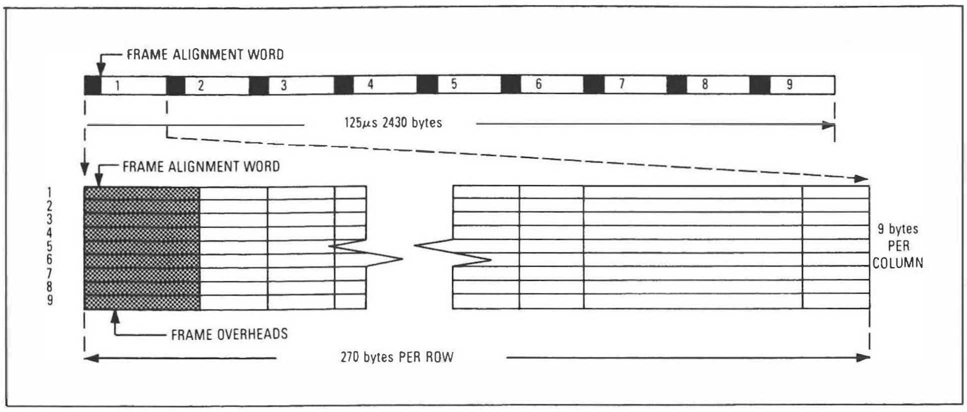


Figure 9
Basic SDH frame structure

The STM frame (Figure 10) comprises 9 rows and 270 columns. The first 9 columns are allocated to some overhead bytes called the *section overhead* (SOH); these are used for getting the signal safely across a network section. In addition to the *frame alignment* signal it includes error monitoring bytes, orderwire channels and embedded operations channels providing transmission for network management messages.

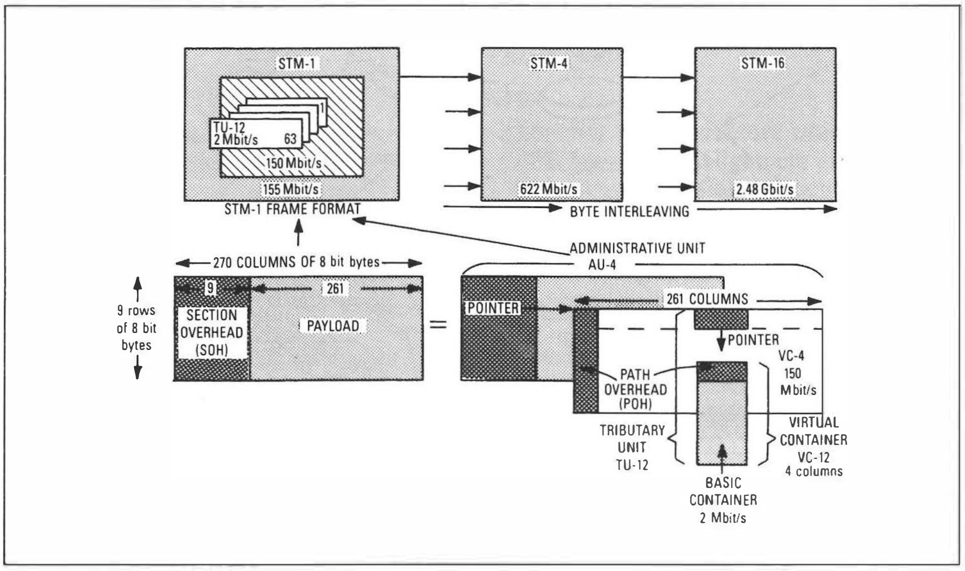


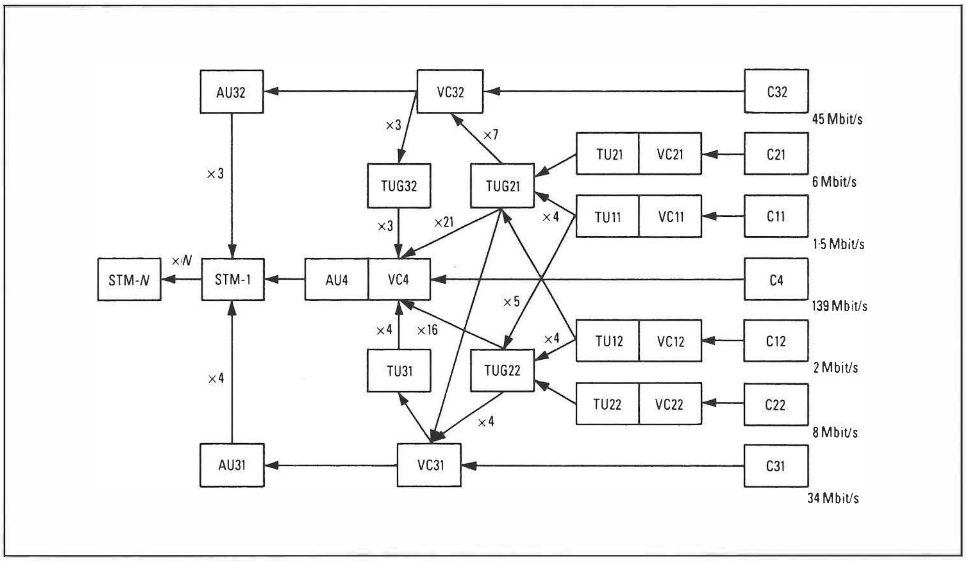
Figure 10
SDH frame structure

The remaining 9 × 261 bytes (equivalent to just over 150 Mbit/s) are available for the transport of signals referred to as *payload*. The SDH frame makes use of two important concepts: the 'container' and the 'pointer'. Signals are never put into the frame on their own; they always have attached to them some overhead bytes called *path overhead* (POH) to form a signal called a *virtual container* (VC).

The VC is an important unit because it remains intact on its journey through the network from point of creation to point of delivery. It is allowed to take an arbitrary phase relationship with the signal into which it is accommodated, with one or more bytes acting as a 'pointer' whose value tells where the first byte of the VC is located. This arrangement, which allows phase/frequency independence between the VC and its parent frame can be exercised in a nested way to give what is effectively a 'frame within a frame, within a frame'.

There is a variety of signal multiplexing routes where this theme is played out and to appreciate the basic idea, the example of how a 2 Mbit/s user signal is fitted into an STM-1 frame is considered (see Figure 10). The signal is accommodated, together with some justification and other bits and bytes, to give a basic container; this has added to it one byte of POH to give a VC-12 whose position is located in a VC of the next size up by a pointer. A VC-12 plus pointer is called a *tributary unit* (TU-12) and 63 TU-12s can be mapped into a larger container, called a *VC-4* comprising 261 columns with a bandwidth of 150 Mbit/s. The TU-12s, which take up 4 columns each, are grouped into 12-column groups to give three TU-12s per 'tributary unit group-21' (TUG-21). The frame structure is such that 21 TUG-21s fit exactly into a VC-4. The usefulness of the TUG idea lies in its capability to support not only a group of three 2 Mbit/s TU-12s, but optionally four 1·5 Mbit/s TU-11s and to mix differently loaded TUG-21s in the same VC-4. The VC-4 includes a set of POH bytes and its position in the STM-1 frame is given by a pointer in the SOH area. The VC-4 plus pointer is known as an *administration unit* (AU-4), which is mapped into the STM-1.

Figure 11
SDH multiplexing hierarchy



TU:	Tributary unit
AU:	Administrative unit
TUG:	Tributary unit group
VC:	Virtual container
C:	Container
STM:	Synchronous transport module

11:	1·5 Mbit/s
12:	2 Mbit/s
21:	6 Mbit/s
22:	8 Mbit/s
31:	34 Mbit/s
32:	45 Mbit/s
4:	140 Mbit/s

There are a number of options in the SDH multiplexing hierarchy and these are shown in Figure 11. The suffix is structured so that the first number corresponds to the hierarchical level and the second to the bit rate accommodated; for example, TU-31 is able to transport the third level of the digital hierarchy first bit rate 34 Mbit/s, whilst TU-32 carries 45 Mbit/s. Three TU-32s or four TU-31s can be accommodated in one AU-4.

Having structured the frame, before sending to line, the bits are scrambled to ensure adequate density of '1s' to provide timing content without having to add any line code. If transmission at bit rates higher than the STM-1 rate is the order of the day, a number (say *N*) of STM-1 signals can be multiplexed together by a process of 'byte-interleaving' and the resulting STM-*N* signal can be sent to line. For example, four STM-1s can be byte-interleaved to give an STM-4 signal at 622 Mbit/s and further interleaved to produce an STM-16 signal at 2·4 Gbit/s.

Junction Network

The junction transmission network is the network interconnecting local exchanges and local exchanges to trunk and junction exchanges higher in the routing hierarchy. Within the junction network there is a high penetration of 2 Mbit/s line transmission systems on existing copper pair-type cables. Higher capacity, 8, 34 and 140 Mbit/s systems are now being introduced on optical-fibre cables. At the end of 1988, over three hundred 140 Mbit/s systems had been installed. The distinction between trunk and junction transmission networks is becoming less obvious with time and they are beginning to merge into a common core network.

LOCAL DISTRIBUTION NETWORK (LOOP)

The modern digital core network is buffered from customers by the local loop (see Figure 12), a largely copper network which accounts for a disproportionate element of the total network cost and is responsible for much of the poor quality perceived by customers.

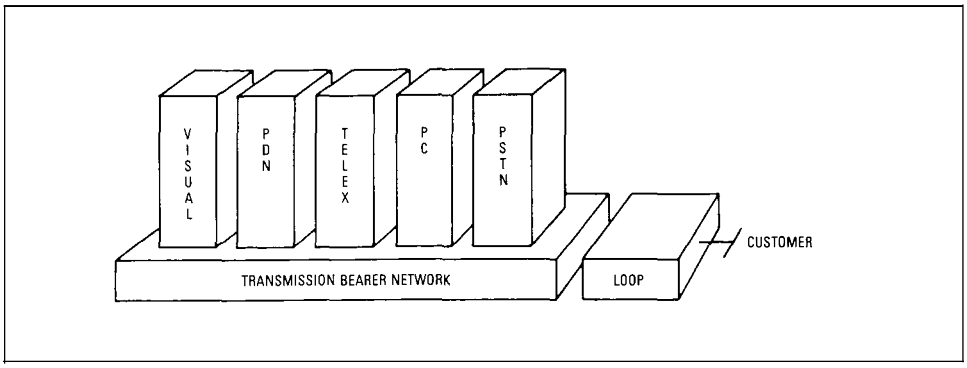


Figure 12
Customer connection to the bearer network

The local distribution network (local loop) comprises mainly copper underground cables to primary cross-connect points (PCPs), or cabinets, where they are fanned out to smaller cables to distribution points (DPs) and thence to the customer premises via overhead feeds or underground, radial or frontage tee (see Figure 13). In some cases, a secondary cross-connect point (SCP), or pillar, is used between the PCP and DP to further break down the capacity.

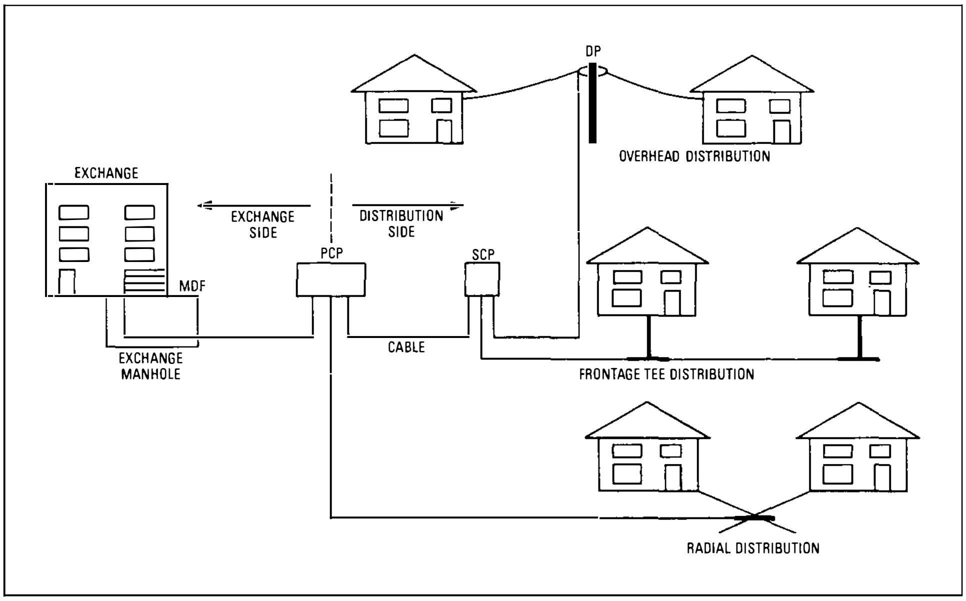


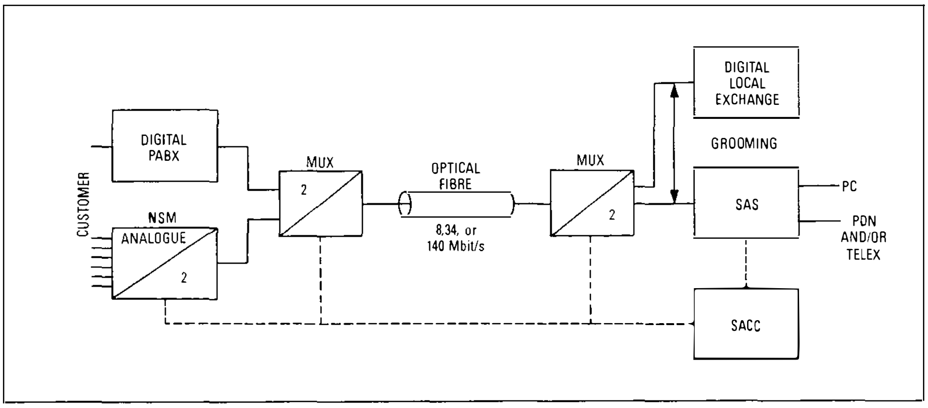
Figure 13
Local line network (loop)

Optical Fibre in the Loop

There has been a relatively low penetration of digital transmission in the local distribution network (local loop), being mainly confined to 80 kbit/s ISDN access, and 64 kbit/s and 2 Mbit/s private circuits (PCs). However, optical-fibre digital systems are now being deployed to the premises of major customers who have a multiplicity of lines to the network for PSTN, PCs etc. access.

The Flexible Access System (FAS) (Figure 14) comprises an intelligent multiplexer at the customer end (network service module (NSM)) to convert the various customer inputs into forms suitable for the network. At the exchange end, the various 2 Mbit/s blocks are distributed to the appropriate functional networks. Private circuits are routed through automatic cross-connect equipment known as a *service access switch* (SAS) and the system is managed from a service access control centre (SACC). A possible future facility could be to provide a control capability in this equipment to enable customers to reconfigure their access channels on demand.

Figure 14
Flexible access to the network



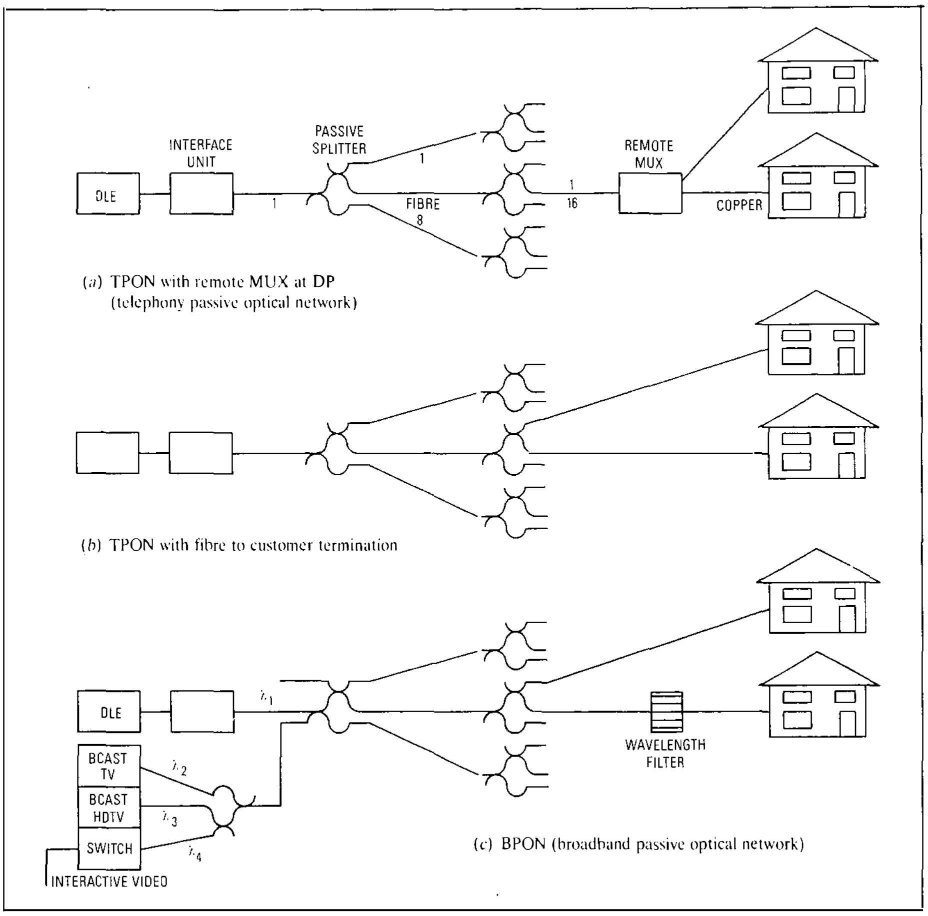
SAS: Service access switch SACC: Service access control centre NSM: Network service module

In the longer term, it is anticipated that optical fibre can be used in the loop for small business and residential customers by locating electronics in street furniture at the last distribution point (DP) and using traditional copper for the drop to the customer premises.

A further development, known as *telephony over passive optical networks* (TPON) could be taking fibre direct to customer premises by using passive networks comprising single-mode fibres fed from the exchange and fanned out via optical splitters at the cabinet and DP positions to feed a number of customers. An arrangement giving eight ways out at the cabinet and 16 ways at each DP would give capacity for 120 customers, each with 144 kbit/s IDA access. Downstream signals could be formed into a conventional time division multiplex (TDM) at about 20 Mbit/s, particular time-slots being assigned to each customer. In the upstream direction, converging traffic streams are passively multiplexed at DP and cabinet branching points, synchronisation being achieved by means of a timing handshake between customer and exchange.

The TPON structure may be evolved to carry broadband services such as CATV, HDTV and broadband ISDN as well as telephony services by using wavelength division multiplexing. This concept is termed *broadband passive optical networks* (BPON). Each optical wavelength can be used to support a different service or provide a dedicated link to each customer. Figure 15 shows the possible evolution to such a network.

Figure 15
Evolution of fibre systems in the loop



(*a*) TPON with remote MUX at DP (telephony passive optical network)

(*b*) TPON with fibre to customer termination

(*c*) BPON (broadband passive optical network)

In rural situations, the cost of long cable or overhead wire routes can be very high, and radio is an alternative method of gaining access to customers that is being investigated. A possible structure is shown in Figure 16.

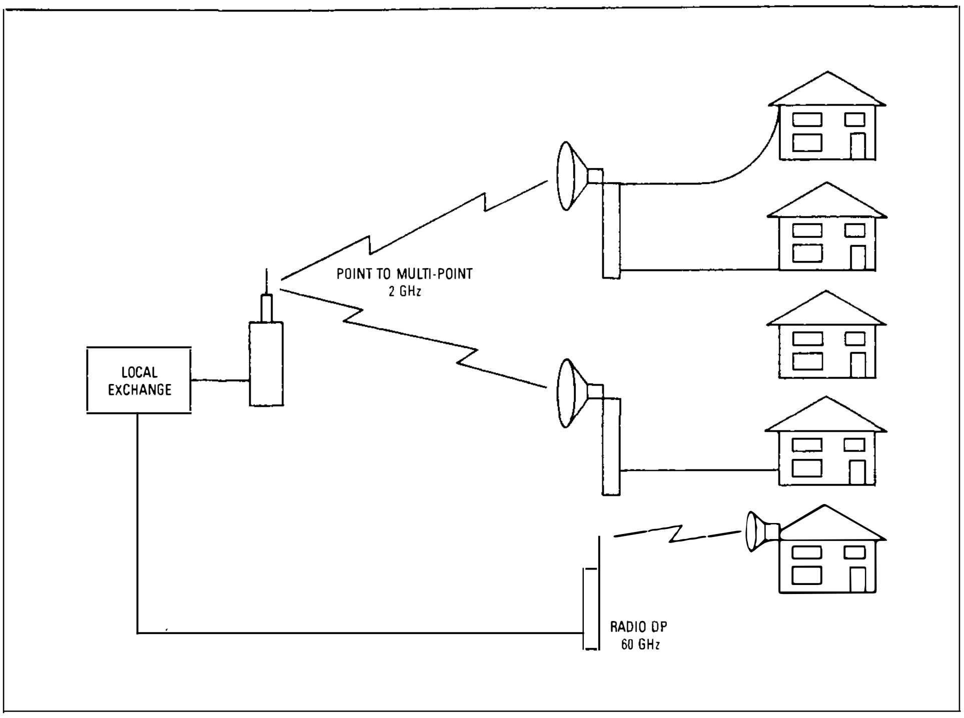


Figure 16
Radio in the local loop

PUBLIC SWITCHED TELEPHONE NETWORK (PSTN)

The modernisation of the PSTN creates the integrated digital network (IDN) which is characterised by the integrated use of stored-program control digital switching with digital transmission and the use of common-channel inter-processor signalling. Extending the 64 kbit/s digital path together with the high-capability signalling to the customer premises creates the integrated services digital network (ISDN) and brings the full network services capabilities to the customer.

By eliminating the primary multiplexing equipment and per-circuit signalling at the transmission/switching interface coupled with the lower cost, reduced accommodation needs and lower maintenance charges of electronic equipment, significant economic benefits have resulted.

The IDN comprises a number of layers. The transmission bearer network supports a 'switched layer' which itself has logical and service specific layers as shown in Figure 17.

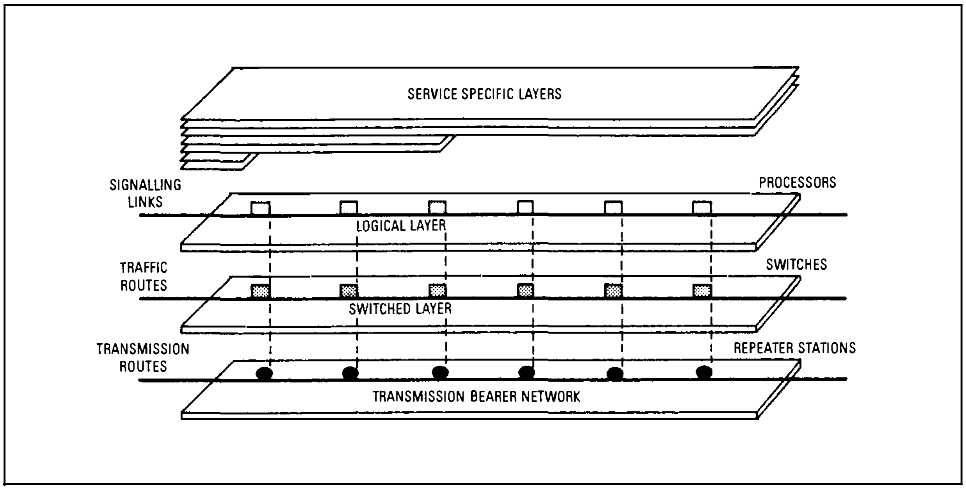


Figure 17
Layers of PSTN

Switched Layer

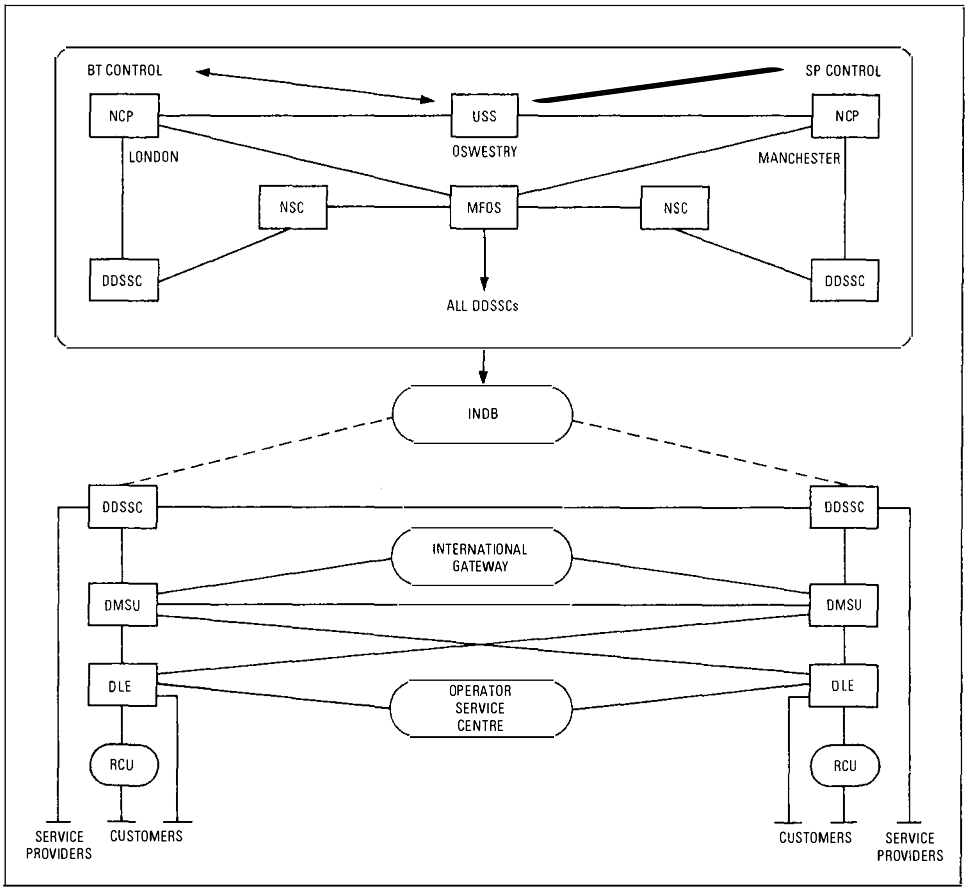
The switched digital network comprises the switching centres interconnected by traffic routes. The structure is shown in Figure 18. It comprises a three-tier routing hierarchy consisting of a local network which will have 4000–5000 remote concentrator units (RCUs) parented on about 50–200 digital local 'processor' exchanges (DLEs). This allows for significant switching and administrative economies by using very large exchange processors to control a number of dispersed switching units.

The trunk network consists of 53 fully-interconnected System X digital trunk exchanges known as *digital main switching units* (DMSUs).

Modern operator services centres (OSSs) are due to replace obsolescent auto-manual centres (AMCs) in 1989. They will be used for operator assistance and directory enquiry calls and will share local exchange processor power to provide advanced operator facilities.

Digital international gateway exchanges are being introduced to modernise the international services and provide digital connection from the inland network.

Figure 18
Structure of switched network



MFOS: Multifunction operations system
NCP: Network control point
DDSSC: Digital derived services switching centre
NSC: Network services complex
USS: User support system

Digital Derived Services Network

The top level of the hierarchy is used to provide specialised 'LinkLine' network services such as 0800 Automatic Freephone, 0345 Economyphone and 0898 Call Stream Services and is known as the *digital derived services network*. It consists of ten digital derived services switching centres (DDSSCs) brought into service during 1988. For special service features, these are controlled by an intelligent network database (INDB) which will come into service in 1989. For security, the INDB is duplicated.

Major business customers, known as *service providers* (SPs), who require advanced network services can be parented directly on to the digital derived services switching centres or on digital local exchanges. Enhanced features can be programmed directly into the INDB by SPs.

The INDB comprises:

- Two network control points (NCPs), at London and Manchester, each normally handling 50% of the total NCP traffic but each can deal with all of the load should the other fail. The NCP provides the centralised database for holding routing translations and other call handling information.

- Two network services complexes (NSCs), at London and Manchester, providing customised announcements and interactive call facilities, using MF4 keyphone signalling from calling customers to, for example, select enquiry or booking destinations.
- The user support system (USS), which is the BT and SP user interface to the NCP for data entry and amendment, non call-related billing data and other related functions.
- The multifunction operating system (MFOS), which gives on-line access to the DDSSCs for alarm processing, switch maintenance and switch database administration including modification to exchange-dependent routing data.

Connection to the international network is being provided by a number of digital international gateway exchanges.

Logical Layer

The IDN is analogous to a network of interlinked computers each having an operating system with specific application software packages to provide particular network services. The logical layer describes the application software in the switching nodes in terms of generic and service-specific attributes. Generic attributes are those common to all nodes; such as, switching a call between the input and output ports of an exchange. Service-specific attributes are those necessary for the network to carry particular services. The establishment of calls requiring specific features may require an interchange of information and instructions between exchange processors; this is carried out via the signalling network.

Each service-specific layer describes how the combination of generic and service-specific attributes in particular nodes, together with messages between those nodes over the signalling network, create specific network services. For simple services such as local calls only the local exchange is involved; that is, the application software recognises the local number, routes the call to the called number and initiates charging.

More complex services, such as enhanced LinkLine services, utilise service-specific application software in a large number of nodes including the intelligent network database. Figure 19 illustrates the service-specific layer for an advanced LinkLine call.

The non-geographical numbering scheme for LinkLine requires that each dialled number is analysed from its point of entry in the network to determine its routing and the tariff to be applied. For basic calls, this digit analysis is done at the DDSSC, but for advanced service calls the DDSSC will access the INDB for instructions on how to handle the call. Examples of such calls are:

(*a*) *Time of Day Routing*: where calls can be routed to different destinations dependent on time of day, day of week or special holidays.

(*b*) *Call Distribution*: where calls can be routed to two or more destinations, the relative proportions being specified by the SP.

(*c*) *Call Prompter*: where a recorded announcement prompts the caller to key additional digits to, for example, route the call to SP enquiry or booking positions.

The use of an INDB to hold this information permits the use of sophisticated algorithms which can be subject to variation by BT or an SP. Thus, an SP can be given direct access to the INDB to change the routing of calls from one destination to another, or to reprogramme the time-of-day routing sequences. Figure 20 shows an example of a routing algorithm that can be directly programmed by the SP.

Additionally, the INDB allows new features to be provided by adding new software to the INDBs instead of all the switching centres. It also provides sophisticated network

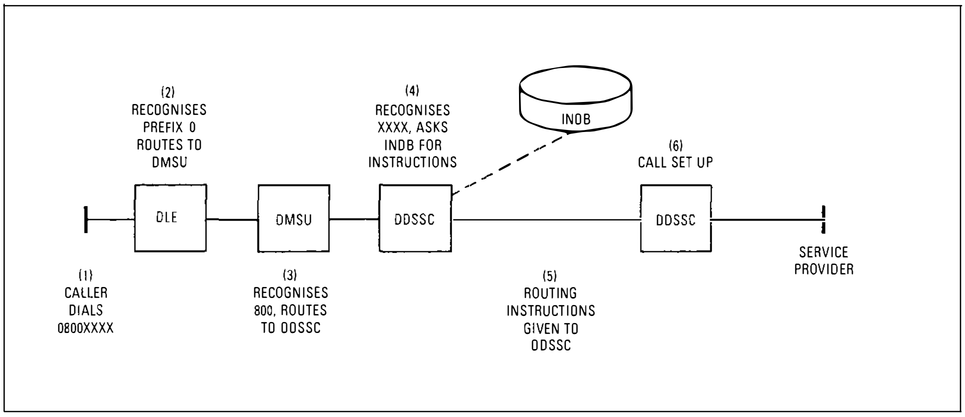
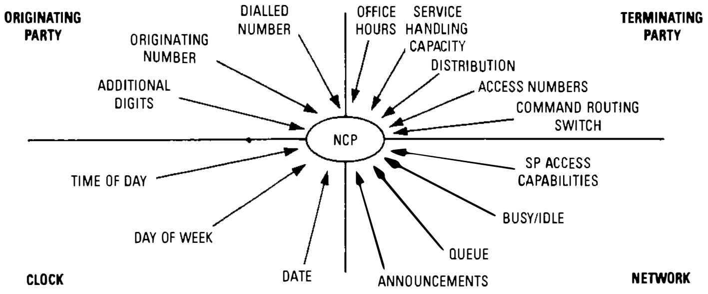
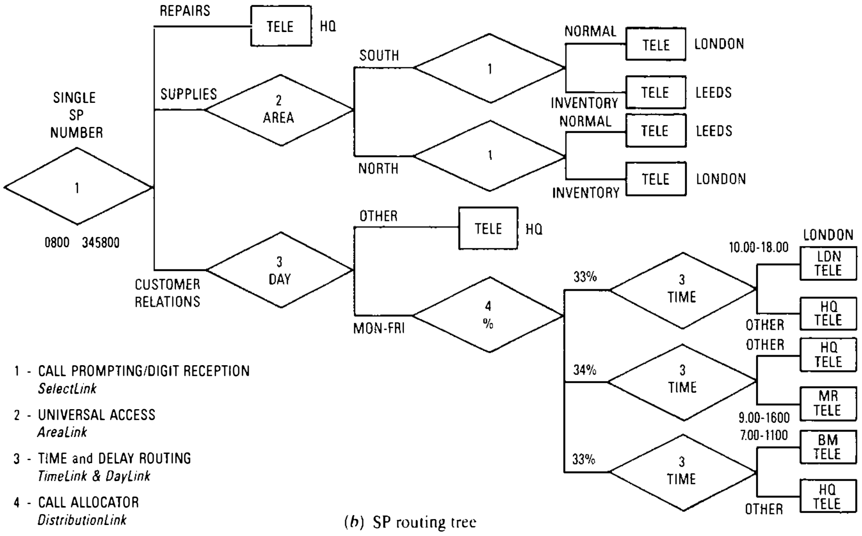


Figure 19
Enhanced LinkLine service specific layer

Figure 20
DDSN centralised call management



(*a*) Central call management



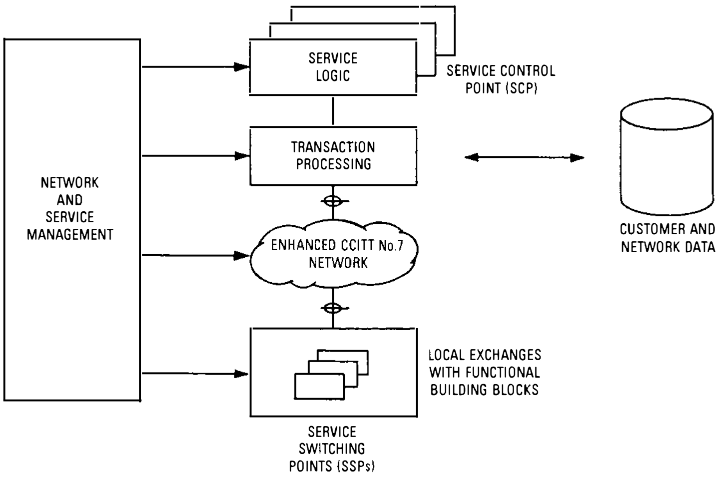
(*b*) SP routing tree

management and maintenance features, together with the facility for SPs to draw information on their calling patterns and volumes direct from the network.

Centralised Intelligence

The addition of centrally located software, detached from the exchange processors, is known as *centralised intelligence*. Work is being carried out to define standard interfaces, protocols etc. to enable general purpose INDBs to be developed capable of access from any exchange and enabling BT to develop its own application software to more rapidly respond to market demands for new services. The current method of modification to exchange software is time consuming, both for development and enhancement of in-service exchanges. Figure 21 shows the main interfaces and elements of centralised intelligence.

Figure 21
Centralised intelligence



INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

To provide customers with the full potential of the 64 kbit/s channel switched digital network with its high capability signalling, the network is being extended down to customers' premises to form the ISDN marketed as *Integrated Digital Access* (IDA).

British Telecom opened its commercial ISDN in June 1985; it was specified in advance of CCITT ISDN standards. It is based on an 80 kbit/s basic access connected to a network of four System X local exchanges. These, in turn, are connected to the digital trunk network by CCITT No. 7 signalling links, see Figure 22.

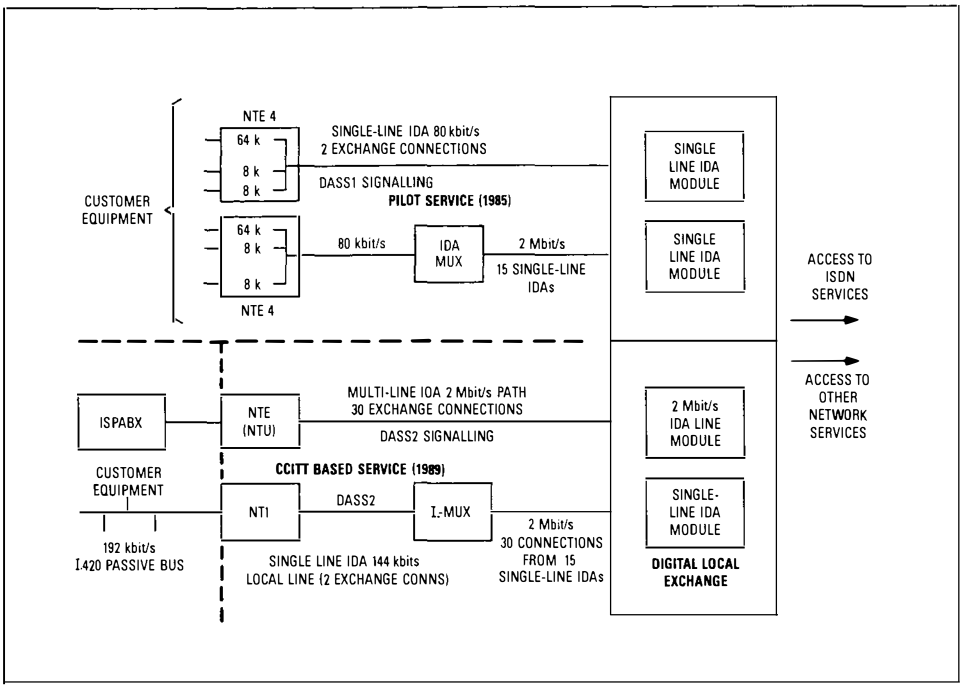


Figure 22
Integrated Digital Access (IDA)

NTE: Network terminating equipment

The two methods of access provided are:

(*a*) The 2 Mbit/s primary rate access consists of 30 traffic channels which can be used for speech or data, with time-slot 16 used as a 64 kbit/s common-channel data signalling link. It uses a high capability customer-to-network signalling system known as *Digital Access Signalling System No. 2* (DASS 2). This access is intended primarily for digital PABXs (ISPABXs, integrated services PABXs). It can also be used to provide access to remote multiplexers.

(*b*) The interim basic rate, or single line, access consists of a digital local line transmission system operating at 80 kbit/s. It offers two traffic channels, one at 64 kbit/s for speech or data, and the other at 8 kbit/s for data only. There is also an 8 kbit/s common-channel signalling link using the BT Digital Access Signalling System No. 1 (DASS 1).

Transmission of the 80 kbit/s access over the existing copper local loop cables is achieved by using both burst mode and adaptive echo-cancelling techniques.

A variety of network terminating equipment (NTE) is provided at the customers' premises to allow customer equipment to be connected to the ISDN. These pieces of terminating equipment have a number of analogue and data ports which support several protocols, including X.21, V.21 and V.24.

Initially, an NTE was developed with an integrated telephone and data port. However, the regulatory requirements now dictate that the telephone instrument and customers' terminal apparatus provision must be open to general competition, working to well-defined network boundary conditions. The network termination that is part of the network is therefore constrained to terminating the line and providing the network interface.

From the middle of 1986, the network was progressively extended and the basic rate digital access will shortly be changed to 144 kbit/s; that is, two 64 kbit/s channels for speech and/or data plus a 16 kbit/s channel for signalling and low speed data to conform to CCITT Recommendation I.420. This also allows the network terminal to support a passive bus arrangement to enable up to eight customer terminals to be connected in a multi-point configuration.

The reach of the service can be extended by connecting the 15 single-line basic accesses to a multiplexer and then through a 2 Mbit/s PCM system to the ISDN exchange.

Access Signalling

The new customer digital access signalling system (DASS) was specified in advance of CCITT LAP D protocols, but has similar characteristics. Indeed, it is one of the inputs on which CCITT LAP D was based and therefore bears similar characteristics.

Its use from PABXs identified the need for an equivalent high capability inter-PABX signalling system for use over digital leased circuits for networking advanced PABX services. This led to the definition of a *Digital Private Network Signalling System* (DPNSS) which is currently being implemented by UK PABX manufacturers. DPNSS uses the same layer 1 as DASS, the same procedures as layer 2 in the same message format as layer 3. Thus DPNSS signalling can be interleaved with DASS signalling in time-slot 16 of 2 Mbit/s line systems from PABXs into the BT network.

INTER-EXCHANGE SIGNALLING

All digital exchanges in the British Telecom network are interlinked by high capability common-channel inter-processor signalling systems compatible with CCITT Recommendations for Signalling System No. 7 (CCITT No. 7). It is one of the first and currently the largest network to employ this form of high-capability signalling in a network carrying public traffic.

BT already has 53 System X trunk and over 1500 System X and AXE10 local exchanges, an AXE10 international gateway exchange and 10 5ESS PRX derived services switching centres in service interconnected using this form of signalling. Interconnect to the System X exchanges in the Channel Islands, the Mercury and Hull Administration networks, and AXE10 exchanges of Telecom Eireann also uses CCITT No. 7 signalling; also, interconnect to the two national cellular radio networks uses this form of signalling.

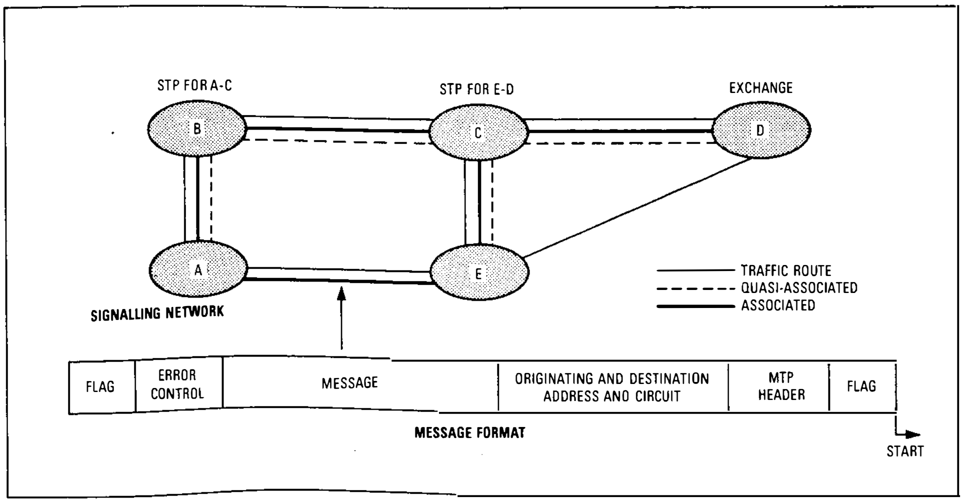
The signalling system is a key element in the evolution of the network. It enables complex messages to be transferred between two exchange processors using a single 64 kbit/s channel (usually in time-slot 16, but in theory any time-slot other than TS0 could be used) which carries information relating to hundreds of traffic circuits. The structure of the signalling system uses the principles of the 7 layer OSI (open systems interconnection) model.

It currently comprises two main parts, namely:

- *Message Transfer Part* (MTP): common to all applications and transferring signalling messages over the network with subsidiary signalling link control functions such as error control, reconfiguration of signalling routes after failure, and sending information about abnormal situations in the signalling network.
- *National User Part* (NUP): application dependent and defining the message codings and protocols that control both telephone and ISDN-type calls, supplementary services and circuits.

The format of the messages comprises bit patterns, known as *flags*, which define the beginning and end of each message; identification of origination and destination nodes, traffic route and circuit, error control information and the message information (see Figure 23).

Figure 23
Signalling network



STP: Signal transfer point

The introduction of centralised intelligence, for example, INDBs, will require two new functional blocks of CCITT No. 7 to support the non-circuit related type of transactions. These functional blocks are known as *signalling connection and control part* (SSCP) and *transaction capability* (TC, but usually referred to as TCAP).

SSCP—with the MTP this provides the OSI layer 3 (network) service allowing messages with an OSI address to be delivered to signalling points in the CCITT No. 7 network.

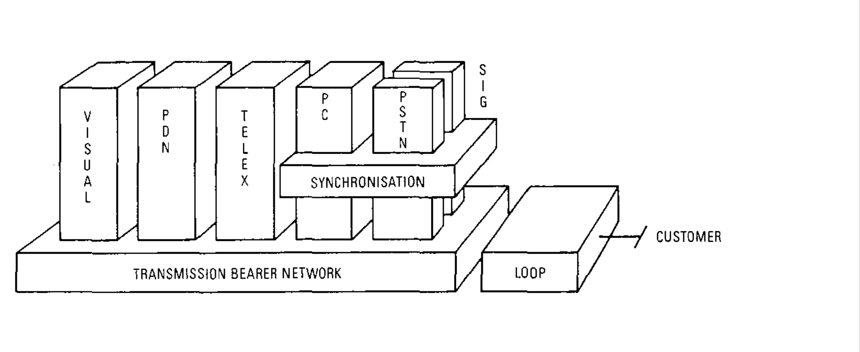
TCAP—allows a non-circuit related dialogue to be supported between two exchanges using CCITT No. 7.

Signalling Network

The signalling network (see Figure 23) is analogous to a packet-switched data network. Each traffic route between a pair of exchanges has its signalling carried on a signalling module between those exchanges, this is known as *associated signalling*. Each signalling module is made up from two to four signalling links in parallel, each of which follows a separate physical path with change-over in case of failure.

A limited amount of 'quasi-associated signalling' is used where signalling messages are routed separately from the traffic path via an intermediate exchange which for signalling purposes is known as a *signal transfer point* (STP). No switching action at an STP exchange is required as a result of a quasi-associated message. This method is more economical for small traffic routes and can also be used for alternative routing for 'associated' routings under failure conditions.

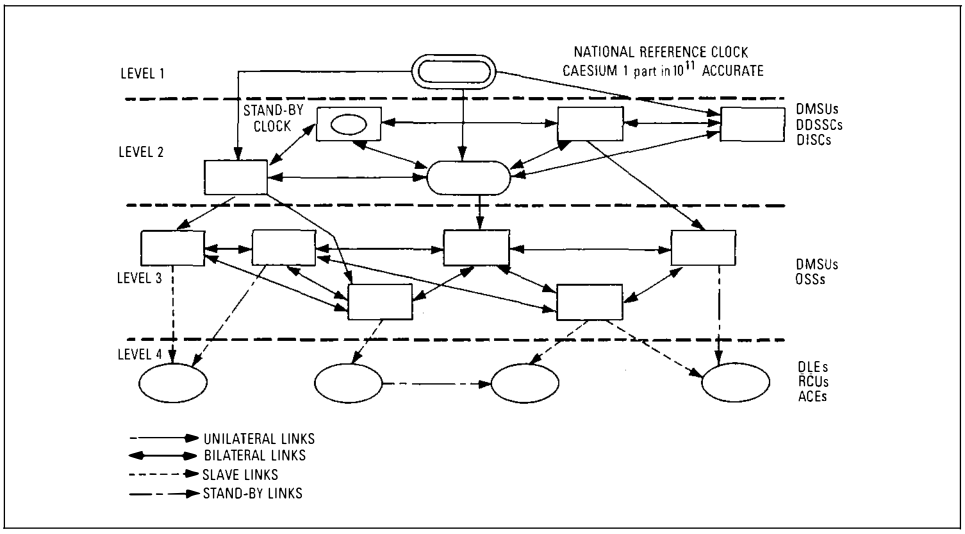
Figure 24
Synchronisation and signalling networks



A synchronisation network (Figure 24) is used to ensure that all digital exchange clocks are operating at the same average frequency. If not, the information rate of a signal received at an exchange would be different from the rate at which the exchange could process the information and retransmit it. This results in loss of information, if the input rate was faster, or repeated if it was slower. This process is known as *slip*.

Mutual synchronisation is used and the synchronisation network is structured as a four-tier hierarchical network, the top level of which contains a triplicated caesium reference clock with a stability of 1:10^{11} (see Figure 25).

Figure 25
BT synchronisation network



Synchronisation information is recovered from the frame alignment pattern of nominated traffic carrying 2 Mbit/s links, known as *synchronisation links*. If a difference in frequency between the bit rate of the link and the frequency of the exchange clock is detected, control signals, for example, 'speed up' or 'slow down', are inserted into TS0 of the synchronisation link and returned to the distant exchange. By examination of all incoming synchronisation signals, a particular exchange can determine, by a majority decision, when its clock is at variance with the network and take the necessary action.

Control between levels in the hierarchy is unilateral, from the higher to the lower level; that is, is only effective at the lower level. Control between nodes in the same level is bilateral and effective at both ends. At the lowest level in the hierarchy, master-slave synchronisation is used; that is, the exchange clock is directly controlled by the bit rate of the nominated synchronisation link.

ADMINISTRATION NETWORK

The data network that interconnects the intelligence embedded in the switching network, transmission network and INDBs to the real-time network control systems and data processing centres for the purpose of transmitting control signals to the network or retrieving information from the network is generically known as the *administration network* (Figure 26).

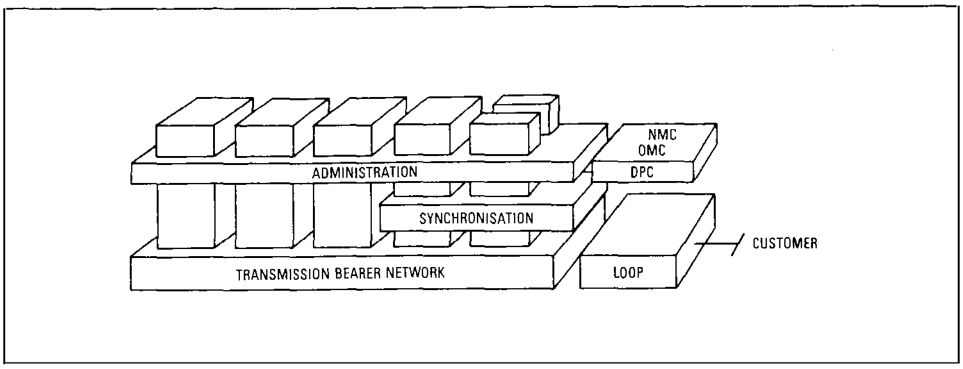


Figure 26
Administration network

NMC: Network management centre OMC: Operations and maintenance centre
DPC: Data processing centre

For the BT switched network, the main elements of the administration network are:

(*a*) *Network data collectors* which collect bulk data (statistics, billing etc.) from the digital exchanges for streaming, storage and forwarding to appropriate data processing systems.

(*b*) *Operations and maintenance centres* (OMCs), for remote man–machine communication to the exchanges, which receive fault reports and other data; allow remote manipulation of exchange software and data for provision of customer service and change of traffic routing patterns etc; and control of field maintenance staff.

(*c*) *Network management centres* (NMCs) which receive and analyse real-time traffic data and carry out traffic rerouting to overcome traffic congestion situations.

Transmission systems are also connected to NMCs via the administration network for service protection switching, network surveillance and remote cross-connection purposes.

Network Management Architecture

Currently, the administration network comprises a number of fragmented proprietary systems interconnected mainly by private circuits. This situation could become worse as a wider range of network equipment with different capabilities, intelligence and control mechanisms is introduced into the network. Hence there is a need to rationalise this network to allow a variety of proprietary equipment to be connected to standard network management, control centres and support systems via standard interface protocols.

BT is facilitating this by developing a structured hierarchical network management framework with a standard set of interface protocols (known as *ANIS* (Admin Network Interface Standards)) and supported by a corporate managed bearer data network.

The hierarchy, illustrated in Figure 27, has five levels; namely, plant, plant management, network control, service management; and customer facing:

- The *plant level* contains the switching and transmission equipment that comprises the network, each element with its proprietary control, alarm reporting system and statistics etc.
- The *plant-management level* provides remote access to the plant, alarm filtering and translation between the standard and proprietary protocols.
- The *network control level* will be BT network specific with functions such as network event management and alarm correlation, traffic and capacity management, network allocation and utilisation, with a common network database.
- The *service-management level* is responsible for service allocation, correlation between network fault and service availability, service oriented test facilities and production of service-related statistics for forecasting and market analysis.
- The *customer-facing level* comprises the interface between customers and BT for such things as order handling, fault progressing and billing etc.

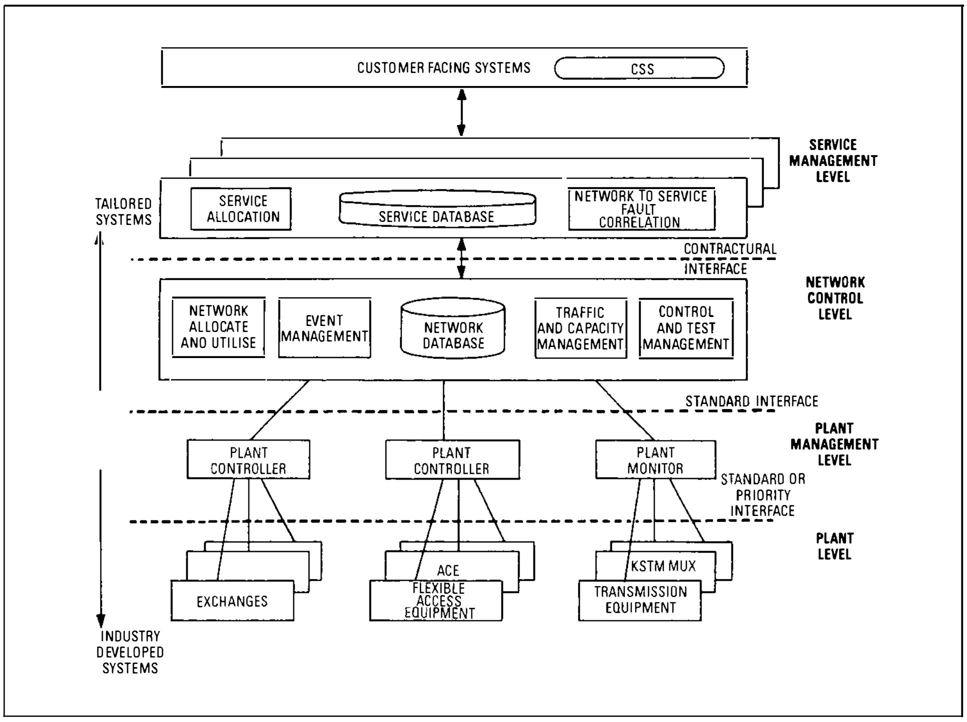


Figure 27
Network management architecture

The ANIS communication protocols are consistent with BT's open network architecture (ONA) which itself follows the ISO (International Standards Organisation) 7 layer OSI (Open Systems Interconnection) recommendations and the administration standards being developed within CCITT.

An essential element of the communication protocols is the development of a generic telecommunications management language to facilitate standard functional message flows between plant elements and network controllers.

NETWORK RELIABILITY AND PERFORMANCE

British Telecom is paying particular attention to the provision of a high performance and reliable digital network. In addition to the inherent high reliability of digital switching and transmission systems, the following measures have been taken to give a good network resilience to equipment failure and traffic overload.

(*a*) *Total network management* is being introduced. This comprises the real-time surveillance of traffic flow and equipment performance in the network remotely from network management centres. These centres allow rapid action to be taken to overcome congestion by re-routing of traffic or blocking traffic surges at their source exchanges, as well as the initiation of rapid repair of equipment breakdown or replacement of faulty equipment.

(*b*) *Diversity.* Circuits making up specific traffic routes between digital exchanges are routed over geographically diverse transmission systems to minimise the loss of capacity if the system fails.

(*c*) *Alternative traffic routing.* Each digital local exchange has traffic routes to two digital trunk exchanges with overflow from one to the other in the event of congestion or equipment failure. In addition, a form of self steering dynamic alternative routing will be introduced into the trunk network. This will allow traffic to be automatically re-routed via the most lightly loaded parts of the network in the event of traffic congestion.

(*d*) *Service protection network.* Protection against failure of the high capacity digital transmission systems is achieved by a network of automatically switched 140 Mbit/s digital service protection links. Some 10% of the total network capacity is allocated for such protection purposes.

Automatic switching by means of the automatic service protection network (ASDSPN) will allow a choice of up to eight different restoration paths for a failed link under pre-programmed microprocessor control, with restoration being completed within 10 s, see Figure 28.

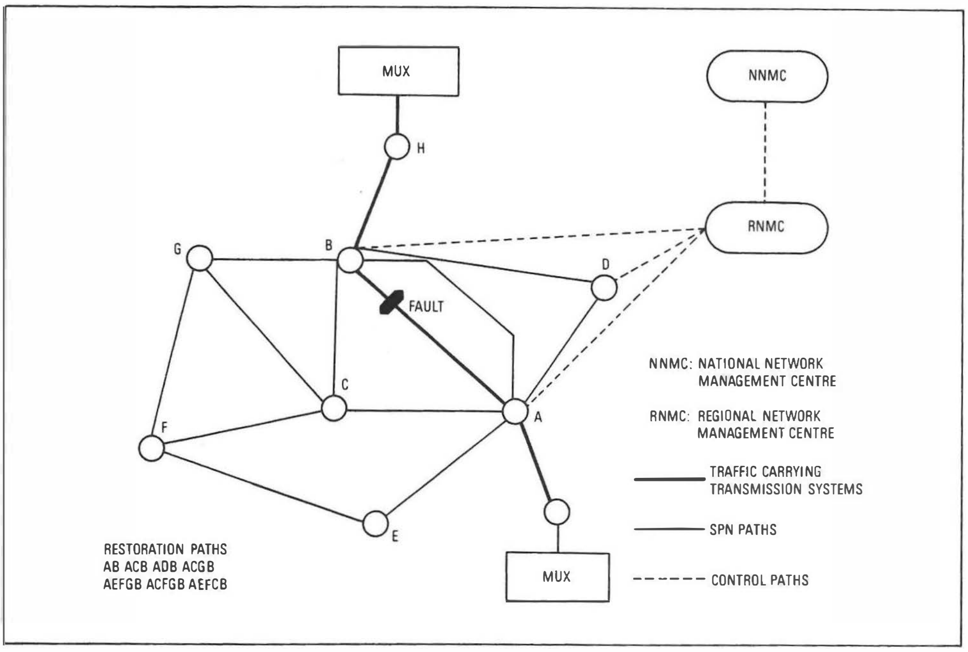


Figure 28
Automatic switched service protection network

(*e*) *Remote surveillance* of the transmission network will be carried out by centralised computer analysis of real-time performance of individual items of transmission equipment to give advanced warning of transmission degradation and failure together with identification and solution of end-to-end transmission problems.

NETWORK MODERNISATION

Because of the economic and service benefits that can be obtained from the integrated digital network, British Telecom has embarked on a strategy for rapidly modernising its network by replacing analogue switching and transmission systems with digital systems.

The first modernisation target is to complete the replacement of the analogue trunk switched network with a digital network by 1990. This provides the essential core network to interlink digital local exchanges as they are installed and to improve network performance from analogue local exchanges. So far, all 53 digital trunk exchanges have already been brought into service and by March 1989, 75% of all trunk traffic had been loaded on to the digital network.

On completion of modernisation, the British Telecom digital trunk transmission network will consist of more than 64 000 system km of optical fibre, 29 000 system km of coaxial cable, and 38 000 system km of digital microwave radio.

At the end of 1987, over 47 000 km of optical-fibre systems (more than 180 000 km of fibre—sufficient to girdle the earth 4·5 times), 26 000 system km of coaxial cable systems, and 31 000 system km of digital microwave radio had already been installed.

In the local network, digital local exchanges (or processor units) and remote concentrator units are being introduced at the rate of about 30 per month, with complementary penetrations of digital transmission systems to ensure that the network grows as a coherent, end-to-end digital network.

The rate of penetration of digital local exchanges at March 1989 was that about 7 million lines of capacity was in service on about 1670 processor units and 1230 remote concentrators.

Conversion from Analogue to Digital Network

The evolution from the existing analogue network to the modern digital network is a particularly difficult exercise. The old analogue network was a four-tiered network consisting of some 6300 analogue local exchanges (ALEs), 360 interconnected trunk exchanges, known as *group switching centres* (GSCs) and a two-tier transit network comprising 36 transit switching centres (TSCs).

This is being replaced by the digital PSTN, basically a three-tiered network consisting of digital local exchanges (DLEs) linked to the 53 fully interconnected digital main switching units (DMSUs).

The analogue PSTN was overlayed by an analogue derived services network (ADSN) comprising eight Strowger derived services switching centres (DSSCs) to provide the advanced customer services; that is, 'Linkline 0800', 'Linkline 0345' and 'Call Stream 0898'. The ADSN has been modernised by a digital DSN consisting of 10 DDSSCs brought into service during 1988.

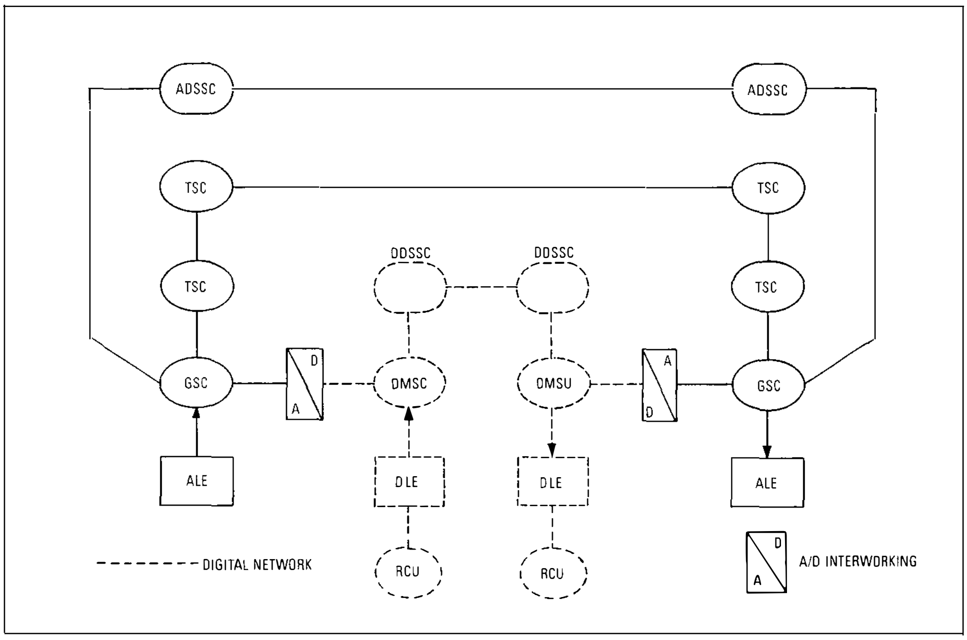


Figure 29
Change-over from analogue to digital network

ALE: Analogue local exchange
ADSSC: Analogue derived services switching centre
DDSSC: Digital derived services switching centre
DLE: Digital local exchange
DMSU: Digital main switching unit
GSC: Group switching centre
RCU: Remote concentrator unit
TSC: Transit switching centre

digital PSTN and DSN will consist of new, purpose designed, digital switching its and transmission systems. However, some analogue transmission systems are being retained in service for analogue private circuits. TXE4 (an electronically-controlled reed-relay switching system) will be retained in service and enhanced with digital encoding, common-channel interprocessor (CCITT No. 7) signalling facilities to interwork with the digital switched network and MF4 signalling capabilities to enable fast signalling from telephones.

Transfer of traffic from analogue to digital trunk networks is planned to be completed during 1990. The scale of the operation is indicated by the size of the analogue PSTN, which carried about 200 000 erlangs of trunk traffic over some 400 000 circuits with 280 000 different source/destination traffic routings.

Digital local exchanges are being introduced to directly replace analogue local exchanges or to overlay them to cater for growth. Priority is being given to business conurbations which will benefit most from the improved service and additional facilities.

During the transitional period, the old and new networks will co-exist with a proportion of customers parented on each network. To provide total connectivity between all customers the two networks must be interconnected, but traffic between the two networks must be carefully controlled. The aim is to maximise the use of the new network whilst limiting the growth of the old, and so minimise the heavy analogue/digital interworking costs of routing calls between the old and new networks. This will also minimise the additional transmission loss resulting from routing calls between the two networks. This transmission loss constraint will restrict the exploitation of interworking routes to only one for any individual call.

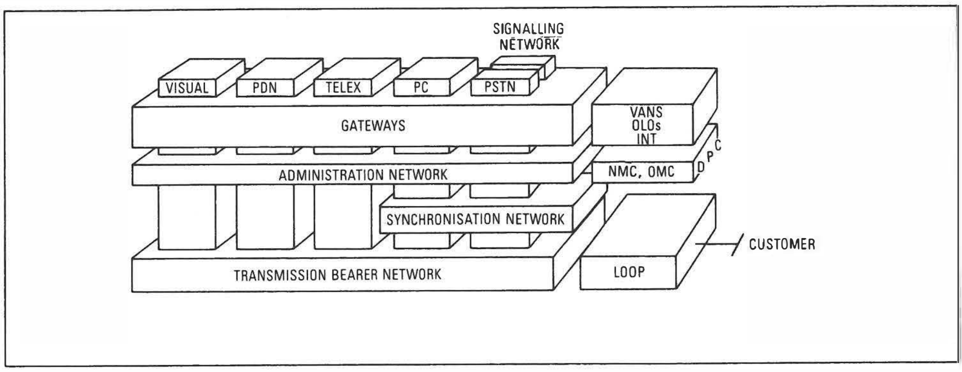
Generally, calls from analogue exchanges are routed on to the digital network as near as possible to their source, know as *near-end handover*, to load as much traffic on to the digital network as possible. Calls between analogue exchanges are routed over the analogue network.

Where the destination local exchange is parented on to a GSC and the destination DMSU does not have a direct route to it, traffic arriving at the DMSU must be routed over an interconnect route to the GSC known as the *return to analogue route*.

OTHER FUNCTIONAL NETWORKS

In order to provide a full range of network services to its customers, BT operates a number of functional networks in addition to the PSTN; namely, the private circuit (PC) network, the public packet switched data network, the Telex network and an emerging visual services network. Gateways (see Figure 30) are provided to link some of these networks together to provide maximum transparency to customers to allow them, for example, to send messages over the public data network from terminals connected to the PSTN. Access to the international network is provided via international gateway exchanges allowing direct dialling to 190 of the 212 possible world destinations.

Figure 30
Gateways



Private Circuit Network

An extensive national private circuit digital network is well established and supports KiloStream services up to 64 kbit/s (see Figure 31). The MegaStream service comprises PCs at 2 Mbit/s and above routed over the transmission bearer network and using digital distribution frames (DDFs) as cross-connect nodes.

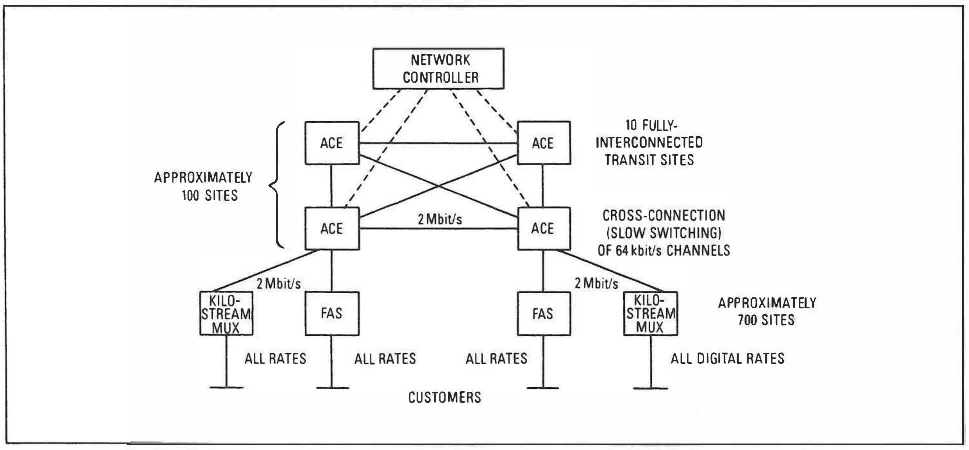
However, there is still a significant number of analogue private circuits using the transmission bearer network and carrying customers' own speech, data or telemetry. This analogue 'network' consists of some 40 000 12-circuit FDM groups covering about 14 000 different routes through the network.

BT provides 2-, 4-, and 6-wire presented speech band, 300–3400 Hz private circuits covering a wide range of engineering performance specifications, also 10 kHz 'music' circuits for such things as broadcast radio services and high quality data lines. Customer wideband services offering a 48 kHz bandwidth (60–108 kHz) are also in existence. Around 1200 FDM wideband circuits are in operation. Much of the broadcast (8 MHz bandwidth) television services are still provided on analogue plant, as used for FDM line systems. Closed circuit TV (CCTV) links are also provided.

The KiloStream service was opened in 1983 and offers the CCITT X.21 digital data networks interface in addition to supporting the existing range of V-Series terminals. Data communications is available at any of the CCITT X.1 user rates of 2·4, 4·8, 9·6, 48 and 64 kbit/s.

The network comprises digital multiplexers located at about 1000 local exchanges, which can combine up to 31 customer local ends on to standard 2 Mbit/s digital links to

Figure 31
Private circuit (KiloStream) network



parent cross-connect sites. At these cross-connect sites, remote-control switching of 64 kbit/s channels between 2 Mbit/s systems is achieved.

Originally the cross-connection was achieved by manual jumpering between back-to-back multiplexers. Now all growth is taken on a new network of digital SPC automatic cross-connection equipment (ACE) which is controlled remotely from centres at Manchester and London. These ACE units also provide remote testing and alarm facilities down to individual 64 kbit/s circuit level. A similar facility may eventually be introduced for the MegaStream service where remotely controlled 2 Mbit/s switches will be installed.

PSS—British Telecom's Managed Data Network Service

Packet SwitchStream (PSS) was the UK's first managed data network service (MDNS). It is the UK's leading and largest MDNS and carries most of the UK's national and international managed data traffic. It is used by a wide range of businesses for applications including file-transfer, electronic funds transfer, database access and messaging. Its major benefit is that it offers customers a high-quality data communications network without customers needing to buy, install, operate and manage their own network. Thus customers can predict their costs and concentrate on managing their own businesses.

The PSS network is based on packet switches which are specifically designed for error-free data switching. The packet switches are also designed to reduce costs by making efficient use of transmission capacity and computer ports. Within the network, the transmission capacity is optimised because data is converted into packets which are sent by the best available route. Within any session, the customer can send data to a potentially unlimited range of destinations without having to 'clear down' and set up new calls. In addition, over 100 virtual circuits can be set up simultaneously to each customer computer port so that port costs can be optimised.

Customers connect to the PSS network using X.25 protocol. X.25 is the CCITT standard for data networking and is now applied world-wide in both PTT and private networks. Gateways to the international service conform with CCITT Recommendation X.75. Customers with personal computers or other simple terminals can use 'triple X' (X.3, X.28, X.29) asynchronous protocols. The network also supports other proprietary protocols including SNA/SDLC and Bisynch.

The service is available nationally and gives access to 120 networks in more than 90 countries. Customers access the network in two main ways. Dataline access provides a dedicated circuit and is aimed at customers with larger volumes of traffic who need fast call set-up or multiple virtual circuits. Customers with smaller data volumes can access the network via the PSTN. Over 6500 PSTN ports are supported. Access speeds and protocols for both Dataline and PSTN access are shown in Table 1.

A network diagram is shown in Figure 32. Thousands of access units provide concentration and protocol conversion at over 200 sites in the UK. These access units

TABLE 1

Public Data Network (PDN) Services

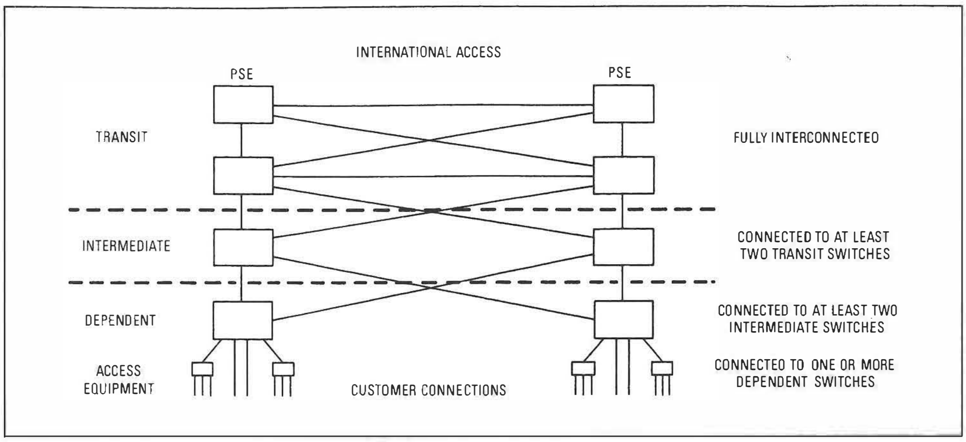
Datalines:

Protocol	Line Speed	Interface Standard
X.28	1200/75 bit/s	V.24
X.28	1200/1200 bit/s	V.24
X.25	2400 bit/s	V.24
X.25	9600 bit/s	V.24
X.25	48 000 bit/s	V.35
Bisynch	2400 bit/s	V.24
Bisynch	9600 bit/s	V.24
SDLC	2400 bit/s	V.24
SDLC	9600 bit/s	V.24

Dial-Up:

Protocol	Line Speed	CCITT Modem Standard
X.28 plus error correction option	300/300 bit/s	V.21
X.28 plus error correction option	1200/75 bit/s	V.23
X.28 plus error correction option	1200/1200 bit/s	V.22

Figure 32
Public data network



are interconnected by the core PSS network comprising over 240 large 'transit' data switches located at 43 packet switching exchanges (PSEs). The core network also directly supports customer access at X.25 and X.28. The PSEs are interconnected so that a maximum of four hops between data switches is needed to send data between any two points. 'Dependent' switches support customer access, concentration and protocol conversion. Each of these switches is connected to at least two intermediate PSEs. Each 'intermediate' switch is connected to at least two transit switches which are in turn fully interconnected with connections to the international gateways.

There are two network management centres (NMCs), one in London and one in Manchester, Each NMC is fully duplicated. They are operated 24 hours, 365 days, and are supported by a range of dedicated computers. In addition to receiving billing records and alarms, these computers actively monitor the condition and loading of switches and access units in the network. With the help of these network management tools, NMC staff are able the maintain system availability consistently above 99·95%.

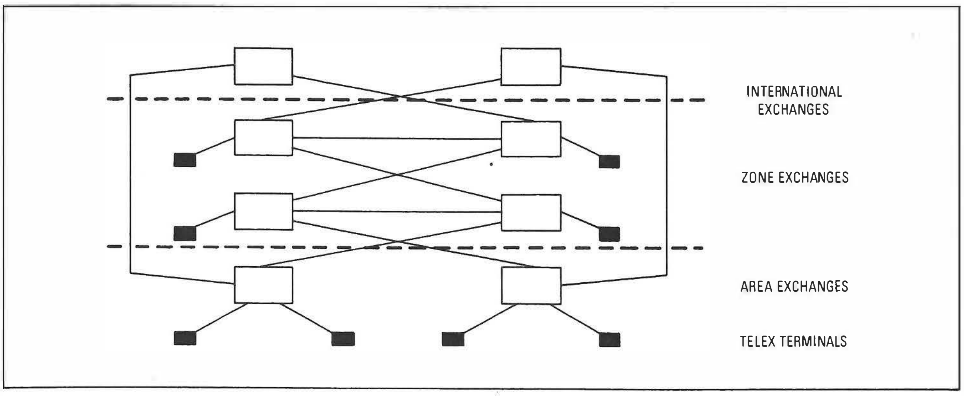
Telex Network

A traditional national and international Telex service is provided from a 45-node network which is currently being modernised by stored-program control exchanges to offer enhanced services, such as messaging.

The Telex network, shown in Figure 33, provides a low-speed 50 baud telegraphy service that is still widely used for national and international business transactions. Automatic direct dialling to more than 200 countries throughout the world is provided; more than half of some 230 million Telex calls made annually are made to international destinations. By 1990, 13 SPC exchanges will be serving over 70 000 lines in most major commercial centres.

Single-channel voice-frequency (SCVF) equipment is replacing the ±80 V signalling over the local line plant, between the line terminating unit (LTU) at the customers' premises, and the telegraph transmission terminal. The connection between the Telex terminal and the Telex exchange may also consist of frequency-shift voice-frequency telegraph (FSVFT), 60- or 184-channel time-division multiplexing (TDM) equipment, junction and local cable. A mesh network of Zone and Area exchanges provides interconnection with the international SPC Telex exchanges, at Keybridge and St Botolphs.

Figure 33
Telex network



Links between Area and Zone exchanges may be 60- or 184-channel TDM, or FSVFT. Links between Zone exchanges may be 60-channel TDM or FSVFT. The inter-exchange links are carried on KiloStream links, or on 2 Mbit/s line systems. Up to 30 of the 60-channel TDM systems may be multiplexed together for transport on a 2 Mbit/s line system.

The Telex Plus store-and-forward facility can deliver both single- and multi-address messages to any direct dial destination, making any necessary additional attempts automatically. To send multi-address messages, users can refer to pre-recorded address lists held within the Telex Plus memory.

Gateway services known as *InterStream* provide access to and from the PDN and Prestel. Telex can also be used to input messages directly to the BT Telemessage and Radiopaging services.

Access to Telecom Gold using direct dial in (DDI) facilities enables Telecom Gold customers to be allocated personalised Telex numbers. The service to Gold is provided using the Telex 25 service which allows a pair of 9600 bit/s circuits using X.25 protocols to be an alternative method of access from BT's Telex network.

Visual Services

Other broadband services provided by British Telecom include a pilot video conferencing network giving colour television transmission carried on 2 Mbit/s bearers.

CHANGE MANAGEMENT

An inevitable consequence of pursuing network objectives to reduce costs, improve quality and extend functionality of the network is a constant change to the network and increase in its complexity.

Figure 34 illustrates the extent of the increase in network complexity and introducing such change to an operating and highly interactive network requires careful management to preserve its high performance and prevent problems migrating through the network.

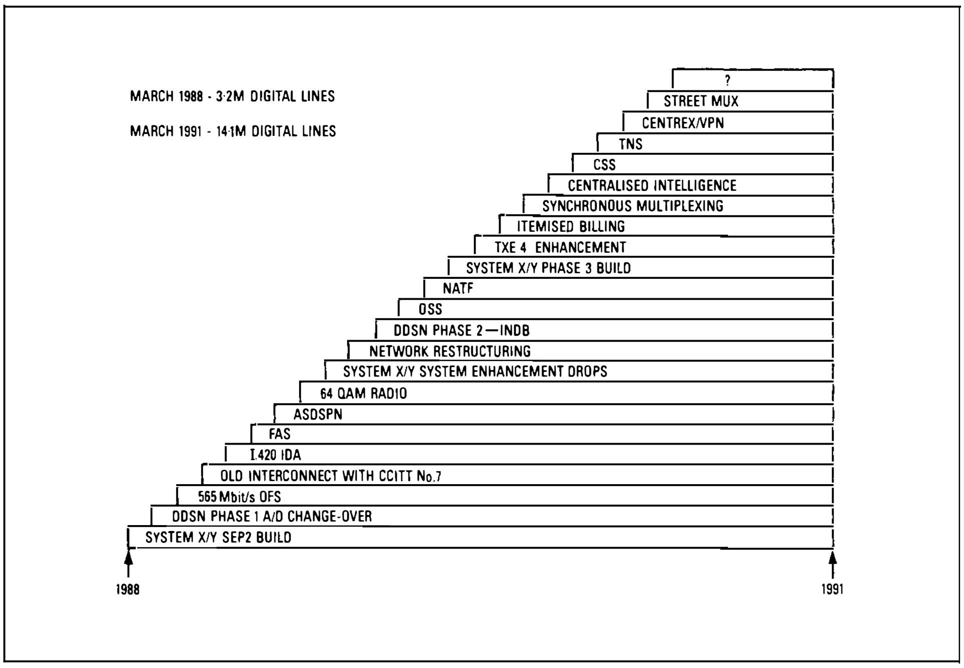


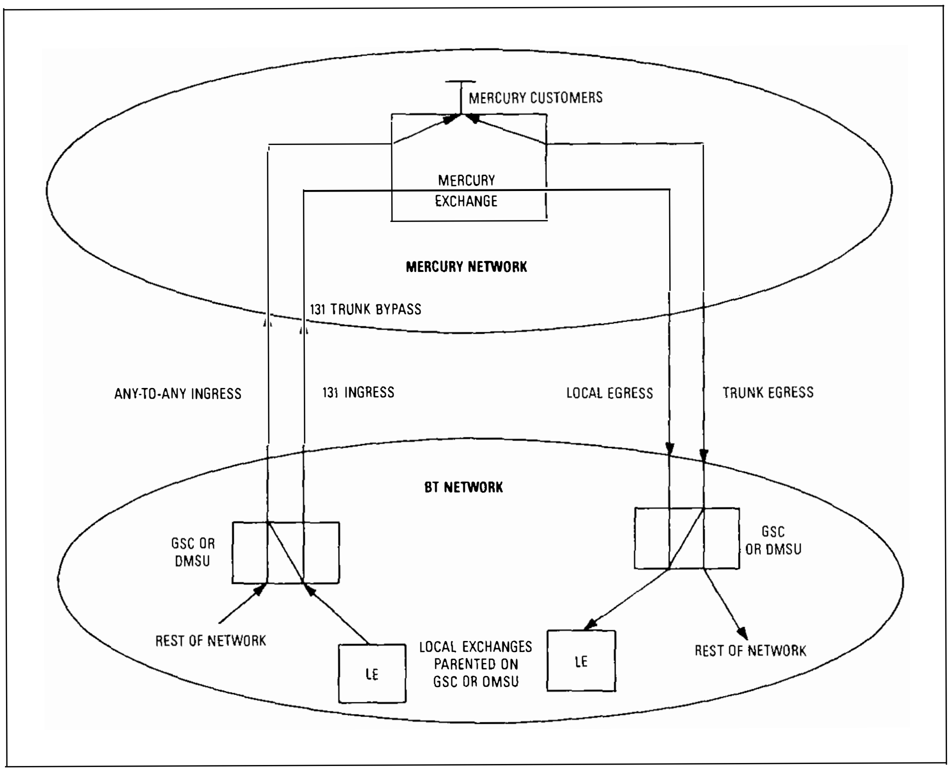
Figure 34
Change management, the complexity staircase

OTHER LICENSED OPERATORS (OLOs)

Under the new liberalised regime introduced in the UK, BT is obliged to provide interconnection to the network of its competitor, Mercury, and the networks of other licensed operators in the UK; namely, the two cellular mobile radio companies, Cellnet (a joint BT/Securicor company) and Racal Vodaphone, Kingston Communications (Hull) and Telecom Manx networks. In addition, the inland network of BT is interconnected to the networks of Eire, Jersey and Guernsey.

Connection to the Mercury network is provided to allow Mercury customers connected to the BT network to route calls via the Mercury network to bypass the BT trunk network (by dialling 131). The connection also allows calls to be made from BT customers to customers directly parented on Mercury exchanges and from such customers to BT customers. Figure 35 shows the interconnect arrangements. At the end of 1988, there were about 30 000 interconnect circuits provided between the BT and Mercury networks.

Figure 35
Interconnect to Mercury network



NETWORK EVOLUTION

Evolution of the network is a continuous process driven by the emergence of new technology, competition and customer requirements. Future evolution through the 1990s is likely to be heavily influenced by centralisation of intelligence, the managed synchronous digital transmission network and passive optical systems in the local loop. The distinction between network sectors will blur to just the loop and core network. The introduction of a broadband ISDN could be stimulated by the development of variable bandwidth switching using techniques such as ATM (asynchronous transfer mode).

Beyond the year 2000, increasing exploitation of optical fibre bandwidth, perhaps up to 50 THz, will be achieved by the use of optical wavelength-division multiplex methods, low-loss fluoride fibre, optical amplifiers and coherent detectors leading to the concept of an optical ether network. Such a distributed switching network could operate in a radio mode with each terminal assigned a specific wavelength, communication being established by, say, the calling terminal tuning-in to that wavelength of the destination. A common wavelength could be used for associated wavelength address information.

A continuing extension of personal mobility will be achieved not only by enhancements to traditional cellular radio, radiopaging and Phonepoint type services, but also to the 'personality' aspects like the introduction of personal numbering which will enable calls to be routed to customers rather than a fixed network address.

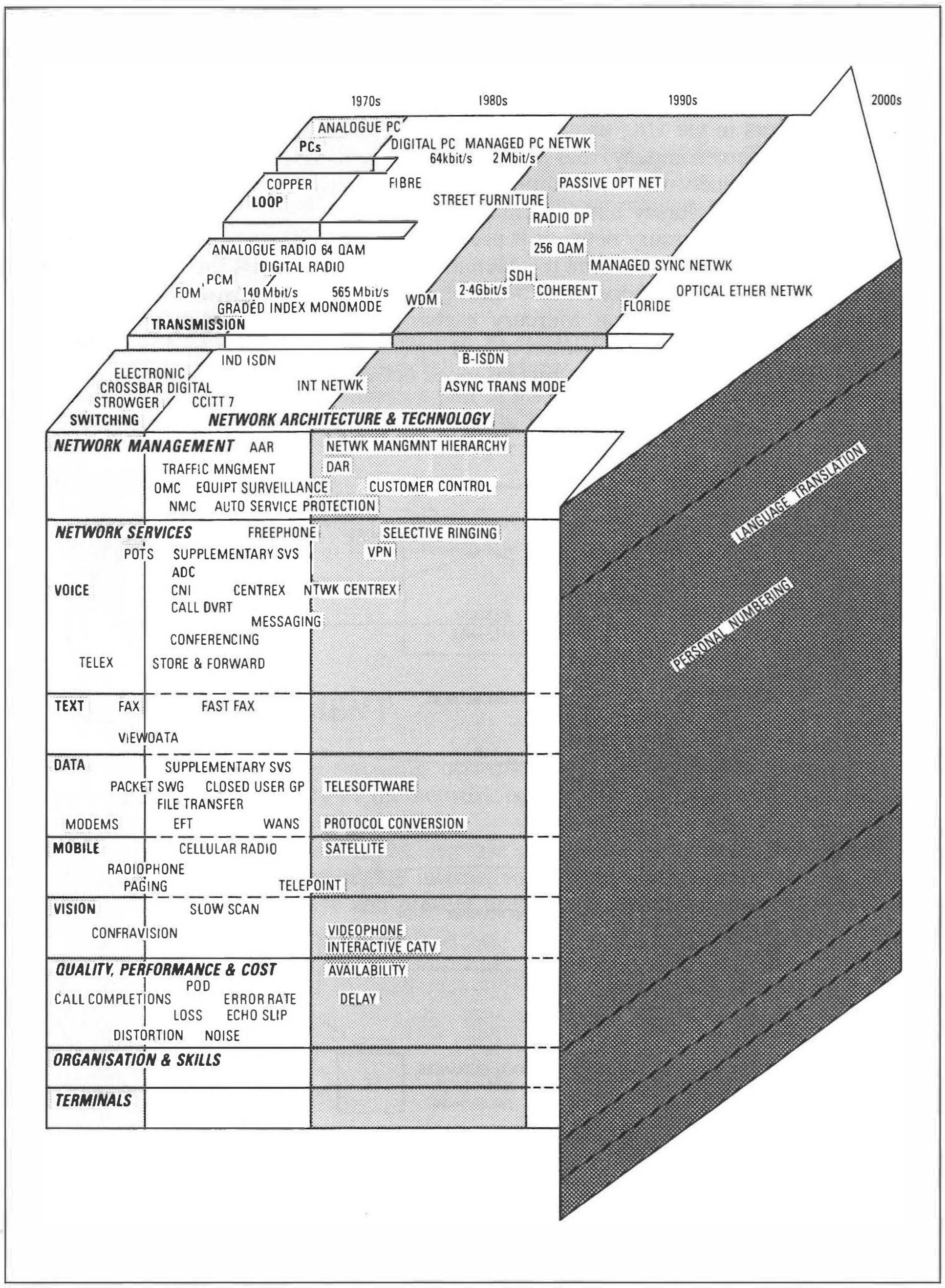


Figure 36
Coherent network evolution

Figure 36 illustrates how the network might evolve. However, to maximise the benefits it is essential that technology and network architecture, network management, network performance and cost together with the organisation and skills necessary to operate the network, move forward in a coherent manner to provide the services required by customers.

The evolution of the network will be influenced by a number of drivers and inhibitors, the most important of which are:

(*a*) The increasingly diverse and sophisticated requirements of customers in a competitive environment, stimulated by the emergence of third-party service providers together with terminal and applications vendors.

(*b*) The rapidly increasing pace of technological development.

(*c*) The ability to develop vast quantities of good quality network and management software, effectively manage its introduction and enhancement and generate the necessary customer and equipment related data. Computer-aided software engineering (CASE) will be essential.

(*d*) A more rapid (than hitherto) formulation of internationally agreed network and terminal standards is essential if network evolution is to be responsive to market demand.

(*e*) A balanced regulatory regime that protects the rights of the customers and encourages competition without stifling innovation is essential. Within the UK, OFTEL performs this function with the DTI controlling the allocation and management of the radio frequency spectrum. However, the European Community is exercising an increasing influence over the regulation of standards with the establishment of the standards body ETSI (European Telecommunications Standards Institute) who issues mandatory standards in the form of NETS.

CONCLUSIONS

This paper has attempted to provide a broad overview of the evolving network with some personal views on how it may develop in the future. Inevitably, due to the pace of technological development, the situation will change and this information will become dated.

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