The dynamics of private wire networks

A. M. Henderson, B.Sc

Summary The demand for point-to-point leased-line data services is increasing rapidly throughout the world. As a result, many new system elements are becoming available to help telecom authorities provision, maintain and modify high-quality services. The article describes how line transmission systems, versatile multiplexers, automatic cross-connect switches and management systems can be combined to provide a national leased-line data network.

The British Telecom KiloStream network is compared with the Australian network, to show how different network needs determine system configuration. The U.K system provides every customer with a complete timeslot, whereas the Australian system uses the X50 standard to share each timeslot between multiple customers. The possibilities for a hybrid network are also discussed.

The applications for automatic cross-connect switches in data networks are described, showing how elements such as sub-rate switching, multi-junction systems, 1544K (T1 standard) to 2048K standard converters, signalling (TS16) switches and other features increase versatility.

Introduction

Telecom authorities around the world are today finding the need to devote increasing proportions of their transmission capacity to providing special services to their major customers. In addition to private-wire voice and leased-line data services, customers are demanding high-quality broadband audio and video links amongst many other special services. Although the concept of a dedicated point-to-point link is simpler than that of a public switched telephone network (PSTN) link, the practicalities of provisioning and maintaining such links are great (figure 1).

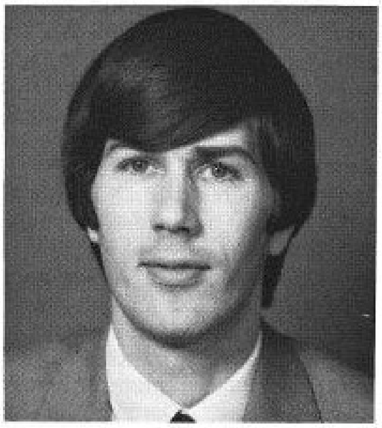
Two major problems with private wire networks are the rate at which requirements change, and the lack of monitoring and control. In the PSTN environment, the links to the exchange are always needed and are always the same. They are in use for only short periods, allowing versatile, but highly expensive, exchanges to switch the intermittent traffic to its destination. In the private-wire environment, the links are fixed between two points and are 100% available. Once installed there is no need for switching. The problems arise during installation and changes of requirement. Unfortunately, the rate of change in the private-wire environment is increasing rapidly. There is an exponential growth in demand for circuits and, once provided, a steady migration to greater capacity. As businesses grow, new branches open and communications requirements alter, resulting in an increasing amount of time being spent on circuit provisioning and re-routeing. Typically this special service network will be provided by hard wiring of links at the various nodes along the line route. Use of high-capacity p.c.m trunks between nodes makes the services more economical, but involves the use of multiplexers and de-multiplexers at each node. As the number of services grows, the size and complexity of these hard-wired nodes increase rapidly. The node routes could be implemented by nailing up of connections on PSTN exchanges but this would involve waste of the valuable resource.

Provisioning and alteration of special services present the authority with a number of problems. Initially, a route has to be found between the customer end points. This is usually a paper work exercise, involving laborious examination of link capacities and accurate recording of alterations. Once chosen, personnel have to be instructed and co-ordinated at each node to make the correct wire link on the distribution frame. On completion of this exercise, end-to-end testing must be carried out to ensure correct implementation. The customer is then able to use his private wire, weeks or months after requesting it.

An additional problem is the

A. M. Henderson
Alistair Henderson joined Marconi Communication Systems in 1985 after eight years with Plessey Controls. After graduation from Glasgow University he joined the Product Planning and Research team at Plessey, where he worked on the development of data logging equipment, high-speed modems and multiplexers. In 1983, he moved from engineering to product marketing for public network packet switching systems.

A period was then spent with Plessey's corporate marketing department before taking up his role with Marconi as Sales Manager for data networks.



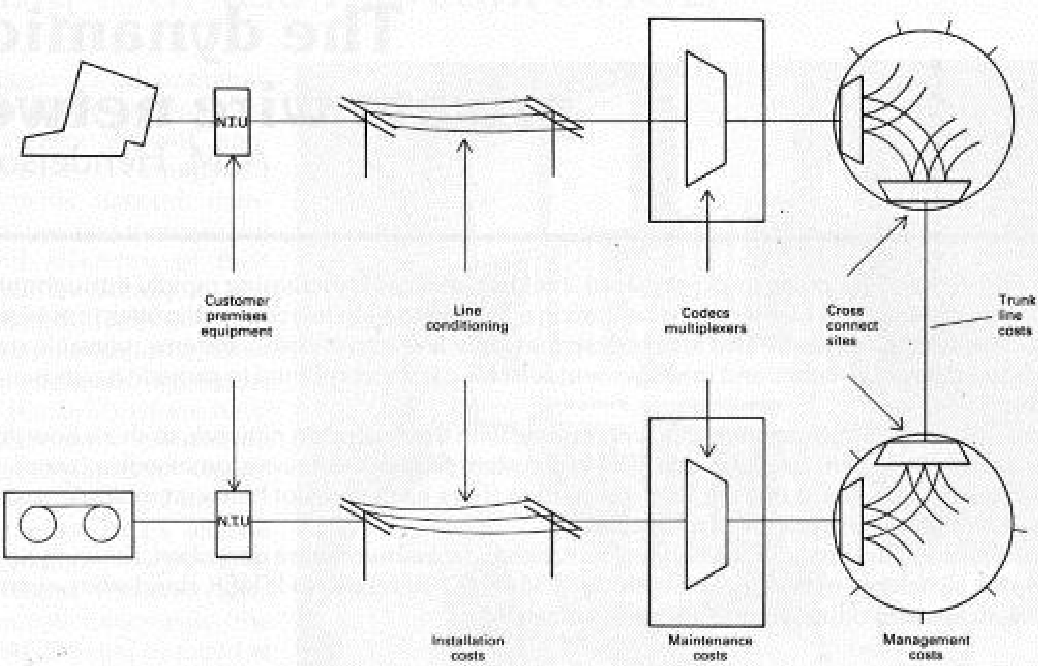


Fig. 1. Elements in a dedicated point-to-point link

ever increasing variety of services required, with widely varying bandwidths, from data at 2.4 kbit/s, upwards through voice at 64 kbit/s, to high-capacity links at 1544 kbit/s, 2048 kbit/s or more.

Provisioning and maintaining such services is beginning to overwhelm many PTTs, prompting them to look for a managed system capable of integrating all the various services.

The elements of a managed service network

The requirements for a national special-services network have been shown to be very different from those of the existing PSTN network. Ideally, an overlay network should be provided, making use of the transmission links provided for the PSTN networks, but using new system elements capable of meeting the needs of special services (figure 2).

The elements of such a service network may be divided into four categories:

a) customer-access equipment located in the customer's premises,
b) exchange-based multiplexers,
c) node cross-point switches to provide automatic remote routeing and test access,
d) centralized control and manage-

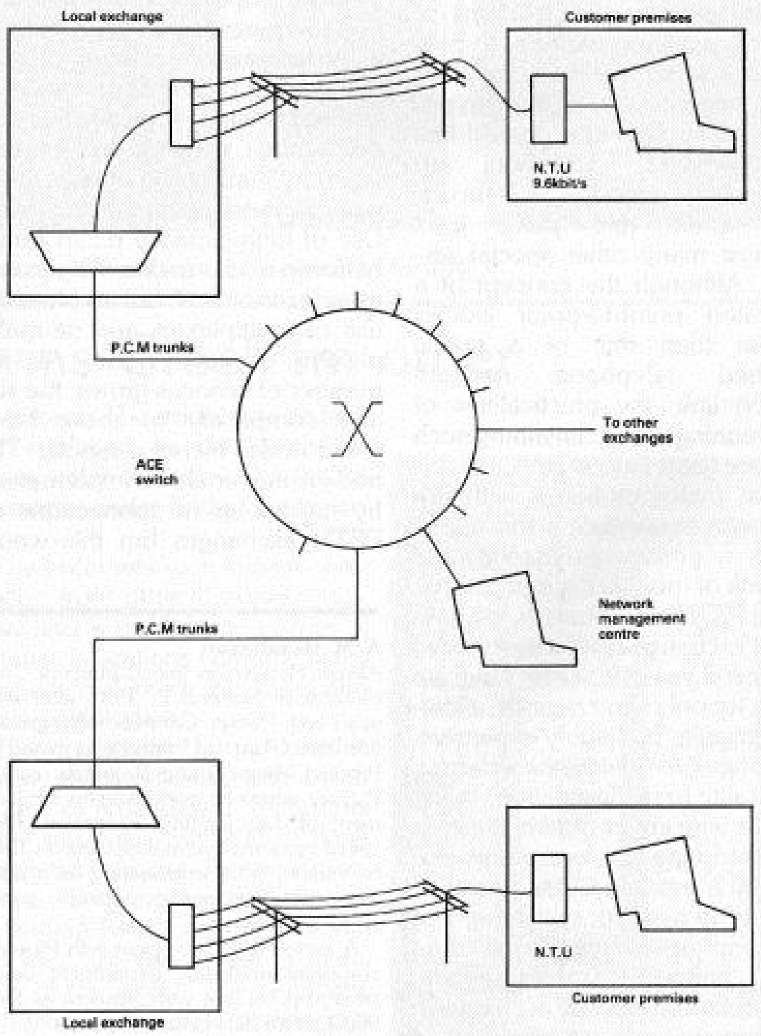


Fig. 2. Elements in a managed network

ment of the complete facility.

Great strides have been made in each of the above areas in the last few years, with the evolution of many new and versatile system elements. Marconi has been involved at the forefront of this field, having provided national networks in the UK, Australia, and other countries, to meet specific and different network requirements. This article will summarize some of the latest advances showing how they can be combined to satisfy the needs of a special-service network.

Customer access

Traditionally, modems have been used to provide special-service access for data links, with broadband analogue circuits catering for other services. As digital technology revolutionizes the network these solutions are becoming inappropriate. The advance of technology has allowed the development of network termination units (n.t.u), which use specialized coding techniques such as WAL2 to bring the full capacity of the p.c.m timeslot right to the customer's premises. The customer can therefore be supplied with point-to-point digital links at any bandwidth needed to meet his special-service requirement.

Currently, Marconi supplies a variety of such n.t.u and customer multiplexers catering for the needs of most data rates from 300 bit/s, through 1.2, 2.4, 4.8, 9.6, 19.2 kbit/s up to the higher rates of 48, 56 and 64 kbit/s. Units are available to provide services at rates above 64 kbit/s and they allow any multiple of 64 kbit/s to be used, up to the maximum of the p.c.m line capacity. Each unit caters for a range of interface types such as V24, X21 or V35, with both synchronous and asynchronous inputs. Customers can therefore be provided with special-service access at a digital interface to meet most requirements. An additional range of customer multiplexers is available to allow most efficient use of the bandwidth. An example of this is the new speech-plus-data multiplexer which provides a high-quality ADPCM speech line, together with four data ports, over a single p.c.m timeslot.

Many improvements are taking place in this area of technology, such as the move towards 2-wire transmissions instead of the four currently required, together with more sophisticated line-coding techniques. The trend is towards higher bit rates, and more versatile integrated access.

Integrated services digital network (ISDN) promises to provide a versatile customer access, but most organizations large enough to require such services are likely to have a substantial number of voice and data lines. For this reason, the trend is likely to be towards multiplexers based on customer's premises, combining all the customer's service needs onto 1.5 Mbit/s T1 or 2 Mbit/s trunks to the exchange. At the very least, multiplexers will be established in roadside cabinets to serve a number of major local customers. The Marconi versatile multiplexer (V-Mux) is designed to fulfill this need, allowing customer-access with a wide variety of voice, signalling and data interfaces. The link to the exchange is over conventional wire, or via monomode local-loop fibre optic systems. The multiplexer gives complete versatility of access by major customers, and includes switching elements to allow traffic management by the customer.

Exchange-based multiplexers

The conventional p.c.m multiplexer can be used simply to provide access for a leased-line service by replacing voice frequency cards with data interfaces. Although this will provide the simplest access to the p.c.m network, several advantages can be gained from having specialized, dedicated multiplexers, independent of the switched voice traffic. The main advantage lies in the ability to monitor and control the customer units. The multiplexer used in the British Telecom KiloStream data networks continuously monitors for line faults and distinguishes between various types of failure, allowing fast and efficient maintenance. Alarms are provided locally and are forwarded to nodal collection points.

Developments in multiplexer technology are leading to increasingly intelligent multiplexer systems capable of handling tasks previously restricted to nodal cross-connect points.

The new generation V-Mux from Marconi is an example of this type of system (figure 3). A control channel to the multiplexer allows local or remote re-configuration. A switch module on the mux enables any port to be connected with any other, to allow local-exchange cross connection of customer routes and variation of services with demand.

Note that the V-Mux provides for up to 40 ports, allowing routes to be connected but not permanently in service. The availability of two aggregate ports allows recovery from p.c.m channel failures. Various versions of the Marconi multiplexer cope with the needs of different countries to provide a comprehensive solution. Three examples are given below.

The British Telecom KiloStream network

The UK has high density and penetration of data users, together with a large capacity of interconnecting p.c.m links. For this reason,

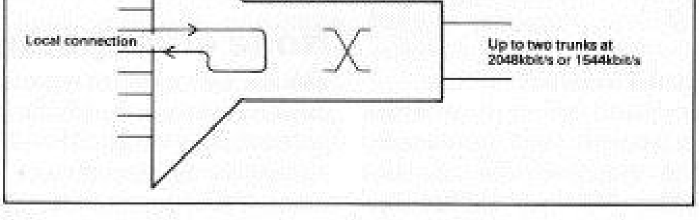


Fig. 3. Diagram of the versatile multiplexer (V-Mux)

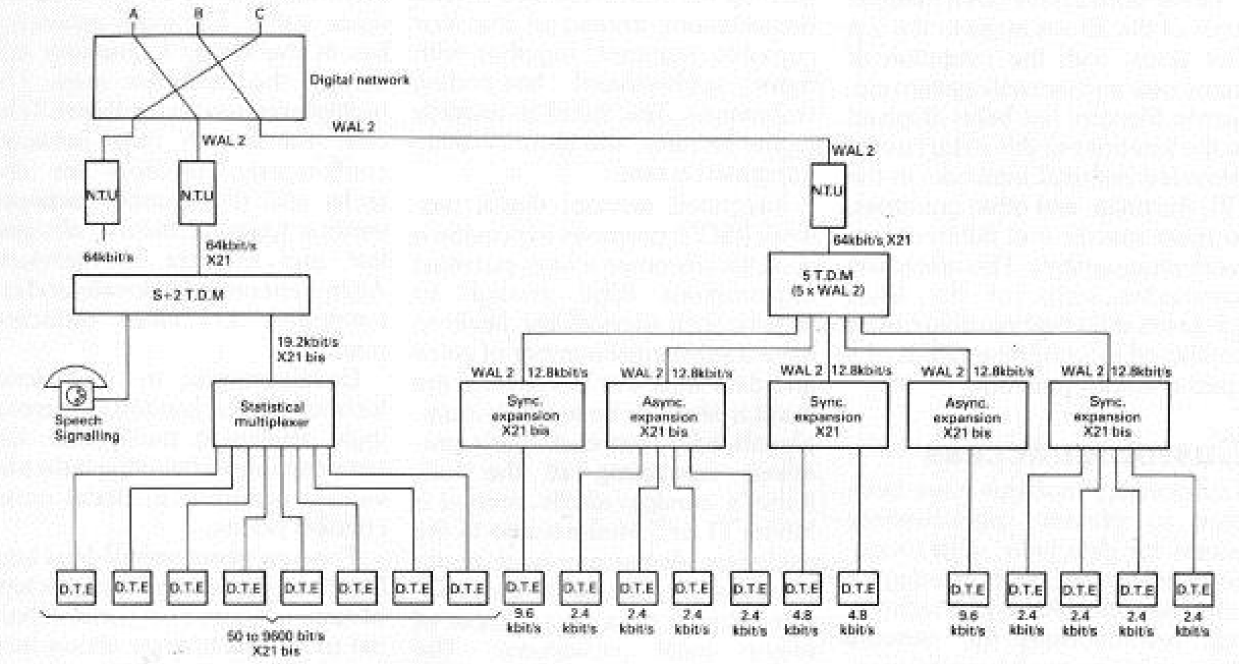


Fig. 4. The Marconi multiplexer in the BT KiloStream network

each user is allocated a full 64 kbit/s channel regardless of requirements (2.4/4.8 kbit/s etc). This may seem wasteful but the cost of the extra level of multiplexers at each end, together with the cost of more complex routeing at nodes, makes it more economical to provide a complete channel. The Marconi multiplexer does this in a most cost-effective manner (figure 4).

The Australian network

The distances between urban centres in Australia are great. For this reason, p.c.m capacity must be filled to maximum. Zero order multiplexers (ZDME) were designed to combine customers at rates from 1.2 kbit/s to 9.6 kbit/s onto each timeslot. The cost of the extra level of multiplexing is offset by the lower use of p.c.m trunks in this case. The ZDME combines up to 20 users at 2.4 kbit/s, ten at 4.8 kbit/s or five at 9.6 kbit/s onto a single timeslot. The multiplexer is designed to meet the X50 standard for the most efficient use of lines (figure 5).

The hybrid network

It is recognized that most countries have a mixed (and continually evolving) concentration of data users. The Marconi V-Mux has been designed to cope with this network topology.

In conventional multiplex mode, the V-Mux will combine full timeslots onto trunks at 2048 kbit/s, or 1544 kbit/s T1. It can provide two trunks, main and standby, with the ability to switch between trunks or, indeed, between any interface port in the multiplexer. (This is useful for local link circuits).

In sub-rate configuration, the V-Mux will accept inputs at the basic data rates (2.4 kbit/s, 9.6 kbit/s etc), combining them onto a number of 64 kbit/s trunks. The sub-rate multiplexers are most economically deployed in areas remote from the main network, with limited customer density. Each timeslot is routed through data access cards on existing p.c.m multiplexers to reach the main network. There the lines are combined with other 64 kbit/s timeslots onto T1 or 2048 kbit/s trunks (figure 6).

The choice of conventional multiplexer or sub-rate multiplexer can be made purely on the basis of economics, allowing maximum versatility in network planning.

Node cross points

The node cross point is perhaps the most revolutionary of the service network elements. The Marconi Automatic Cross-connect Equipment (ACE) is now in operation with a number of telecommunication authorities in both 2Mbit/s CEPT environments, and in T1 1.544 Mbit/s environments (figure 7). The equipment accepts lines at either the 2 Mbit/s or 1.5 Mbit/s line standard, providing a completely non-blocking electronically controlled cross-connect matrix (figure 8).

As a nodal point, the ACE can connect, on a semi permanent basis, any 64 kbit/s timeslot with any other. Such cross connections are a direct replacement for the banks of demultiplexers, digital distribution frames, and hard-wired links. There are many immediate advantages, such as the ability to provision and alter routes from a remote location, the availability of computer data bases holding route details, and the centralized monitoring and alarm gathering capability. A more obvious advantage is a great reduction in size, power requirements and cost over alternative methods.

Marconi's basic ACE switch is configurable up to 128 ports with T1 and/or 2 Mbit/s lines, providing a maximum of 3968 basic timeslot cross connects. The smaller Mini Ace covers the range up to 32 ports, and a 3-stage 512 port ACE will be deployed soon for larger nodes (see accompanying article).

The ACE is designed to be the central node switch of special services networks, and has thus been

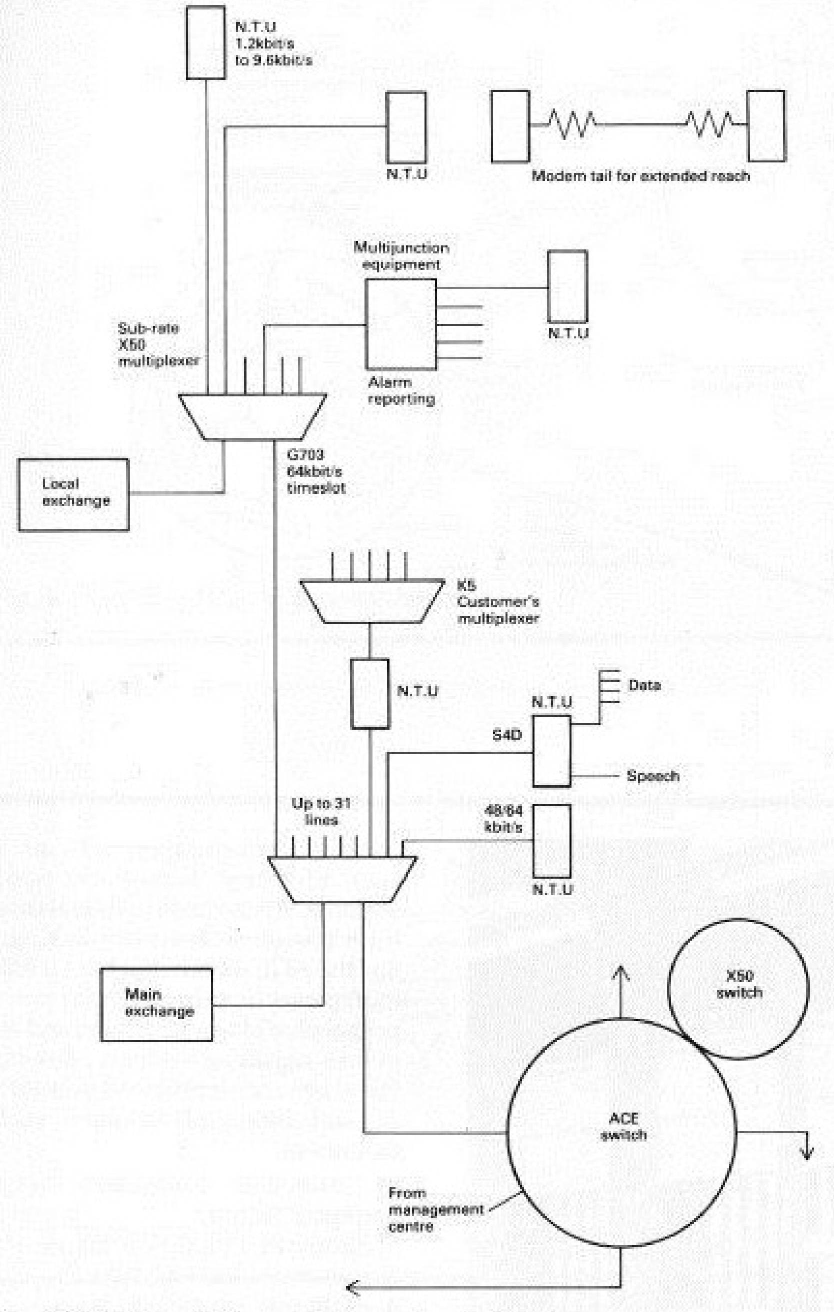


Fig. 5. ZDME multiplexers in Australian network

designed for maximum circuit reliability. No single failure will affect more than a single 2048 kbit/s or 1544 kbit/s line. The various elements of the system's reliability are described below:

a) individual line cards buffer each trunk line, continuously monitoring for frame alignment problems, high error rates or remote alarms. Each line connects to the switch plane through separate back plane links,

b) the switch plane is fully non-blocking and is duplicated for maximum reliability. All signals pass continuously through both switch planes. The output of each line from the switch plane is continuously monitored for discrepancies, providing instant recognition of any failure,

c) the clock synchronization system is fed from two external sources, with an internal oscillator to take over should both fail. Within the system, triplicated clock paths are fed to the cards, where majority voting systems ensure maximum reliability.

d) all cross-connect routes are held in non volatile memory, ensuring that even complete power failure does not destroy the route map,

e) duplicated computer systems continuously monitor and manage the system. However, should both computers fail completely, the transmission paths are unaffected and remain open for traffic (figure 9).

Apart from high reliability, the other major consideration in design was economy. As there is no requirement for real-time switching of routes, the system can be implemented in a most cost-effective manner. This allows widespread use of the ACE switch throughout the network to maximum effect.

Special-service modules

The needs of the various special services produce a demand for a number of sub-modules located at the node switch. A range of these has been developed and they are in use in a variety of networks, as described below.

In sub-rate networks such as the Australian DDN, it is insufficient to provide cross connection at 64 kbit/s timeslot level. Many customers share each timeslot, each with different destinations. For this reason, the sub-rate switch module was developed. This module carries out cross connection between user lines at the various data rates such as 2.4, 4.8, 9.6 kbit/s etc, allowing connection between (for example) one end of a 2.4 kbit/s data channel in Timeslot 5 of one line, with the other end in Timeslot 11 of another line. Complete flexibility and cross-connection capability is thus available (figure 10).

A further enhancement, to aid more efficient use of the network, is the multijunction equipment. This is available in a number of variations to assist in polled networks.

The multijunction equipment (or MJE) is used to control a number of remote offices, such as bank branches. Each bank has a link to the local MJE, which combines the traffic onto a single link to head office. The head-office computer sends out a message for a branch which is broadcast by the MJE to all branches. The correctly addressed branch responds and the MJE switches in the return path to the head office. The use of polled MJE systems greatly reduces the requirement for long leased lines in many cases. The Marconi MJE will control up to five branches, and may be cascaded to control as many as required.

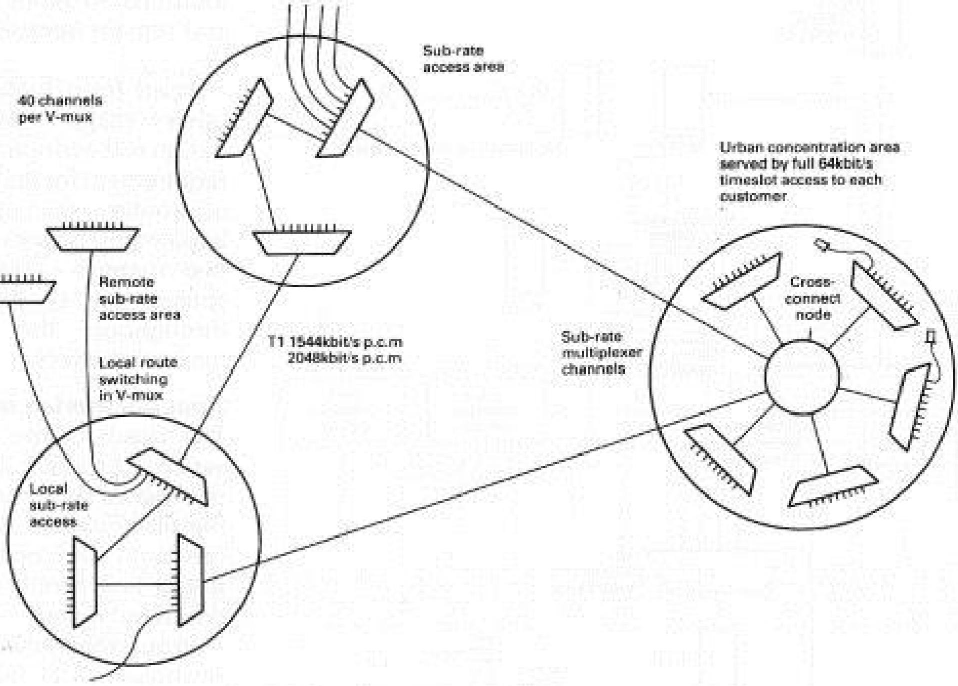


Fig. 6. V-Mux as a sub-rate multiplexer

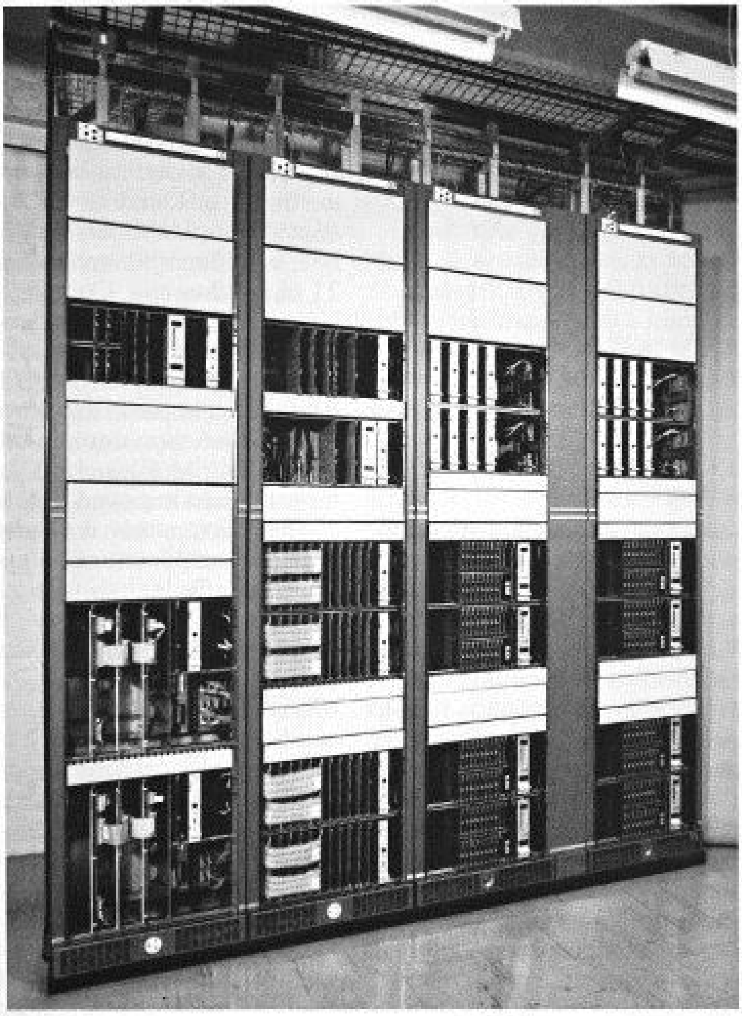


Fig. 7. Automatic Cross-connect Equipment (ACE)

Alarm concentration units are a vital additional feature on node switches. These units collect alarms from the whole local network, not just the AÇE switch. Each n.t.u and multiplexer is provided with comprehensive alarm structures and an in-line signalling system, allowing the alarm concentrator to be aware of, and distinguish between, such failures as:

a) particular customer's n.t.u hardware failure,
b) customer n.t.u power failure,
c) customer local line failure,
d) exchange multiplexer failure,
e) p.c.m line loss of frame,
f) high error rates.

The alarms are available locally, or can be forwarded by the ACE to a centralized computer management system.

On receiving the alarm information, the operator can re-route the traffic around the failure by remote command. A further enhancement in this area is the development of localized restoration and normalization plans. These are alternative emergency routes which may be pre-planned by network operators and stored in the switch. Operators can quickly choose the appropriate plan to cope with a fault and institute the change with a single command. Expert systems to provide

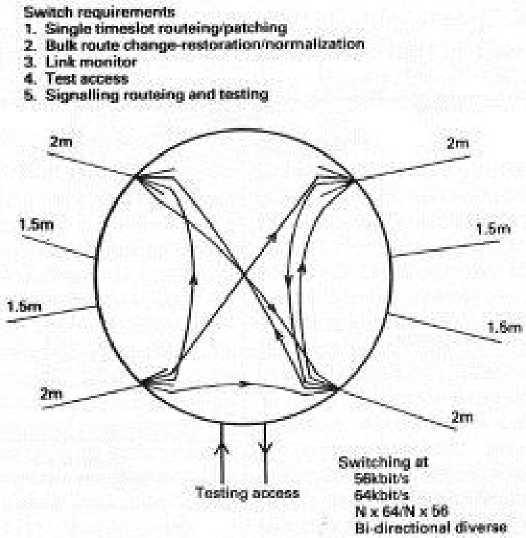


Fig. 8. Diagram of the ACE switch function

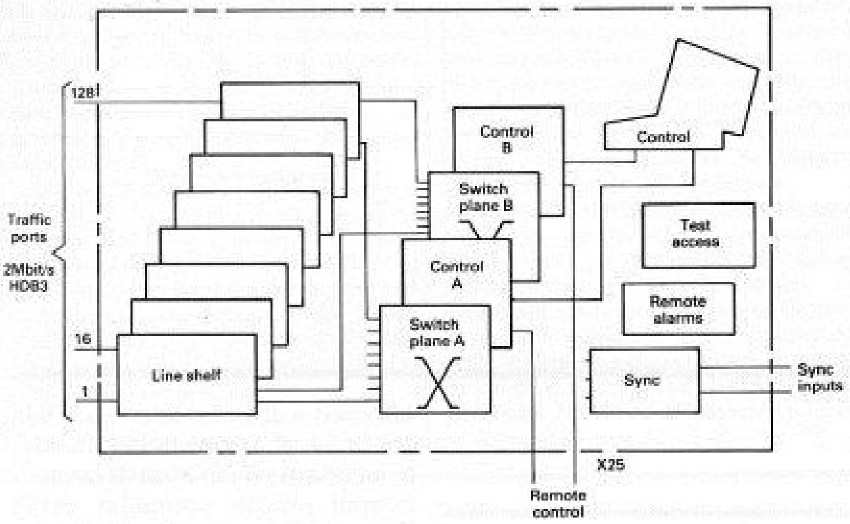


Fig. 9. Modular format of ACE switch

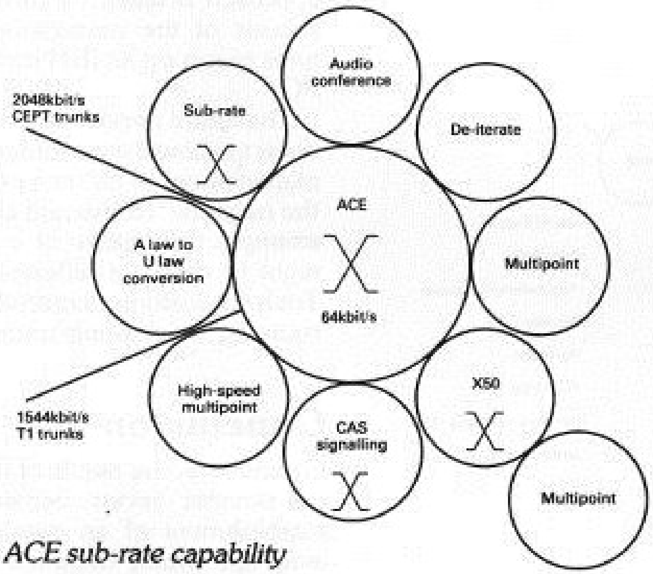


Fig. 10. ACE sub-rate capability

automatic choice of plan are an obvious progression. The above feature is particularly applicable where the switch is used in applications such as international transmission maintenance centres (I.T.M.C) (figure 11).

Signalling switch modules have been developed to cater for voice applications where inter-exchange signalling and control must be passed and switched in the correct manner. An example is the Time-slot 16 signal switch developed for the 2048 kbit/s market.

Various other add-on units such as line concentrators provide a full range of facilities to meet most current special-services network needs. Many more units are in development or under study to meet new requirements.

Control system

A number of different philosophies have been adopted for network control, depending on specific requirements.

A fully integrated approach was adopted for the UK network. Two DEC750 computers were based in separate locations in the UK, each able to manage the entire UK network. Communication between the network and the computer centres takes place over packet switch service. Each ACE node communicates with the computer centres, allowing full maintenance and control from a single location. By having a single data base for the entire network, service provisioning becomes simple (figure 12).

On requiring a link between two end points, the operator asks the database for a recommended route. The data base, which holds details of all cross connects and trunk loadings, provides the recommended route. If judged suitable, the operator can instruct the ACE switches to make the links, providing a route through the network.

The other major function of the centre is an alarm gathering point. The ACE switches are well provisioned with alarm messages to identify problems accurately. In addition, alarms from multiplexers and customer units are combined and forwarded to the centre.

The Australian network has

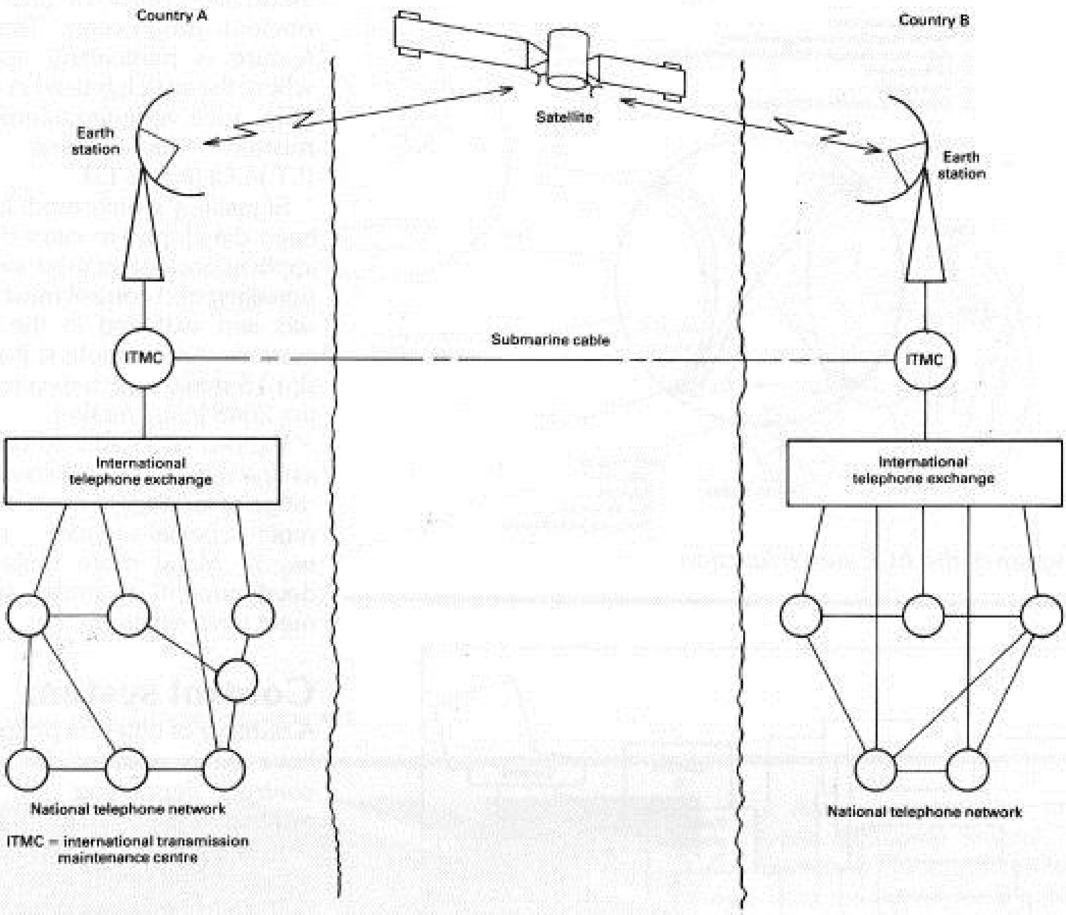


Fig. 11. ACE in ITMC configuration

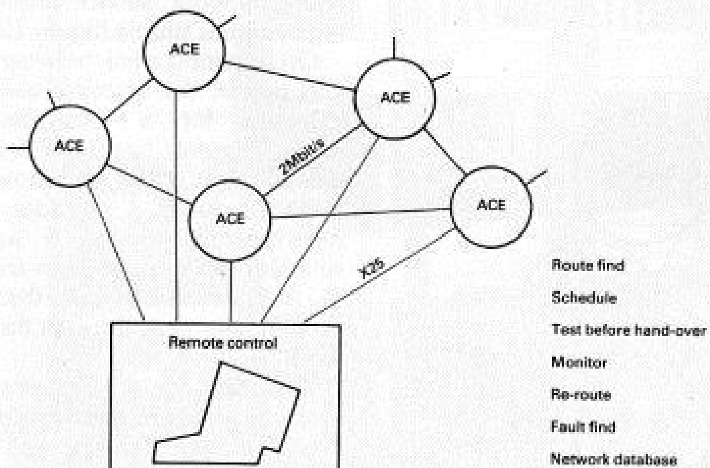


Fig. 12. Remote network control system.

adopted a different approach, with control and alarms being invested in a control centre in each state. An overall master computer centre then co-ordinates the state computers.

For smaller networks, or local control, a more economical approach is taken by providing a sub-set of the management features to run on an IBM compatible PC.

The future trend in network control is to allow the customer greater management of his own portion of the network. This would allow, for example, alteration of routes at night to cater for different needs. Trials for customer-controlled ACE routeing are currently under way.

Conclusion

In summary, the needs of the special-services sector demand the establishment of an overlay network specifically designed to take advantage of existing p.c.m trunks, and to maximize the revenue-earning capacity of the telecom authority.

By providing a fast, high-quality service, growth will be stimulated, and time consuming and costly provisioning and maintenance reduced. This can clearly be seen in countries where such a managed network has been established, and many other countries are now poised to follow.

RÉSUMÉ

La demande en services de transmission de données d'un point à l'autre au moyen de lignes privées connaît actuellement une croissance accélérée dans le monde entier. En conséquence, beaucoup de nouveaux éléments on fait leur apparition dans les systèmes pour aider les Télécommunications à fournir, entretenir et modifier les services de haute qualité. L'article montre comment les systèmes de transmission en ligne, les multiplexeurs polyvalents, les commutateurs automatiques à connexions croisées, et les systèmes de gestion peuvent être combinés pour fournir un réseau national de données en lignes privées.

L'article compare le résau KiloStream de British Telecom au réseau Australien, et montre comment les besoins différents des deux réseaux déterminent la configuration du système. Le système du Royaume-Uni fournit à chaque client une tranche horaire complète, tandis que le système Australien utilise la norme X50 pour partager chaque tranche horaire entre plusieurs clients. Les possibilités d'un réseau hybride sont également discutées.

Les applications des commutateurs à connexions croisées dans les réseaux de données sont décrites, montrant comment les éléments tels que les commutateurs de sous-catégories, les systèmes à jonctions multiples, les convertisseurs de 1544K (norme T1) en 2048K, les signaux (TS16) et autres augmentent la polyvalence du système dans son ensemble.

RESUMEN

La demanda de servicios de transmisión de datos a base de línea arrendada entre puntos fijos está aumentando rápidamente en todo el mundo. A raíz de esto, se encuentran ya a la disposición muchos nuevos elementos del sistema para ayudar a las Autoridades de Telecomunicaciones a abastecer, mantener y modificar los servicios de calidad superior. El artículo describe cómo pueden combinarse los sistemas de transmisión por línea, los multiplexores adaptables, les conmutadores automáticos de interconexión y los sistemas de administración, para proporcionar una red nacional de transmisión de datos a base de línea arrendada.

Se compara la red británica de telecomunicaciones KiloStream con la red australiana, para demostrar cómo determinan la configuración del sistema necesidades diferentes de redes. El sistema británico suministra a cada cliente un segmento de tiempo completo, mientras que el sistema australiano utiliza el estándar X50 para compartir cada segmento de tiempo entre varios clientes. Se discuten las posibilidades de una red híbrida.

Se describen las aplicaciones de los conmutadores automáticos de inteconexión de las redes de transmisión de datos, demostrándose cómo aumentan la estabilidad elementos tales como la conmutación a subvelocidad, los sistemas de unión múltiple, los convertidores normales de 1544K (T1 estándar) a 2048K, los conmutadores (TS16) de señalización y otras características.

ZUSAMMENFASSUNG

Die Nachfrage nach Datenübertragungsdiensten, die von Punkt zu Punkt über Mietsleitungen geführt werden, ist in der gesamten Welt im schnellen Anstieg. Als Ergebnis kommen viele neue Systemelemente auf, die den Fernmeldebehörden ermöglichen, Qualitätsdienste vorzusehen, aufrechtzuerhalten und zu ändern. Dieser Aufsatz beschreibt wie Leitungsübertragungssysteme, vielseitige Multiplexgeräte, automatische Querverbindungsschalter und Managementsysteme miteinander verbunden werden können, um ein Landes-Datennetz über Mietsleitungen zu erstellen.

Das Netz KiloStream der britischen Telefonbehörde British Telecom wird mit dem australischen Netz verglichen, um darzustellen, wie unterschiedliche Netzforderungen die Systemausführung bestimmten. Das britische System gibt jedem Kunden einen vollständigen Zeitspalt, wogegen das australische System die Norm X50 anwendet, um jeden Zeitspalt auf mehrere Benutzer zu verteilen. Die sich für ein Hybridnetz ergebenden Möglichkeiten werden auch erörtert.

Anwendungen für automatische Querverbindungsschalter in Datennetzen werden beschrieben, um anzuzeigen, wie gewisse Elemente, wie z.B. untersetztes Schalten, Mehrknotenpunktsysteme, Wandler zum Umformen von 1544K (Norm T1) auf 2048K, Signalisierschalter (TS16) und weitere Merkmale die Vielseitigkeit erweitern.