The British Telecom KiloStream service – reflections following the first two years of operation

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Summary It is now more than two years since British Telecom introduced its KiloStream service. This article examines some of the operational problems which have been encountered during this period and the work which has ensued in consequence, as well as outlining the function of KiloStream equipment. Also opportunity is taken to look forward to new developments and, in particular, the use of currently planned Automatic Cross-connect Equipment (ACE) including improvements in remote testing which this equipment will allow.

The employment of KiloStream in a typical customer's network is discussed, emphasizing the need to achieve successful overall communications between terminal and computer.

Introduction

Articles[1,2,3] have been written and a wealth of other information provided which describe, primarily from a technical stance, the KiloStream service in terms of the dedicated digital data equipment from which it is derived. The main purpose of this article is to examine the way KiloStream is settling in as a new service in terms of some of the problems it has to cope with in the real-world telecommunications environment, to refer to some of the important developments which are taking place and to give some information on the ways in which KiloStream circuits are being put to use. However, to give the reader some background against which to view these aspects, the significant component parts of the current KiloStream network are described briefly.

The KiloStream service was opened in January 1983, providing service initially via a mere four multiplex sites. Since then the network has grown steadily with currently some 4000 to 5000 KiloStream circuits in use or in the course of provision, supported by approximately 400 multiplex sites. This growth is expected to continue well into the foreseeable future with expansion within the network to approximately 750 multiplex sites by 1987, depending upon the growth strategy adopted.

The current KiloStream network – a brief description

The basic component parts of the KiloStream network are shown in figure 1. The equipment was developed by Marconi Communication Systems Ltd (MCSL) in conjunction with British Telecom (BT). MCSL also produced the equipment for the majority of the supply contracts.

As shown in figure 1, the transmission paths on the high-speed side of the multiplex are at 2048kbit/s. The multiplex signal at 2048kbit/s conforms to CCITT Recommendation G732. This gives 32 64kbit/s timeslots, 31 of which may be used for data communications with the remaining timeslot, designated Timeslot 0, used for framing, alarm and general housekeeping purposes. On the low-speed side of the multiplex, digital distribution to the customer is normally made via physical pair type cable which has been provided for telephony. Digital channels of 12800bit/s or 64kbit/s are provided for the data signals. The particular form of signal used for this purpose has been devised so that a satisfactory transmission path will be given without any departures from normal telephone distribution network planning rules.

The interface with the data-processing terminal equipment at the customers' premises conforms to the CCITT X21 Recommendation, and within this offers a V series compatible format (X21bis) so that existing type terminals may be served by the network.

User data transmission rates range from 2400bit/s through to 64kbit/s. With the exception of 64kbit/s, all other rates are structured in a 6+2 envelope for transmission across the network. This is

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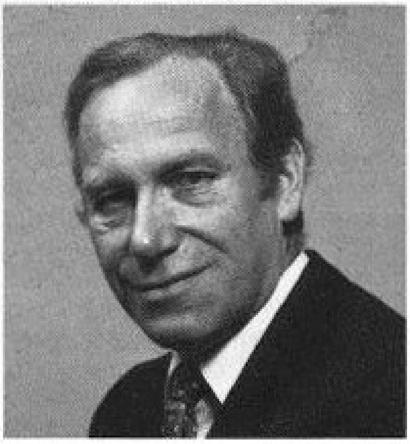
His early interest was submarine cable systems and he spent a number of years taking an active part in the provision of cross-channel systems to Europe, as well as transatlantic systems. This was followed by a period of a few years working on special circuit design for high-speed facsimile and data transmission.

With the advent of digital communications he moved into data network design and was, until recently, responsible for implementation of specialized networks including KiloStream.



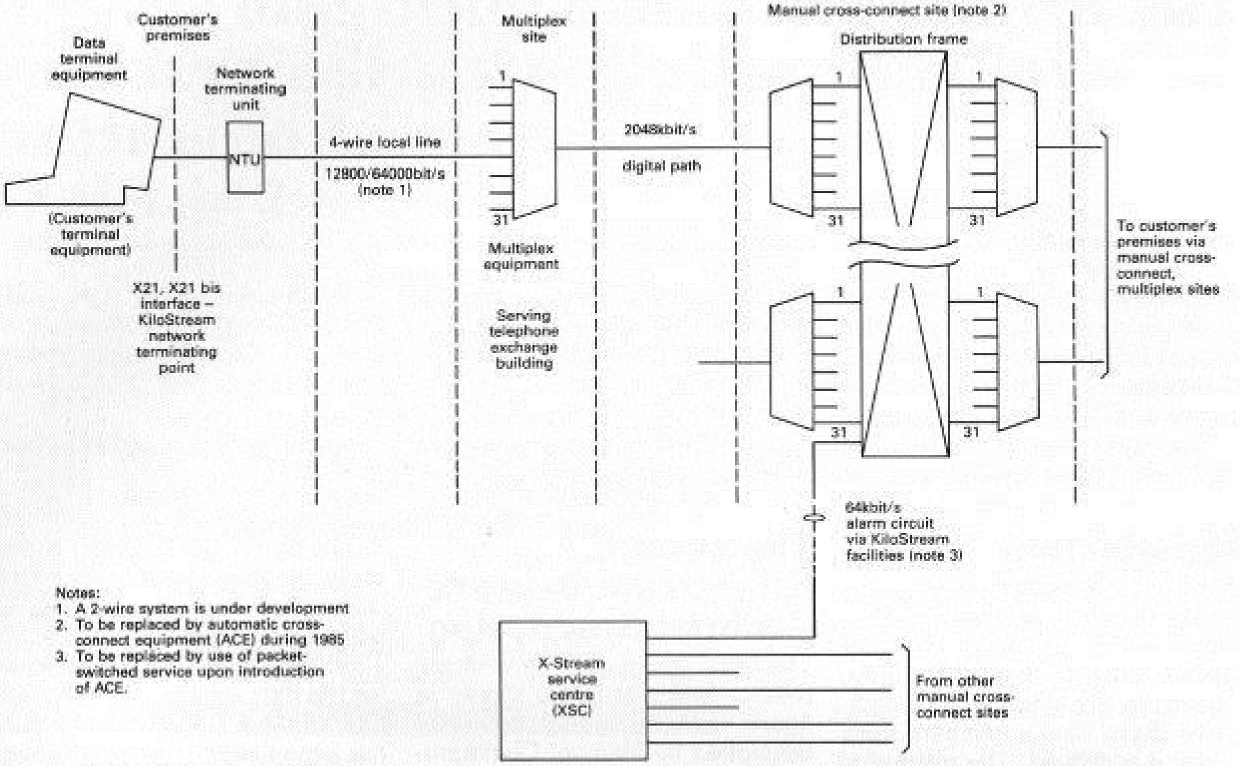


Fig. 1. Basic elements of KiloStream

accomplished in the network terminating unit by adding to every 6 bits of user's data a framing bit and status bit. The status bit signifies whether the envelope contains user's data or signalling information, and in the latter state may be used to control the switching of test loops on circuits for maintenance purposes. The framing bit is, of course, required to establish the position of an integral 6+2 envelope within the received bit stream.

Multiplex equipments are located either at multiplex sites, from which customers are served, or cross-connect sites which are an essential element in the flexible routeing of circuits by virtue of the manual jumpering facility which they offer.

Alarm conditions may arise on equipment at multiplex sites, cross-connect sites, network terminating units at customers' premises, or on transmission plant which is used to interconnect these equipments. The multiplex site acts as a primary collection point and passes alarm conditions, in a concentrated form, along the network to the cross-connect site for processing and for onward transmission to the appropriate X Stream Service Centre (XSC), of which there are two, one in London and the other in Manchester. Additionally alarms are displayed locally.

During 1985 the manual cross-connect sites are to be progressively replaced by Automatic Cross-Connect sites (ACE) of which more will be said later.

Some operational considerations

To be provided economically the KiloStream system must share provision overheads with, and thus use, 2048kbit/s digital transmission plant that is being installed primarily for telephony. This plant has been designed on the basis that a voiceband signal currently requires 64kbit/s of digital capacity for its transmission, to commercial standards, across the network after coding through the standard A-law p.c.m multiplexing process. A 2048kbit/s digital path therefore, when terminated by a standard p.c.m multiplex, will present on its low-speed side an analogue voiceband channel which typically will be capable of supporting a 9600bit/s signal from a data modem.

In KiloStream, standard p.c.m multiplexes are replaced by the digital multiplex shown in figure 1. In this case the 64kbit/s digital capacity is not subject to the analogue-to-digital conversion process through a p.c.m multiplex, and is fully available to be exploited directly for digital data transmission. On the basis of the equivalent voiceband capacity, the user therefore sees at least a fivefold increase in potential data throughput and it is this factor above others which marks the significant technological step which KiloStream has brought. However, it is worthwhile analysing what this increase in efficiency to the user means in network performance requirements. In very general terms each line transmission bit transmitted within the telephone digital transmission system may be converted to a user's data bit in the KiloStream network terminating unit. As a typical telephony transmission system from which 2048kbit/s paths are derived operates at 140Mbit/s, this in effect means that user's data is being resolved in this system at intervals of less than 1/100th of a microsecond, and that therefore an impairment in the transmission path or associated equipment of nominal duration down to this value could result in a data transmission error. This would have been less likely to happen in the case where a p.c.m multiplex was used with a similar digital transmission path, as the voice coding process would have made the user's data signal, which is significantly lower-speed in any event, relatively insensitive to the very short transmission impairments.

Although this example is imprecise in the detailed mechanism of overall data transmission through the KiloStream network, it does serve to emphasize the highly intensive manner in which digital bearer systems are being exploited by the service, and in consequence the need to ensure that line plant meets the exacting criteria necessary to support a service of this nature.

Requirements for digital transmission plant

The KiloStream network is provided on an overlay principle in that the facilities it provides are dedicated to KiloStream traffic. This has meant that there has been, and continues to be, a significant element of advance provision of KiloStream equipment and interconnecting 2048kbit/s digital paths related to planned network size at a particular time, rather than to the inevitably lesser demand in terms of actual user circuits at that stage. In some cases, making the 2048kbit/s digital paths available by the required dates has necessitated routeings being established which were longer than purely geographical considerations would have dictated, due to the relatively limited penetration of digital plant at that time.

The intensive use of this plant by KiloStream had been anticipated, and commensurate preparation made in advance of opening the service. However real experience of actual use by customers proved invaluable and brought to light other problems, which were, of course, on occasions exacerbated by the greater route lengths in use at the time. In consequence, a thorough examination was urgently undertaken of all line and radio systems, and their associated transmission equipment to identify any shortcomings which might have a bearing on the performance of the KiloStream circuits routed over them. This exercise has been extensive and has led to investigations into potential problem areas which would not necessarily have become sources of trouble in the presence of the more robust digital voiceband signals. This has been a valuable learning area and has given a better understanding of interference mechanisms and their correction, particularly in the context of high-speed digital data signals.

To overcome identified problems an exhaustive programme of refurbishment of line and radio systems has been undertaken and is nearing completion; as a result a very significant improvement in the performance of the plant and equipment concerned has been achieved, together with the KiloStream circuits routed through it.

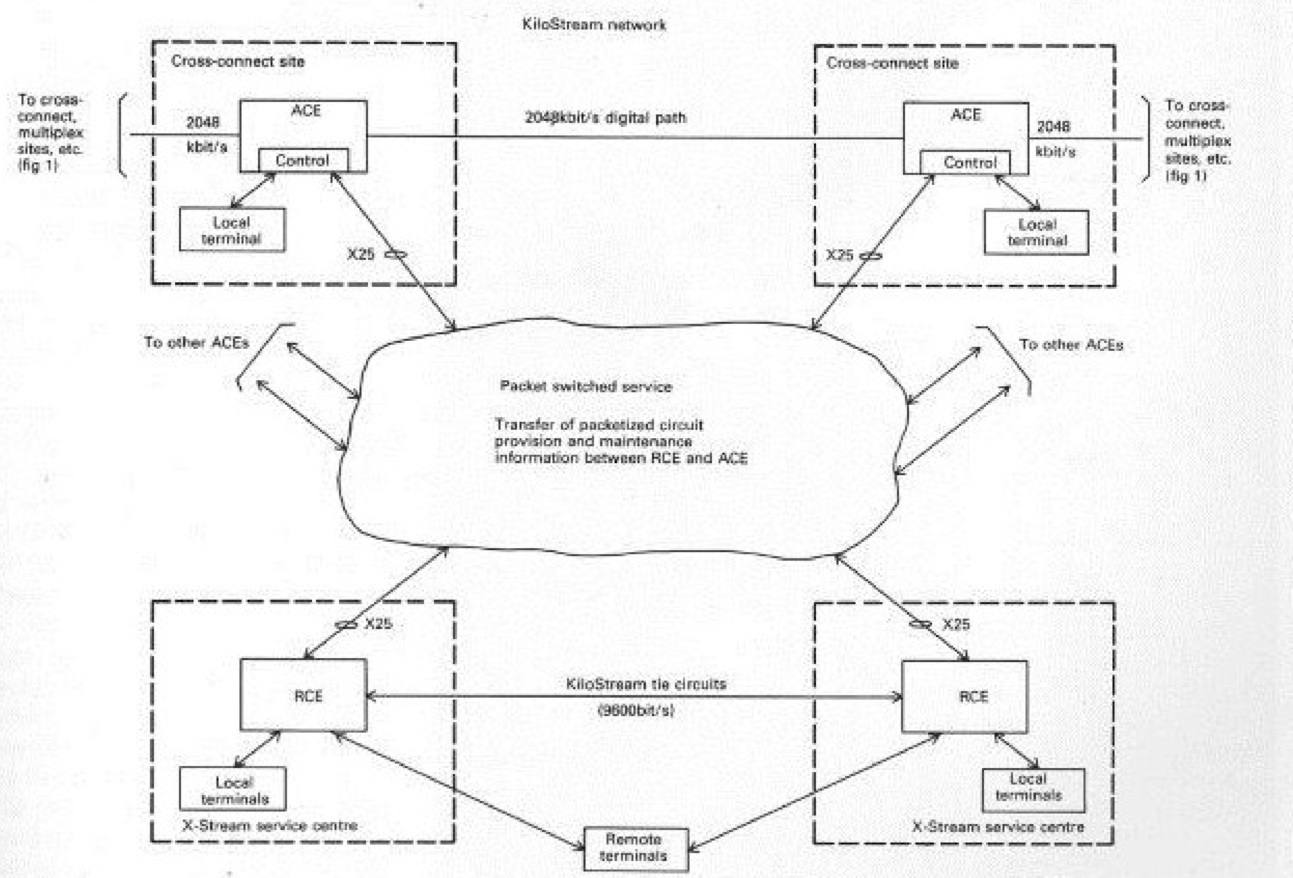


Fig. 2. Basic control of ACE

Automatic Cross-Connect Equipment (ACE)

Since the introduction of service, the first major network facility to be added to KiloStream will be ACE which will be progressively installed throughout this year. ACE will replace the manual cross-connect equipment shown in figure 1 and will confer a number of important benefits, notably a saving in cost and accommodation requirements, simplified circuit provision procedures and improved maintenance facilities. When the current installation programme is complete, there will be approximately 50 ACE sites throughout the KiloStream network.

Switching of circuit crosspoints in ACE will be controlled from terminals on a Remote Control Equipment (RCE) situated in each X Stream Service Centre (XSC). To give the required reliability, the network will thus contain two RCEs; there will be continuous updating between them so that in the event of a failure either may take control of the overall network. The significant control elements of the network are shown in diagrammatic form in figure 2.

Communications between an RCE and on-board ACE controllers are provided through a closed user group in the Packet Switching System (PSS). Hence each RCE and ACE will have an X25 packet port and address. In addition to carrying circuit provision messages, the packet switched system will also carry maintenance messages between an ACE alarm concentrator and RCE, where the messages will be processed for display and follow-up action. Remote access to a circuit for test purposes may then be obtained using the Remote Access Testing Equipment System (RATES) together with RCE facilities. Figure 3 is an outline diagram which shows the interrelationship of equipments to give remote testing facilities.

The Video Display Terminal (VDT) controls access to timeslots within ACE in the normal way via PSS. The selected timeslot associated with the circuit to be tested may be connected to a test access timeslot in a non-intrusive way for monitoring purposes, or it may be split for testing. The test access timeslot is connected to a test multiplex via a dedicated 2048kbit/s port. The low-speed channels from the multiplex are connected to RATES, which is accessed from the VDT via a host processor and the Public Switched Telephone Network (PSTN). Certain circuit protocol requirements are observed in establishing the PSTN connection, after which the VDT may control a range of tests on the intercepted circuit through RATES via the associated IEEE controller and Tester 294.

The ACE/RCE system has been developed by Marconi in conjunction with BT. Marconi is also manufacturing the ACE equipment and is responsible for provision of applications software for the DEC Vax 11/750 computer, which forms the basis of an RCE.

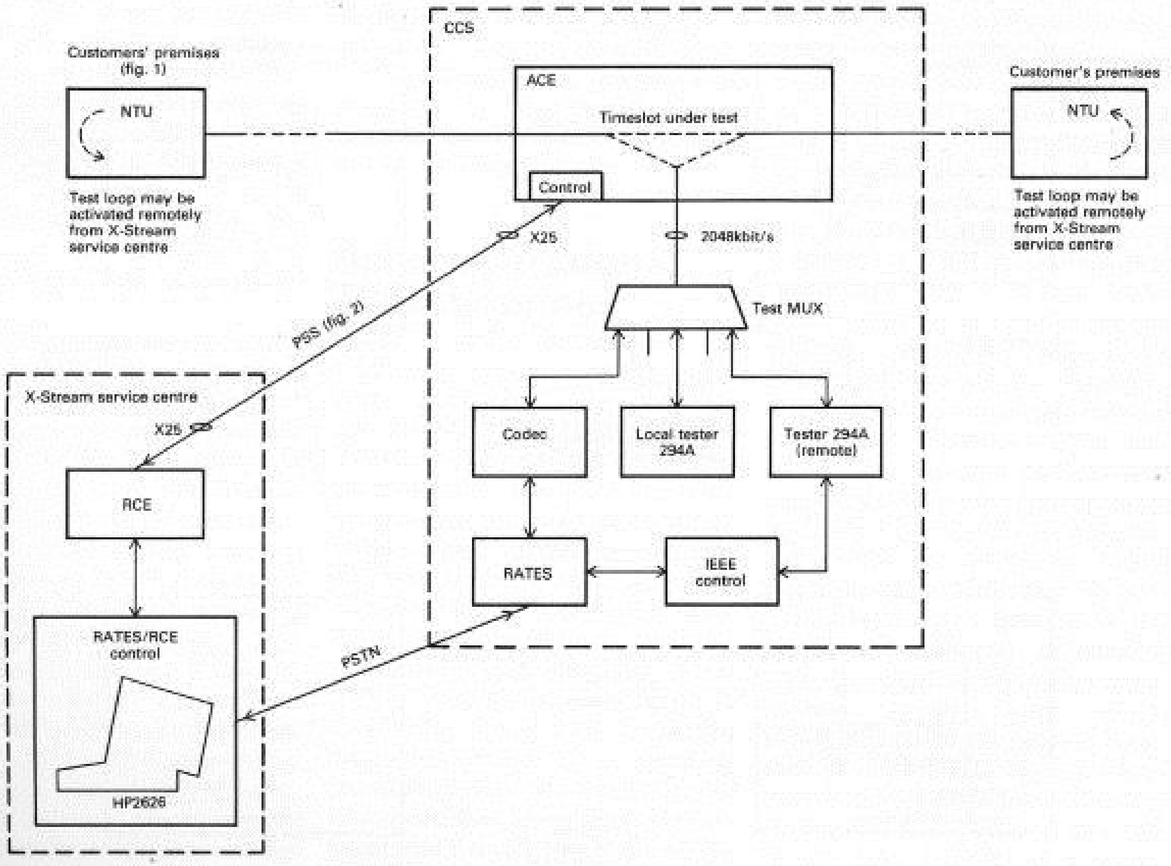


Fig. 3. Remote interception of circuits for test purposes

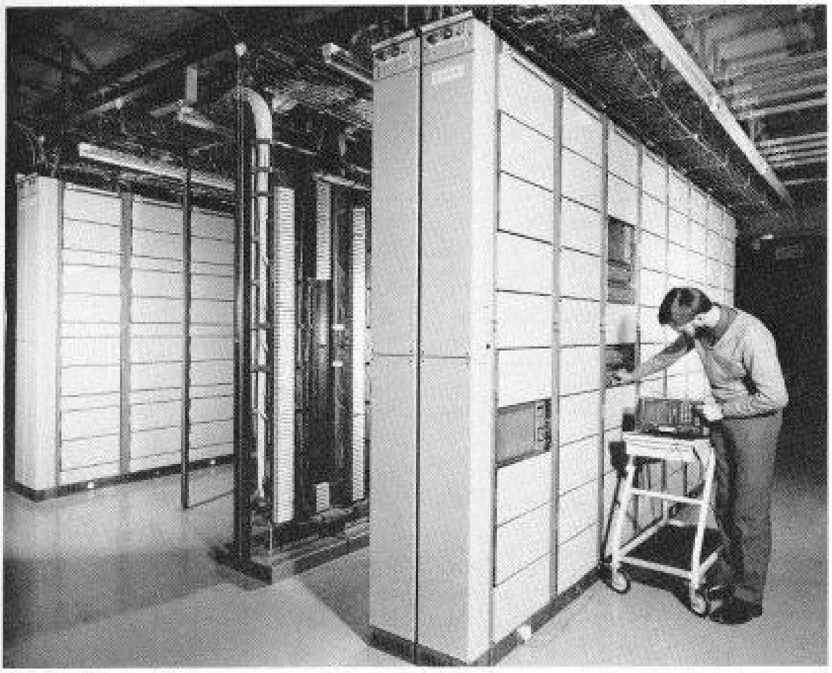


Fig. 4. Manual cross-connection site

Circuit and plant database

In operating and administering KiloStream there are a number of tasks which BT has to perform in support of the service; order handling and circuit provision fall into this category. From the opening of service these activities have been controlled by computer, such that a request for service has been immediately translated into equipment and plant availability and the request processed on that basis. This has necessitated details of the expanding network, in terms of nodes and plant, being filed in a database. The database is also used for providing circuit routeing through the network to link serving multiplex sites, including allocation of timeslots. Monitoring of the database also provides valuable statistics regarding progress of work in hand, and other management information.

With the availability of ACE, this type of information will be required in the RCE database to enable it to route and switch circuits. In implementing the ACE programme, one of the important considerations is the provision of this network information as it exists at the time of bringing a particular ACE into service. This data must be written in precise terms into the RCE database and into individual ACE controller memories, before change-over from the manual cross-connect sites can occur.

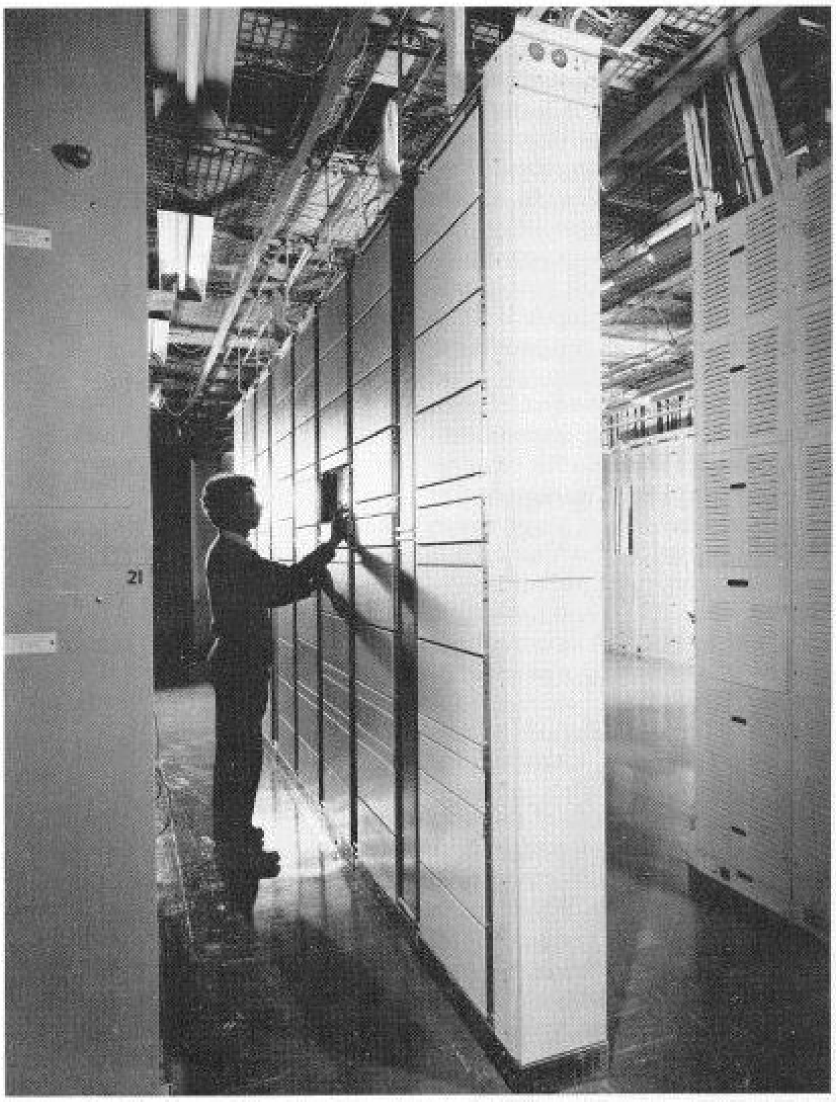


Fig. 5. 192-port ACE installation at Cambridge

Use of KiloStream

As in the Datel service, which in many ways KiloStream is supplanting, the major usage of circuits by customers is for some form of computer communications. Such applications may be for direct communication between computers or, more commonly, to give remote access from a terminal to a computer. The higher speed facilities are popular as they allow very efficient use of a basic KiloStream circuit through derivation of a number of channels from a customer-located multiplex.

While some applications may require only a few circuits, many customers operate data networks of considerable size. These have often been built over a period of time and are therefore likely to comprise speech-type private circuits and Datel circuits, as well as KiloStream circuits, with perhaps a natural progression in time towards the latter.

Figure 6 shows a data network typical of many in use today, in which KiloStream predominates as the data transmission medium.

It is important to appreciate that in an overall network the data transmission link provides but a component part, albeit a vital part, of the terminal-to-computer communications channel. This is illustrated in the diagram where a terminal and computer are shown obtaining access to data transmission facilities via a cluster controller and front-end processor (FEP) respectively. These two devices not only provide the terminal and computer interfaces, but also provide the overall communications control. In exercising the latter, data from the computer or terminal are structured in the FEP/Cluster controller into blocks for storage and onward transmission over the KiloStream circuit. Should a data error occur in the transmission link the receiving FEP/Cluster controller will detect this and call for retransmission of the stored block. It is evident, therefore, that the communications control should be optimized in the knowledge of the typical error characteristics of the transmission link. As there is scope for progressive optimization as experience of error characteristics of transmission media is gained, at this time there is probably margin for further optimization and, in consequence, a more efficient overall data throughput for the relatively newly introduced KiloStream service. Although BT has an important role to play in this work, ultimately the communications control arrangement lies in the hands of the data processing equipment designer.

Figure 6 also illustrates the use of different KiloStream transmission speeds within a user's network. The cluster controller is connected to a 5-port (K5) multiplex via a 9600bit/s KiloStream circuit and controls access from a terminal to it. The multiplex passes the aggregate signal over a 64kbit/s KiloStream circuit to the FEP via complementary multiplex equipment. Further 64kbit/s circuits interconnect the main and standby computers for high-speed transmission, primarily for file updating and loading. Although not shown in the diagram, the standby computer could well have some direct circuits from nodal points within the network to give added standby coverage.

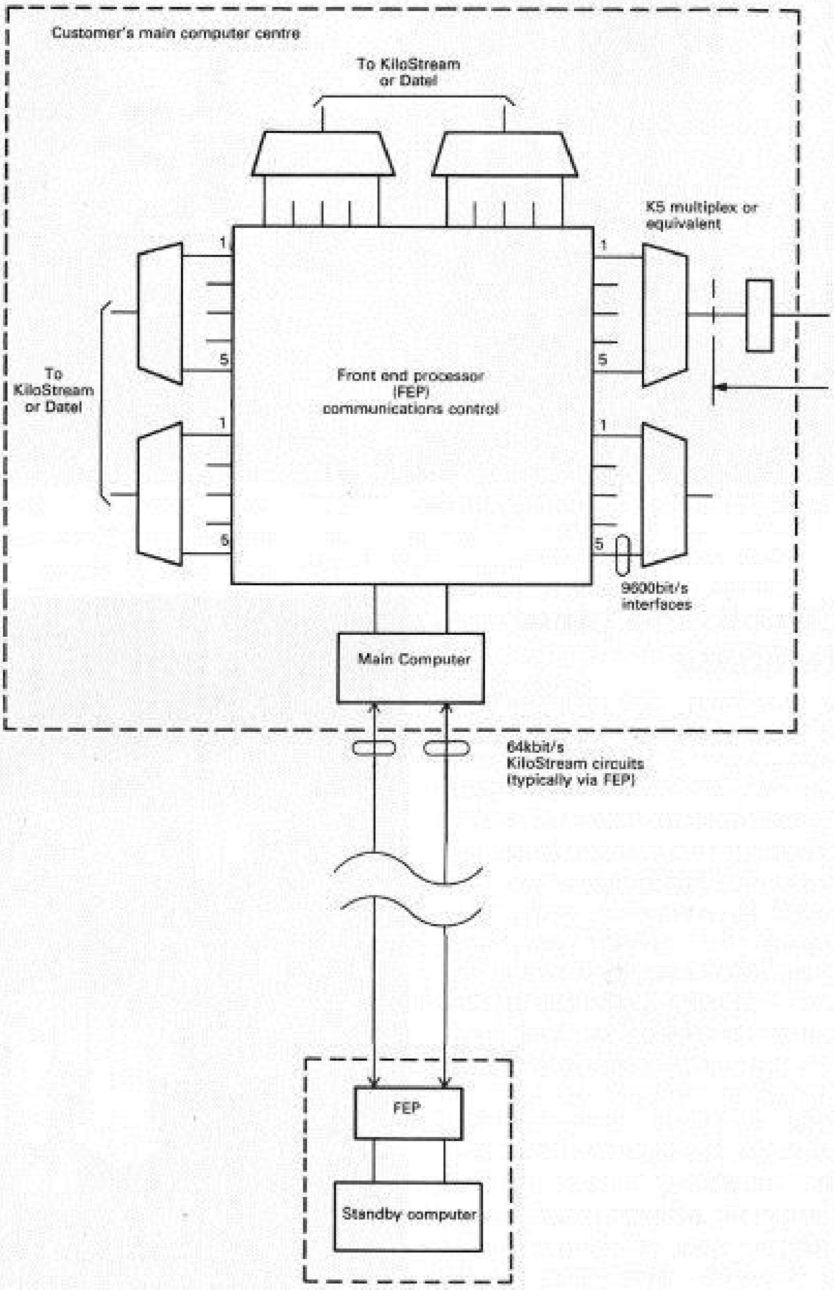
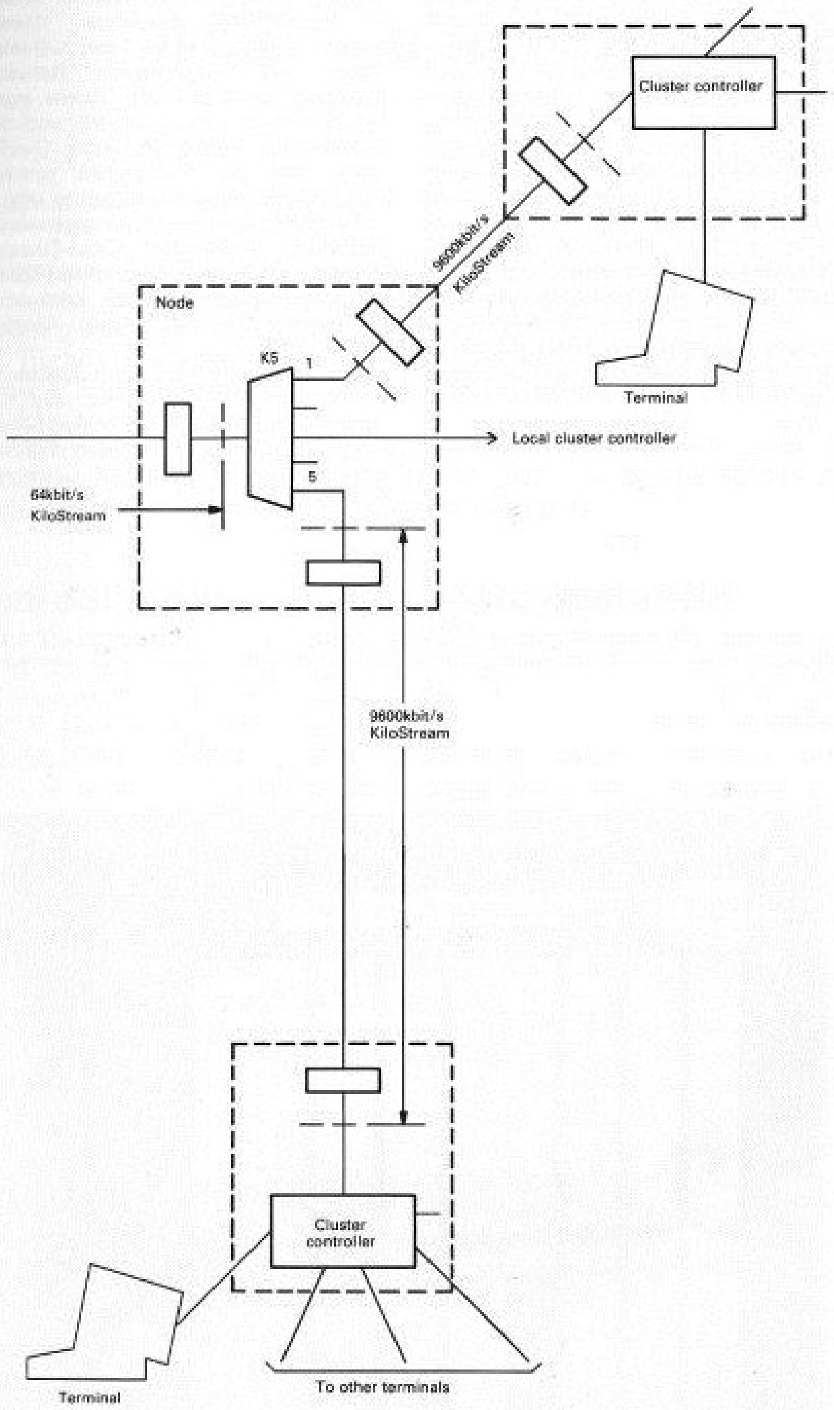


Fig. 6. Use of KiloStream in a typical customer's network

Conclusions

In concluding this article there are a number of important areas that should be emphasized. Foremost is the introduction of KiloStream itself and the technological step which has accompanied it, bringing with it



a high level of bearer transmission network performance which has to be achieved to exploit fully the potential of the service. In this respect reference has been made to the strides by BT to keep apace with the new service, firstly in getting to grips with novel problems that have arisen and secondly in mounting an energetic drive to solve them. There is still some way to go – but a great distance has been covered and there is confidence that our aspirations will be met.

The KiloStream network management and maintenance facilities have been briefly described and the benefits they will bring, particularly ACE with its associated operational databases. As KiloStream spreads it will play an increasingly important role in customer networks and some insight into this has also been given.

Turning to the future there are a number of things which have to be done. An immediate requirement is to give access economically to users in parts of the country that currently are not served by KiloStream. This will mean the use of customer loop extenders to increase the size of a multiplex catchment area, also the use of low-cost flexible multiplexes which, through a variety of methods, will allow additional catchment areas to be established. Accompanying this will be the need to establish additional network nodes so that KiloStream traffic may be loaded more efficiently on to cross-network transmission plant.

In the market place the need for new KiloStream-based products and facilities is continually under surveillance. In a sense the open-endedness of KiloStream makes this relatively easy, as the system has been designed on the basis of upwards compatibility. This means that the elements used in the early network should continue to be used and to be built upon as a core as new facilities are added. Thus the system takes on the role of digital transport and can endure beyond the foreseeable future to carry services not yet conceived.

Acknowledgement

The writer would like to thank British Telecom for permission to publish this article.

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RÉSUMÉ

Il y a maintenant plus de deux ans que British Telecom a introduit son service KiloStream. Cet article examine certains des problèmes opérationnels qui ont été rencontrés durant cette période et les travaux qui ont été faits en conséquence; il donne aussi les grandes lignes de la fonction de l'équipement KiloStream. Les nouveaux développements qui seront mis en oeuvre dans l'avenir sont également examinés, notamment l'emploi de l'équipement de sous-répartition automatique (Automatic Cross-connect Equipment ou ACE), y compris des améliorations des essais à distance qui seront possibles avec cet équipement.

L'emploi de KiloStream dans un réseau d'abonné typique est examiné; l'article souligne la nécessité de l'obtention de bonnes communications générales entre le terminal et l'ordinateur.

RESUMEN

Hace ya más de 2 años que la British Telecom introdujo su servicio del KiloStream. Este artículo examina algunos de los problemas operacionales que se han encontrado durante este período y la obra que ha resultado a raíz de esto, lo mismo que un bosquejo de la función del equipo del KiloStream. Se aprovecha también la oportunidad para considerar los nuevos desarrollos del futuro y, particularmente, el empleo de equipos interconectados automáticos (ACE) planeados actualmente, incluso los perfeccionamientos de pruebas a distancia que puede permitir este equipo.

Se discute el empleo del KiloStream en una red de abonados, dando énfasis a la necesidad de lograr comunicaciones completas de éxito entre terminal y computadora.

ZUSAMMENFASSUNG

Es sind nun mehr als zwei Jahren verstrichen, seitdem British Telecom seinen KiloStream-Dienst einführte. Dieser Aufsatz erörtert einige der während dieser Zeit aufgetretenen Betriebsprobleme sowie die sich daraus ergebenden Arbeiten und umschreibt auch die Funktion der KiloStream-Geräte. Gleichzeitig wird die Gelegenheit genutzt, neuen Entwicklungen entgegen zu sehen, insbesondere dem Einsatz der gegenwärtig geplanten Automatic Cross-Connect Anlagen (ACE) – automatische Quervermittlungsanlagen – sowie verbesserte Fernprüfung, die durch diese Anlagen ermöglicht wird.

Der Einsatz des KiloStream-Systems in einem typischen Kundennetz wird besprochen, wobei die Notwendigkeit betont wird, erfolgreiche Gesamtkommunikation zwischen Endgerät und Computer zu sichern.