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Current and Medium Term Developments in Switching

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Phil. Trans. R. Soc. Lond. A 1978 **289**, 43-63
doi: 10.1098/rsta.1978.0045

Phil. Trans. R. Soc. Lond. A. **289**, 43–63 (1978) [43]
Printed in Great Britain

Current and medium term developments in switching

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The current and medium term developments in switching are characterized by the extensive use of stored program control, digital switching and common channel signalling. In implementation terms, integrated circuit silicon semiconductor technology dominates. From the user's viewpoint, these developments should result in large reductions in equipment size and procurement times, improved operational, maintenance and subscriber facilities, and an enhanced ability to cope with the evolving needs of both public and private telecommunication networks.

Introduction

Developments in switching can be considered from many points of view. Probably the most important is from the point of view of the ultimate customers, the subscribers. At the other extreme the developments can be discussed in terms of advances in the implementation technology. However, neither extreme provides an adequate picture of the subject as a whole. An intermediate approach has therefore been adopted where the main emphasis is on system developments. Implications in regard to customer service, operational convenience and technological realization are covered as part of the main system theme.

A further explanation is required in regard to the interpretation given to current and medium term. Progress throughout the world is not uniform, and many systems about to be introduced are probably less advanced than certain other systems which have been in service for several years. Current and medium term developments have been taken therefore somewhat arbitrarily to include stored program control (s.p.c.), digital switching and common channel inter-exchange signalling.

These techniques are not all being introduced together. For example, stored program control has already found wide application in conjunction with crossbar and reed relay switching techniques. However, they are considered collectively to represent a revolution in exchange switching, similar in importance to the original introduction of automatic control, and the later introduction of automatic common control. In purely practical terms this revolution is characterized by large reductions in equipment size, large reductions in the necessary exchange procurement times, improved operational and maintenance facilities, and greater flexibility in meeting subscriber requirements, both in terms of calling habits and special facilities. In technological terms they collectively represent the advent of a total electronic realization.

A comment is also necessary concerning the use made of telecommunications networks. In spite of predictions of a massive growth in data communication, speech will probably remain the most important mode of communication for many years to come. This paper therefore concentrates on exchanges designed primarily for speech communication, i.e. public and private telephone exchanges.

General background

In most networks the subscribers' telephone instruments are connected by individual subscribers' lines to a local, centrally located exchange, which comprises routing switches and associated control equipment. When a subscriber initiates a call, the control first has to receive, translate, and sometimes retransmit, control messages from the subscriber, particularly the number of the required party. The control then has to establish, supervise and terminate the connection. It also has to carry out certain subsidiary tasks, such as call recording (primarily for charging), equipment monitoring and faulty equipment isolation.

To economize in the total amount of equipment required, wherever possible it is provided on a shared basis. To achieve this aim the switching equipment has to be split into two or more stages to provide a concentrating as well as a routing function. Control equipment to supervise calls is provided on the basis of the normal maximum number of simultaneous calls expected. The control equipment to set up calls can be provided centrally or distributed with the routing switches, the extremes being referred to as fully centralized common control, and fully dispersed control. Various intermediate realizations are also feasible. There is no simple way of deciding which way is optimal; it depends both on specific exchange requirements and the details of the technology available.

In early manual exchanges, the routing function was performed by operators inserting plugs into jacks on which the subscribers' lines terminated. The plugs were connected in pairs by cord circuits. The supervisories formed part of the cord circuits and were equipped with lamps and keys to enable the operators (the set-up controls) to control the connections.

Although this approach provided virtually all the necessary features of a telephone exchange, for economic reasons it became necessary to introduce automatic working, at least for local calls. It was not possible to copy the system organization of a manual exchange, since it was impractical to imitate the operators' dexterity in inserting plugs into jacks, and their intelligence in carrying out the control functions. The problem was overcome by adopting a fundamentally different philosophy, where the routing function was split into several discrete stages, with each switch in each stage being provided with an individual set-up control. The connection was established by the subscriber dialling a series of time-sequenced digits, with each digit in turn operating a switch in each stage. Probably the most famous realization of this dispersed control, step-by-step technique was the Strowger system, which employed two-motion switches, each switch stepping vertically in accordance with the dialled digit and then hunting in a rotary manner to a free outlet to the next stage.

Because no common control equipment was incorporated, Strowger and similar systems could not provide many of the facilities available on manual systems. For example, translation of the dialled information received from the subscriber was not possible, except in an extremely limited manner. Whereas this limitation was of little consequence in simple local networks, in large networks with complex routing patterns, it would have resulted in the subscribers being required to dial numbers containing a routing code that could vary depending on the point of origin of the call.

To overcome this difficulty, register-translator equipment was introduced, first in the large metropolitan area exchanges, and then to enable subscriber trunk dialling to be realized. In a step-by-step exchange, equipped with register-translators, the dialled number no longer operated the switches directly, but was passed to a register where it was assembled and

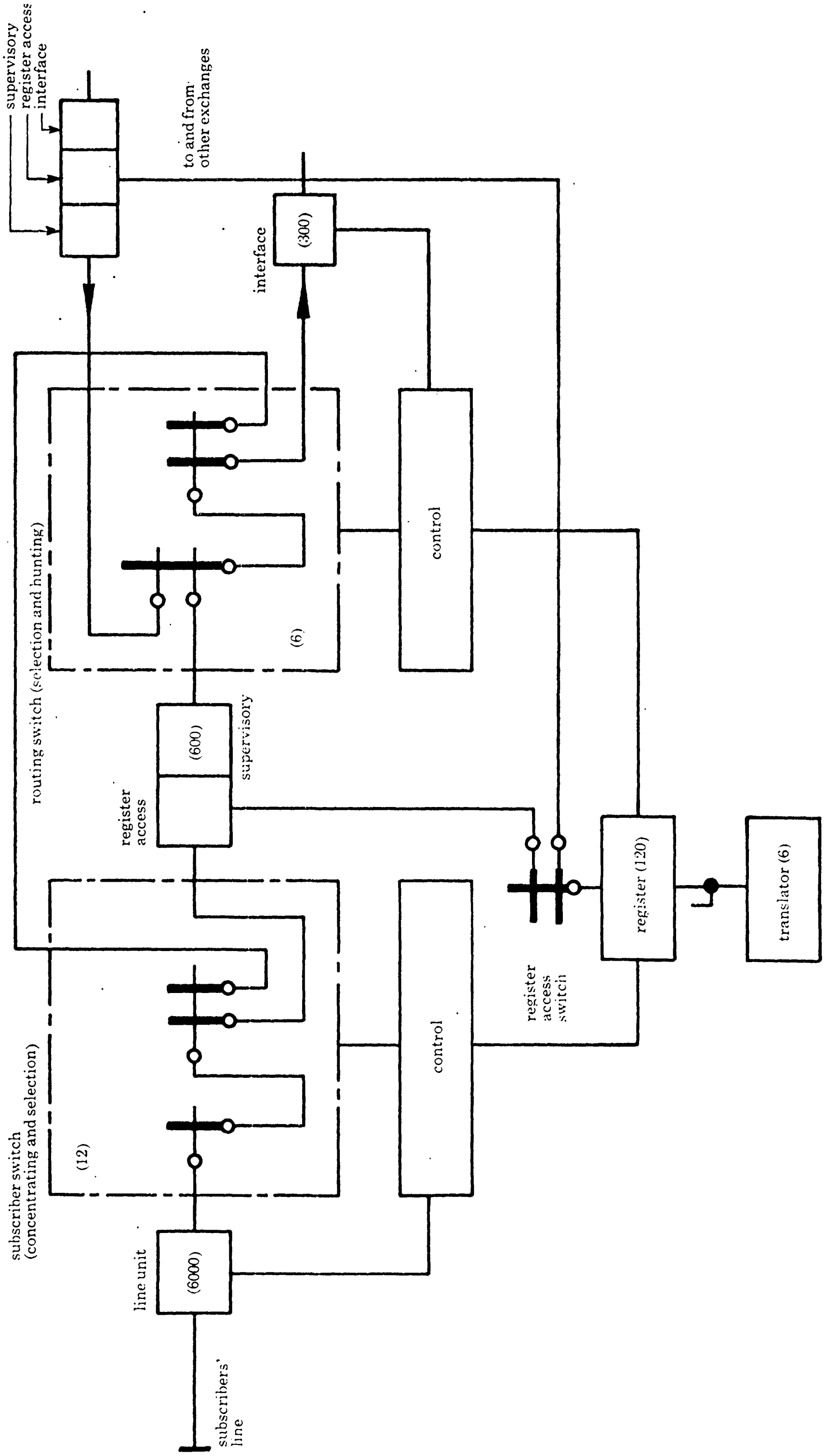

FIGURE 1. Common control crossbar system.

translated to a second number capable of routing the call through the network. The register then pulsed out the second number to operate the switches. By varying the translations from exchange to exchange, it became possible to allocate unique numbers to each subscriber's line which did not depend on the origin of the call.

With the rapid growth of the telephone network, reliability problems became more serious, and it became necessary to devise techniques to reduce maintenance and to ensure that subscriber difficulties caused by faulty equipment were reduced. A particular problem was switch contact noise. To achieve an improvement, switches were introduced using precious metal contacts. This resulted in an increase in individual switch costs, and revised switch provisioning methods had to be adopted to reduce the quantities required. Strowger, and other similar switches, also lost favour due to mechanical wear problems, and were largely replaced by switches incorporating matrix arrangements of individual contact sets, as exemplified by the crossbar switch. The step-by-step approach to setting up the switches was replaced by a procedure where the switches were set up in a more integrated manner, termed link-coupled trunking. This required the introduction of common set-up equipment, which was necessary to search for, and establish, suitable free routes through the composite switching stages.

A schematic diagram of a typical crossbar exchange is given in figure 1. The link-coupled switches were incorporated in composite subscriber switches and routing switches. Representative quantities are illustrated in the diagram. A common control was provided for each composite switch. Relevant information to set up the switches was obtained primarily from the registers which were connected to the switch controls over common control highways. The subscribers' switching stage combined the rôle of traffic concentration for subscribers' originating calls, with part of the routing rôle for subscribers' terminating calls.

Common control crossbar exchanges started to be installed in reasonable quantity from about 1950, and today represent a large proportion of installed working systems. However, this period overlapped with the upsurge in the use of electronic techniques, and systems were also introduced containing a large proportion of electronic equipment, notably to fulfil control functions. The various electronic equivalents of the crossbar switch met with considerably less success. However, the reed relay did find wide acceptance, particularly in conjunction with electronic control. The combination had the advantage of inherently faster operating speeds, and hence systems with more centralized control were feasible. Nevertheless most of the system principles remained substantially unchanged.

Stored program control

With the introduction of common controlled exchanges incorporating precious metal switching techniques, a day-to-day quality of service could be offered to the subscribers which exhibited few shortcomings. However, particularly as networks and exchange requirements became more complex, certain features of a wired-logic common control realization became increasingly restrictive. Examples of these restrictions included:

(*a*) Although the establishment of an individual connection might be considered a simple operation, the control must be able to deal with connection requests from many thousands of subscribers and trunk lines in an order dictated entirely by outside events. Such a complex would produce problems even when all the equipment was working correctly. In a practical situation such perfection does not occur, and the control has to function satisfactorily in the presence of externally and internally induced faults. In the short term these faults must be bypassed, while in the longer term they must be recorded and the appropriate maintenance action indicated to the repair personnel. Wired-logic systems with an adequate performance in this respect are becoming increasingly difficult to realize.

(*b*) Although all exchanges show a basic generic resemblance, each particular application is unique. Not only are the collective subscriber calling habits on the exchange liable to be unique, but also the particular combination of network and subscriber facilities which the particular application demands. Providing these variations are not too great, they can be accommodated by employing suitably located strapping fields to provide the necessary flexibility. However, where more significant differences must be accommodated, for example to cater for the particular requirements of an individual export market, the wired-logic approach presents considerable difficulties and sometimes large scale equipment redesign is necessary.

(*c*) The telephone network of a country constitutes a very significant national investment. Whereas this investment cannot be scrapped overnight, it must nevertheless evolve so that it can cope with the changing environment which it is required to satisfy. This implies that individual exchanges have to be modified while in service to meet this change in demand. If the change is represented by pure growth, then again wired-logic systems do not present serious problems. However, should the growth involve changes to either subscriber or network facility requirements, such as caused by the introduction of a new signalling system, then wired-logic systems can present serious limitations.

Looked at in another way, the requirement for stored program control can be appreciated by considering the reduction in flexibility which occurred when automatic control first replaced manual control. Manual systems manifestly employed a very advanced form of programmed logic, and the attendant flexibility that could be obtained has in many ways still to be surpassed.

The basic organization of a computer suitable for exchange control is illustrated in schematic form in figure 2. It comprises four main sections: the central processing units, the storage units, the input/output peripheral interface, and the internal highways. The central processing units can take many forms, the one illustrated in the figure being reasonably typical. The address registers indicate the data, instruction or peripheral location involved in a particular information transfer or operation. The system sequencing unit decodes the main control instructions into pulses suitable for driving the various central processing units. This unit is now normally constructed in a micro-programmable form. The arithmetic and logic unit, together with the working registers, perform the required information manipulation operations. The interrupt unit enables the processor to respond to urgent processing requests, derived from external peripherals, from internal processing demands, or from some form of clock interrupt.

The technology employed in the central processing units invariably involves integrated circuits, with many of the units being realized as large scale integrated devices. Since it is convenient to employ word lengths of 16 bits and above for the main controlling processors in medium/large exchanges, single chip processors are usually only to be found in small exchanges, although with technological improvements it is likely that the microprocessor approach will become increasingly used as the main processor even in large installations.

The storage units forming part of the main computer are normally organized in a random access form, and comprise destructive readout memory and read-only memory. While historically core stores have been used, semiconductor stores predominate in new designs.

The third unit which the computer comprises is the main input/output peripheral interface,

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which provides the address, input and output highways to the various external units connected to the computer. These external units comprise three basic types: computer backing storage, which normally takes the form of fixed-head disk and magnetic tape systems, man/machine control interfaces such as teletypes or visual display units, and exchange units. The external input/output highways are often of considerable length, and pulse transmission problems involving attenuation, reflexion and interference can become serious. To ease some of the difficulties short-distance optical systems show considerable promise.

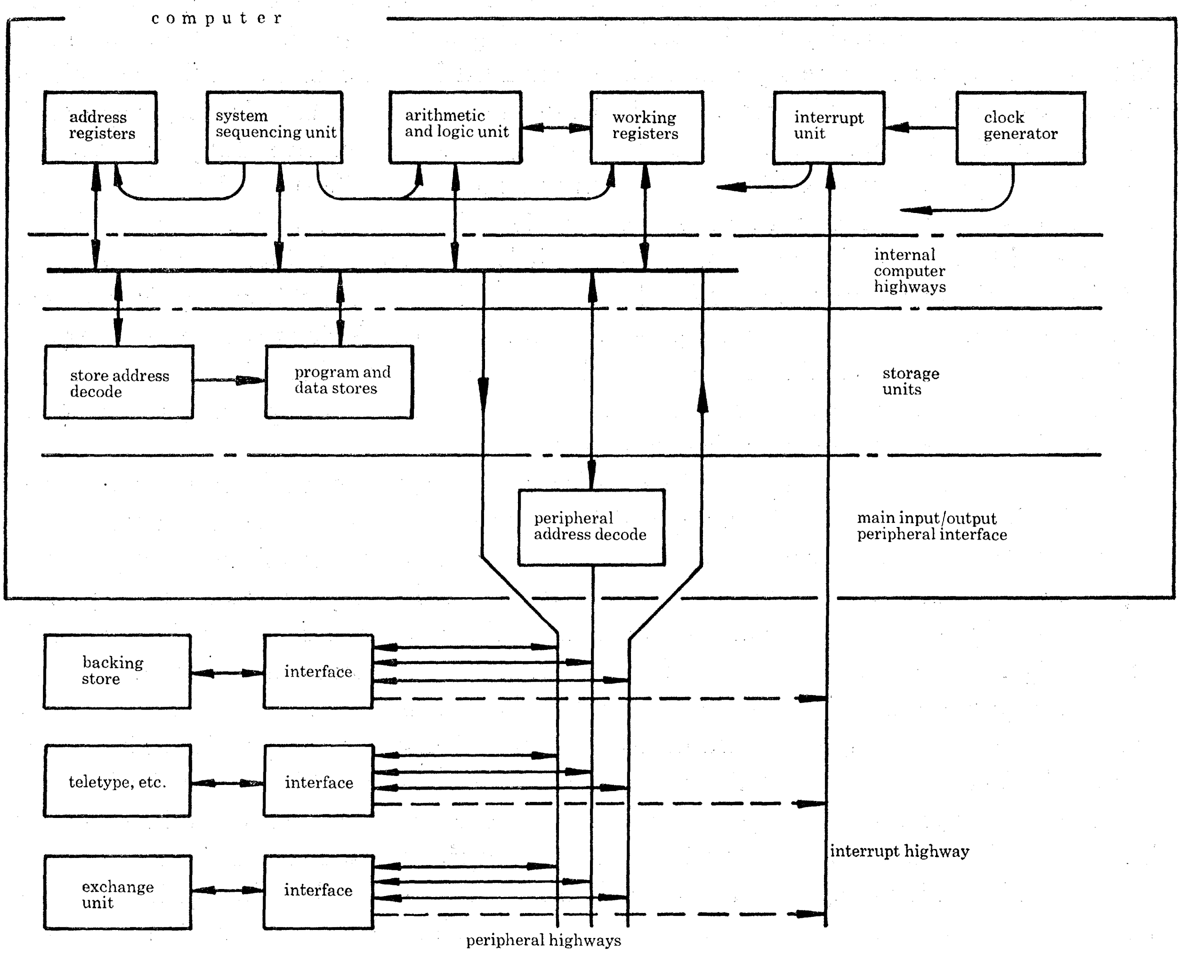

FIGURE 2. Control computer: basic organization.

Stored program control can be applied to part, or to the whole control function of a telephone exchange. The partial application of stored program control is exemplified by a Strowger exchange equipped with register translators, but where the register translators are realized using computers. An example of full stored program control is illustrated in figure 3 where the various control units in figure 1 have been replaced by a duplicated central computer, the duplication being necessary in order to maintain service in the event of a computer failure. In such an arrangement, tasks such as supervision, translation, equipment monitoring, etc., are carried out in time sequence on the central computer. However, it is not necessarily convenient to perform all the more menial tasks centrally, and tasks such as dial pulse counting are often more economically carried out within the appropriate line or access unit.

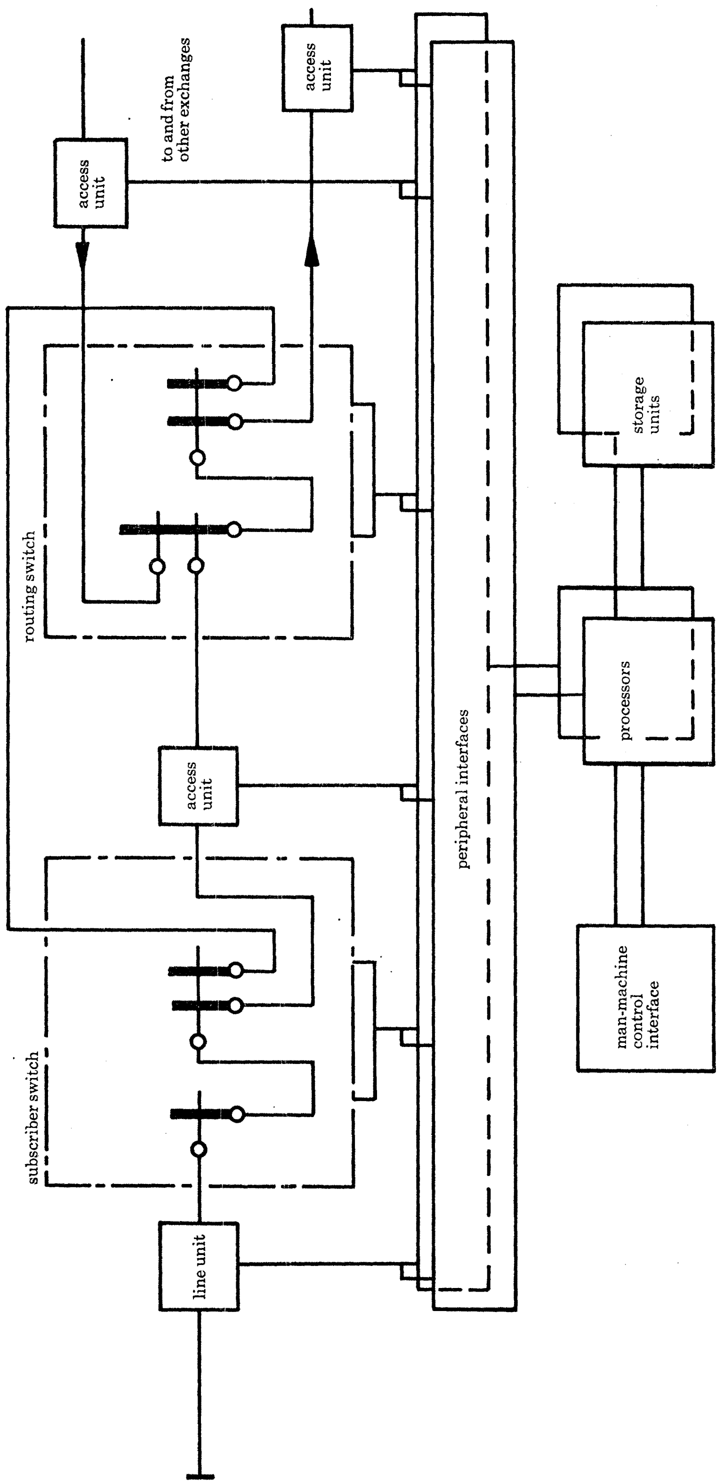

FIGURE 3. Common control exchange with s.p.c. control.

As with wired-logic control, computer control can take many forms. Even within the context of centralized control, various configurations are feasible to permit adequate operational security against equipment failure, and to allow an increase in computer power to accommodate exchange growth. Figure 4 illustrates two realizations of a central computer complex. In the first realization, quasi-independent computers are employed which communicate via an interprocessor communication channel. Each computer has its own peripheral highway with the peripheral interfaces connected to both highways. In certain arrangements the two computers run in synchronous duplication, that is, both computers work together obeying the same instructions at the same instance, on the same data. However, only one computer actually controls the exchange. When a fault occurs, self-diagnostic routines operate in both computers and the offending machine is isolated, the good machine takes over, and the relevant alarms are operated. A second variant involves traffic sharing, where the traffic is shared between the computers, with the interprocessor communication channel ensuring that the machines operate to the same exchange data. In the event of a computer or an inter-computer link failure, one computer takes the full exchange load.

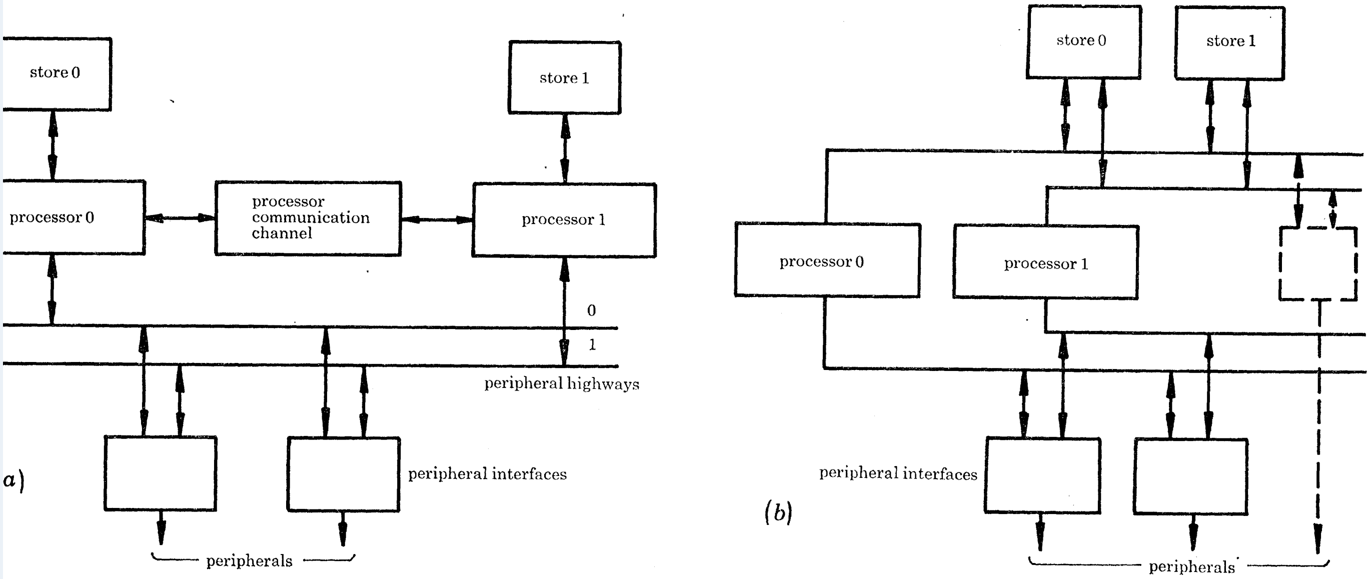

FIGURE 4. Control security: (*a*) multicomputer; (*b*) multiprocessor.

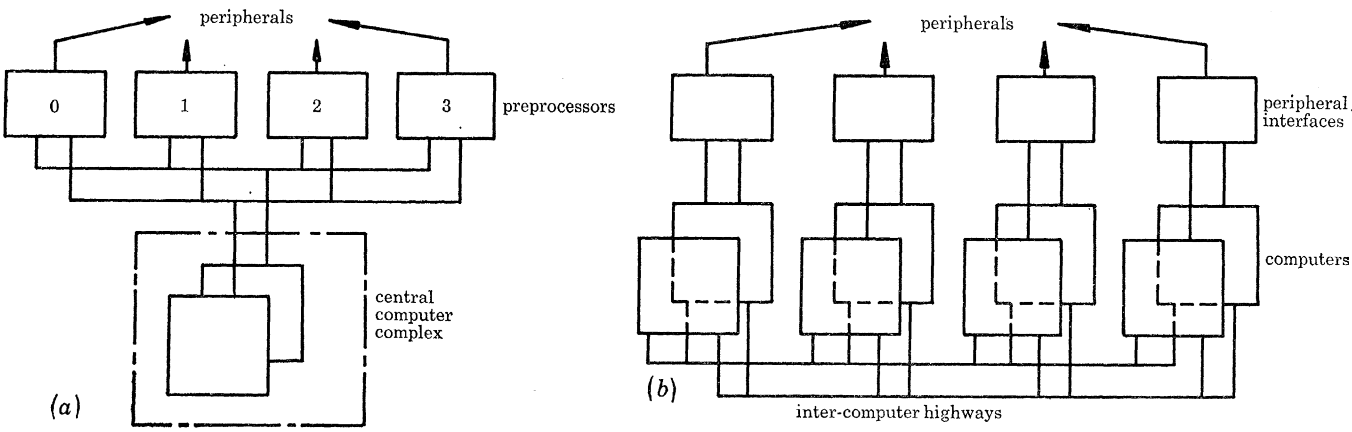

FIGURE 5. Control decentralization: (*a*) preprocessing; (*b*) distributed control.

Another traffic sharing approach employs multiple central processing units which share a common array of store modules as illustrated in figure 4*b*. The emphasis here is on the economy of storage, as essentially many processors can share the same storage, with security provision on a '1 in *n*' sparing basis, and not on full duplication as required with multi-computers. This security approach is extended to the central processing units, where a single extra processor above that required to carry the traffic is provided, so that full service can be maintained in the presence of a faulty processor. In the multi-processor arrangement common store highways have to be provided in addition to the peripheral highways. Since in principle these highways are similar, only one set need be provided with the peripheral interfaces being treated effectively as store blocks.

In all the above arrangements, the individual processors normally provide all the control functions. However, with the advent of small inexpensive processors, notably micro-processors, a more dispersed system of control can be adopted. Again, two basic approaches are evident. First, many of the routine functions, plus those functions dealing with processing of peripheral units, (such as inter-exchange signalling receivers), can be off-loaded on to pre-processors. Figure 5*a* illustrates such an approach where the routine functions of the exchange have been off-loaded, but where the main call processing functions remain on a centralized computer complex.

In the second approach, illustrated in figure 5*b*, the control is split into units where each unit carries out a particular exchange function, such as the register function, the supervisory function, the maintenance function, etc. Since each function is of vital importance to the overall working of the exchange, then each unit must contain some form of redundancy to enable an adequate service to be maintained.

Control software presents possibly more difficult security of service problems than the corresponding hardware. It is virtually impossible to write totally correct software, and, even in the absence of hardware faults, there is a real probability that software errors could bring the exchange operation to a halt. These errors are often of a pattern sensitive nature and do not necessarily show up during testing. This problem is, of course, not unique to stored program control, since it also occurs if wired-logic control is employed, but with s.p.c. it is easier to identify as a well defined problem.

A second problem concerns the actual compilation of the necessary programs to operate the exchange. Various approaches can be employed. It is possible to write a single program which can effectively set up a single call, the system then being organized so that this program can be used by several simultaneous calls without mutual interference. Alternatively, programs can be written for individual functions, such as the register function and the supervisory function, which are then brought together so that calls are effectively handed from one function to another as the call establishment process progresses. Both approaches require some form of operating system to schedule the work and to allocate resources. Such an operating system can vary in complexity, but would normally have to contain the following resources:

(*a*) some form of overall work scheduler, interrupt handler and queue handling mechanism;

(*b*) some form of resource allocator, for example, a storage allocator;

(*c*) some form of application program linkage mechanism;

(*d*) some form of fault location, reconfiguration and re-start mechanism, which could enable faulty equipment to be identified, switched out of service, possibly standby equipment brought into service, with a partial or full system re-start;

(*e*) some form of communication control system with the computer peripherals, the exchange equipment, and the administration and maintenance centre;

(*f*) some form of overload control system;

(*g*) ancillary items such as testing aids and performance monitoring systems.

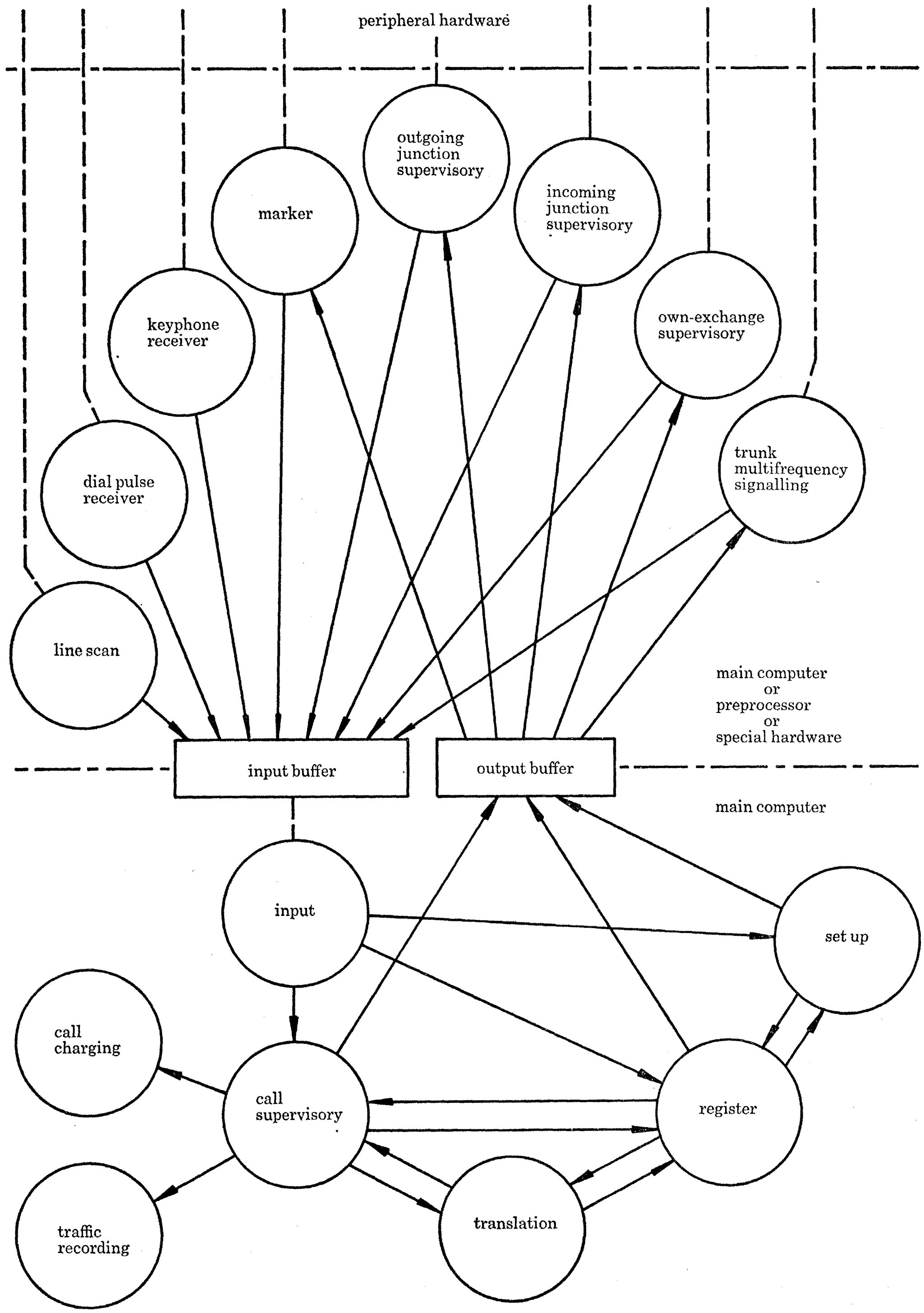

FIGURE 6. Typical software organization.

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The amount of program required for a typical telephone exchange can vary from somewhere between twenty thousand and half a million words, the upper limit being required to accommodate comprehensive diagnostic and maintenance aids to avoid lengthy manual-based testing procedures.

Programs also have to be written so that updating is possible without the necessity for a complete rewrite. This again suggests that programs must be modularized so that individual modules can be rewritten and modified on an individual basis. One such organization is illustrated in figure 6, where the software is split up into a series of processes, each of which handles a particular exchange function. Two types of process are evident, those that deal essentially with peripheral equipment and those that deal with actual call processing. The two types of process are interconnected by means of buffers realized either in hardware or effectively in software. This has the advantage that all the processes can be run on a central computer complex, or alternatively the peripheral-associated processes can be run on pre-processing computers or on special hardware. If the software is correctly organized, a change from central to distributed processing might be accomplished with few software changes. It is thus possible, for example, to design an exchange where initially no pre-processing is used, but, as the exchange increases in size, pre-processing can be introduced to avoid overloading the central computer complex.

With simple exchanges the software is normally written in some assembly language form. This approach has the advantage that the resultant code can make efficient use of both storage and computer power, which is particularly important since one basic program will ultimately be incorporated into many exchanges. However, with large programs, assembly language programming presents serious difficulties, even if the assembler hides the programmer from the complex security arrangements that might be employed. As with any other computer system, the use of high-level languages has an attraction in terms of programmer output and program readability. Provided the high-level languages do not result in undue operating inefficiencies, they are to be preferred. In the U.K. the Coral high level language has gained wide acceptance and is now being used for exchange control, albeit in a somewhat modified form.

Because of the somewhat unique nature of the application, computers for exchange control have tended to be different in detail from general purpose real-time computers. Requirements such as long life, high availability, and the ability to work in normal exchange environments, have precluded the use of many general purpose machines. However, many of these requirements are now becoming more widely specified as computers take over control rôles where manual back-up is either inappropriate or virtually impossible. It is therefore likely that there will be some convergence of design as the requirements become more similar.

Digital switching

Precious-metal switching, as exemplified by the crossbar switch and the reed relay, can provide a reliable and reasonably economic method of switching. However, certain fundamental difficulties exist, including:

(*a*) Owing to the intrinsically high cost of the crosspoint, methods of trunking have to be devised to minimize the number of crosspoints required without seriously affecting the traffic handling capacity. Such trunking approaches tend to be complex and require considerable ingenuity to ensure adequate results.

(*b*) Whereas such trunking arrangements can be made satisfactory for a given condition, complex rearrangements are often required when the condition is changed, for example, to accommodate changes in traffic patterns.

(*c*) The physical size of the switching blocks in large exchanges entails mounting the equipment on a large number of racks, which have to be transported individually to site. This results in a large amount of inter-rack wiring to be completed and tested on site.

(*d*) Whereas the large number of paths through a typical switching network ensures that the consequences of individual faults are not serious, the actual detection of such faults can be very difficult.

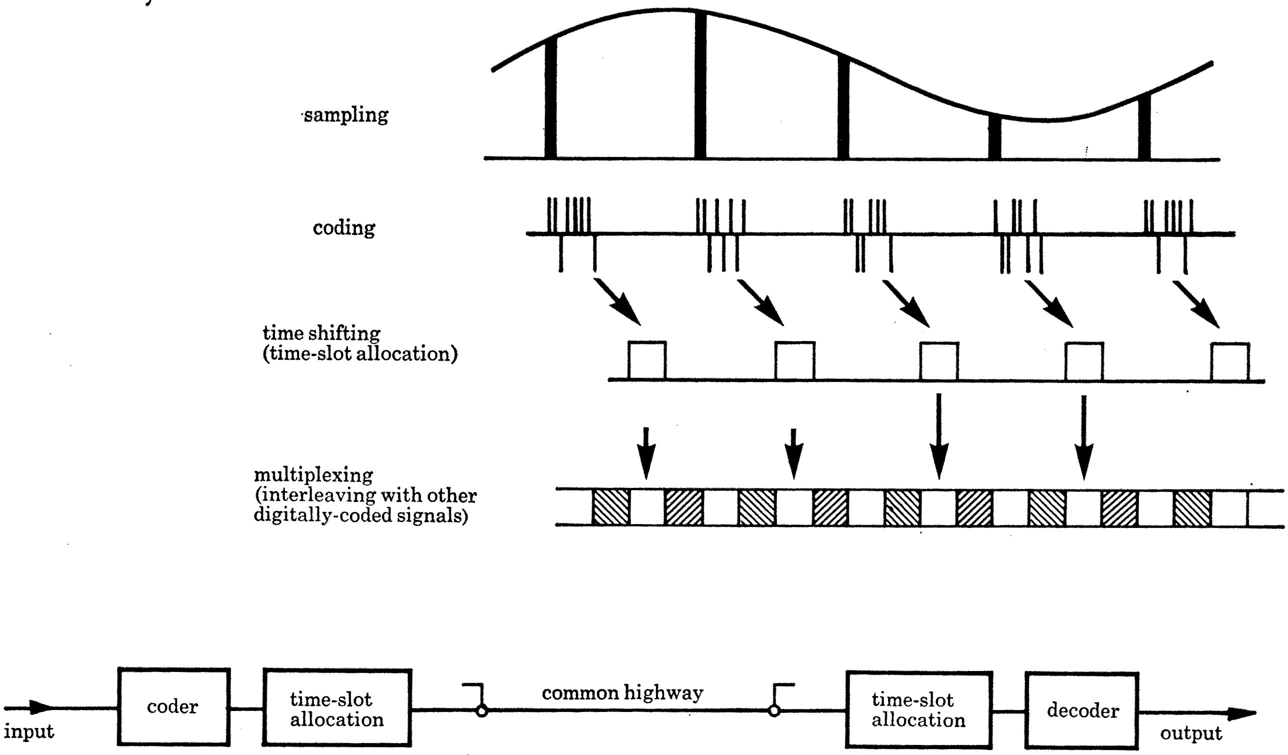

FIGURE 7. Principle of time-division multiplex digital switching.

These problems have been recognized for a considerable time and attempts to minimize them have taken many forms. For example, trunking methods have been devised where crosspoint economy has been partly sacrificed in the interests of easy extension and/or less susceptibility to traffic imbalance. However, it was appreciated that the problems would better be solved if a satisfactory crosspoint could be devised with an intrinsically small size and low cost, so that the rather elaborate trunking methods could be avoided. Some method of physical circuit sharing, as offered by a multiplex technique, appeared to provide a promising approach. Frequency-division multiplex switching was feasible, and systems were built using this technique. However, time-division multiplex switching showed considerably more promise and systems were developed, initially employing thermionic valves and subsequently transistors, but it was not until the advent of integrated circuits did the promise become a practical economic reality. In addition, technical difficulties were reduced by combining time-division multiplex with pulse code modulation (p.c.m.) to avoid the switching of high speed multi-level pulses with the inherent crosstalk and distortion problems.

Figure 7 illustrates the principle of a commonly adopted form of time-division multiplex digital switching. An individual speech channel is sampled at a rate somewhat above twice the highest audio frequency to be transmitted in order to minimize sampling distortion. For telephony purposes an 8 kHz rate is common. Individual samples are then coded as binary numbers, typically 8 bits long, usually in conjunction with some form of companding to avoid excessive distortion of low level signals. Alternatively, but less commonly, a longer sampling code can be used of 10–12 bits. The individual binary numbers derived from the various speech channels are allocated time slots and multiplexed together in an order controlled by temporary storage. By arranging for a given speech outlet to have the same time slot allocation as a speech inlet, pulses can be routed from an inlet to a chosen outlet, thus effectively connecting them together for the transmission of the speech signal.

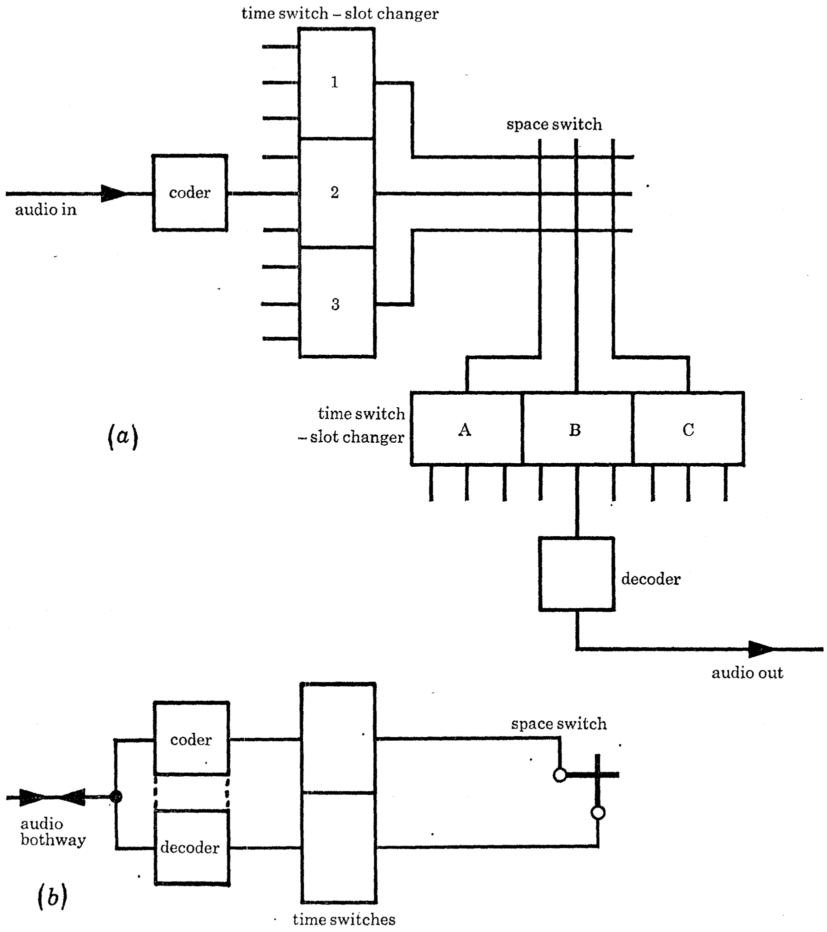

Figure 8. Digital switch configuration: (*a*) basic schematic; (*b*) simplified representation.

In practice, such a basic scheme suffices for small exchanges, but in larger exchanges at least one extra stage of switching is necessary. This extra stage can take a variety of forms, although a preference now appears to be shown for the arrangement illustrated in figure 8*a*. In this arrangement an audio input from a subscriber's line is coded and allocated the required time slot in the input time switch. The pulses then pass to a space switch where they are routed, without changing the time slot, to the output time switch associated with the required

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outlet. At the output time switch the pulses are shifted in time to the time slot allocated to the required decoder. Many variations on this basic idea exist such as:

(*a*) the sampling actually occurs in the required slot and hence effectively the coder and time-switch slot-changer are combined as one function;

(*b*) If the audio channels are already coded as part of a p.c.m. transmission system, the coding and decoding processes can be remote from the actual exchange;

(*c*) in very large exchanges more than one space switch can be employed.

Whatever the arrangement, as amplifier-like devices are involved in the connection, a single path through a digital exchange is essentially unidirectional. To complete a connection, two such paths are therefore required, one for speech communication from the calling to the called subscriber, and one for speech communication in the reverse direction. Each subscriber has a coder and decoder and access to input and output time switches, as illustrated in figure 8*b*.

The great advantage of time-division multiplex digital switching is that, with modern semiconductor technology, the effective crosspoint cost can be reduced by more than an order of magnitude, compared with the corresponding space crosspoints, and hence it is not necessary to use elaborate trunking techniques to minimize the number of individual crosspoints required. To give some idea of the dimensioning of an exchange, the main digital highways might be designed to carry 256 channels. The space switch could be made to interconnect 32 such highways, giving approximately 8000 unidirectional channels or 4000 bothway channels. Such a system would normally be adequate for over 20000 subscribers, and at normal traffic levels would introduce negligible internal blocking. The equipment would be physically very small, and in particular the central switching equipment could be mounted on a very few number of racks. Wiring problems would be further minimized since internal exchange speech highway cables would carry multiplexed channels.

Common channel signalling

One of the most important features of a telecommunications network is the inter-exchange control signalling system required to enable connections to be established, supervised and terminated, and also to enable the various network management messages to be communicated. Although the minimum number of individual signals required can be small, in a modern network providing many subscriber and administrative facilities, the number becomes considerable. Examples concerned with an individual call include:

(*a*) supervisory and register signals – forward direction:

(i) circuit seizure;
(ii) called party number;
(iii) calling party number and/or class-of-service;
(iv) nature of circuit indicator;
(v) echo suppressor/transmission pad requirement;
(vi) forward transfer;
(vii) coin box signals;
(viii) service required;
(ix) end of signalling indicator;
(x) clear forward.

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(*b*) Supervisory and register signals – backward direction:
(i) congestion, blocking and unblocking signals;
(ii) proceed to send and acknowledge signals;
(iii) called subscriber class-of-service;
(iv) called subscriber line state;
(v) called subscriber answer;
(vi) charging and metering signals;
(vii) coin box control signals;
(viii) call trace;
(ix) release guard;
(x) clear backward and forced release.

These lists are not exhaustive, but should give some indication that a fairly complex signalling system is necessary in a modern network.

In early manual systems supervisory signalling was carried out largely by keys and flashing lamps, while the register signalling used the spoken word. Initially the circuits to be used for the final speech communication were employed for this purpose, but later designs incorporated a bypath method of signalling over so-called order wires. With the advent of automatic switching, both supervisory and register signalling were carried out over the actual speech paths by means of controlled d.c. breaks and polarity reversals, for register signalling using typically a rate of 10/s. This approach in basic form was satisfactory for metallic junctions, but, when carrier circuits were used, the signals had to be modulated on to audio tones to permit transmission over the carrier systems. This caused a difficulty in that speech imitation became a problem, although in many systems this was overcome by the use of a separate signalling channel. Both approaches were costly; the first since a complex relay set was required to separate the speech from the signalling at the exchange/transmission interface, and the second since an extra channel per speech circuit had to be provided.

With the advent of common control systems offering potentially more facilities, d.c. pulse signalling became inadequate for register communication, and was replaced by faster systems using multifrequency tones. Although this approach increased the potential speed of register signalling, it introduced added complexity into the exchanges.

With processor control of switching, a far more efficient way of transferring information between exchanges is to provide a two-way high-speed data link directly between the controlling processors. This common channel can provide the signalling for many speech circuits, with the proviso that some form of replication must be incorporated in order to guard against possible failure. Such a common channel signalling approach has several merits including:

(*a*) signalling is completely divorced from speech and switching;
(*b*) significantly faster signalling can be achieved within the same effective bandwidth;
(*c*) a potentially larger number of signals can be sent;
(*d*) management signals can be sent at any time;
(*e*) a greater ability to accommodate change;
(*f*) considerably cheaper for large speech groups;
(*g*) relay sets on a per-speech-channel basis are no longer required.

A typical common channel system is shown in figure 9. The signalling channels occupy one or more dedicated circuits on the routes between the exchanges, either in a directly associated manner for routes with many circuits, or in a quasi-associated manner for routes with few circuits. The International Telegraph and Telephone Consultative Committee (C.C.I.T.T.) have specified a common channel signalling system known as the C.C.I.T.T. No. 6 system. Although intended primarily for use in conjunction with international analogue circuits, the principles are applicable to national systems. In this system the data link operates at 2.4 kbit/s. Signalling information generated in the controlling processor is transmitted in parallel form to the signalling terminal which in turn transmits the information in serial form to a modem. As illustrated in figure 10, a signal unit block comprises 12 units each of 28 bits, 20 bits for information and 8 bits for error checking. The transmission of signalling information relevant to a connection comprises one initial signalling unit (i.s.u.) and up to five subsequent signalling units (s.s.us). In the i.s.u. only 4 bits are available for signalling information whereas in s.s.us 16 bits are available, since no further circuit labels are required.

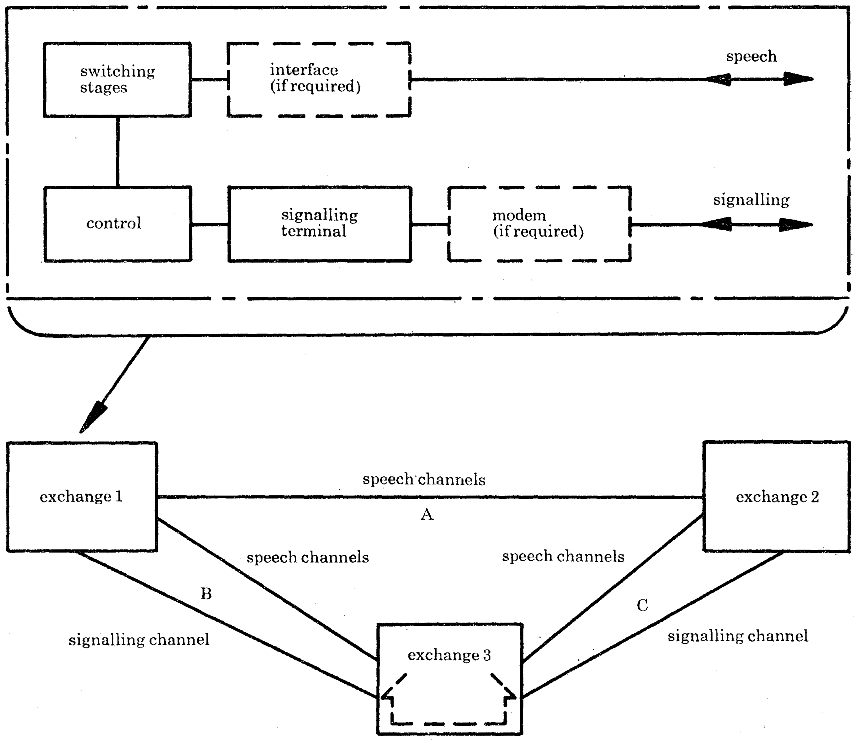

FIGURE 9. Common channel signalling: route A, quasi-associated signalling; routes B and C, associated signalling.

The 12th unit of a signal unit block is the acknowledgement signalling unit (a.s.u.), used primarily to acknowledge messages sent in the reverse direction. Error control is based on error detection by redundant coding, and error correction by retransmission. Acknowledge bits 4–14 indicate whether retransmission is required. If a signalling unit in error is part of a multi-unit message, the entire message is retransmitted. If a data channel fails completely, or if the error rate is excessive, arrangements are made to signal over an alternative path. In this context it should be noted that the 2.4 kbit/s rate can be accommodated in a normal speech channel.

The above brief description refers to a common channel signalling system incorporated into a basically analogue transmission environment. If p.c.m. transmission is used, it is possible to select one of the p.c.m. channels for interprocessor signalling, where the major difference

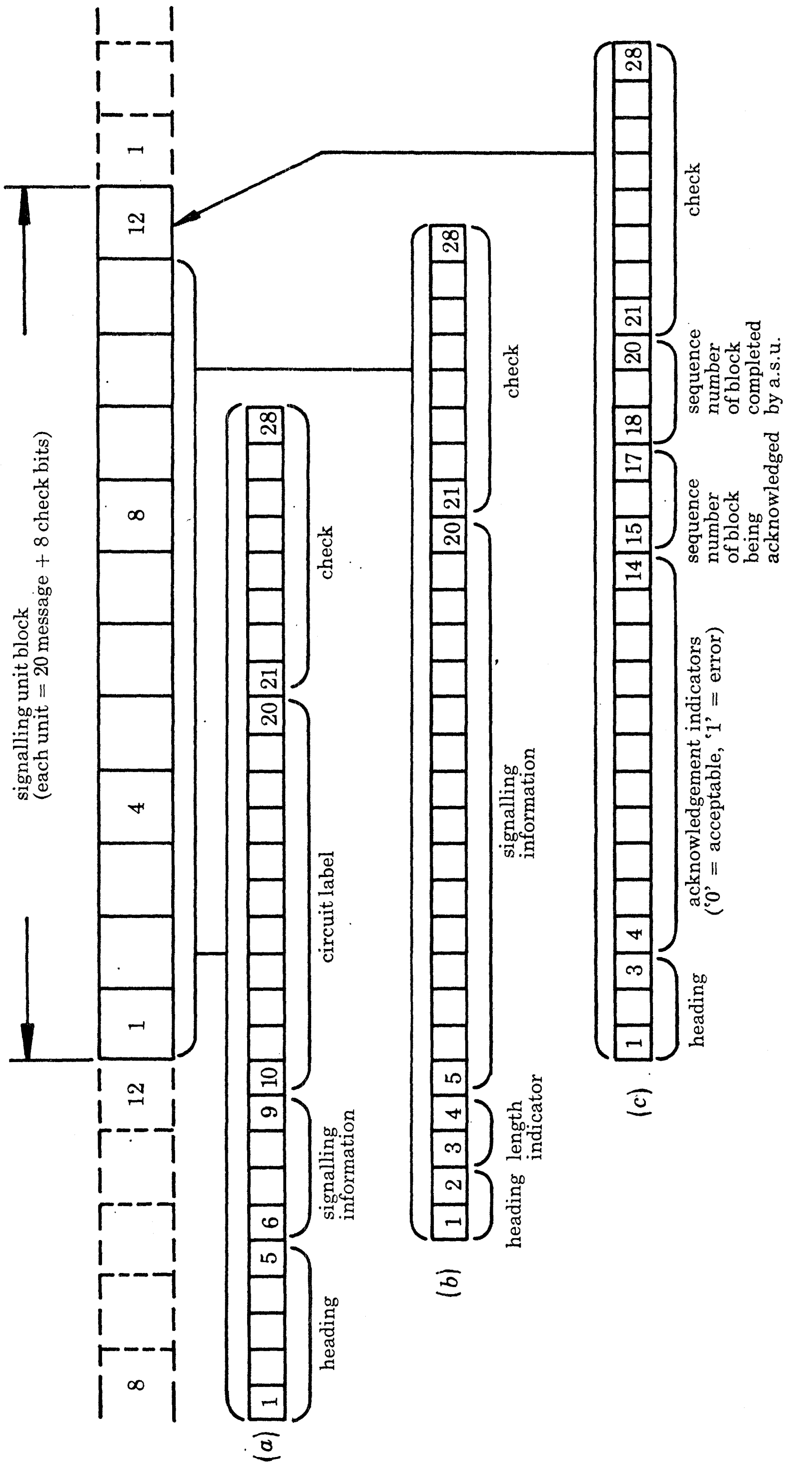

FIGURE 10. C.C.I.T.T. No. 6 signalling formats: (*a*) initial signalling unit (i.s.u.); (*b*) subsequent signalling unit (s.s.u.); (*c*) acknowledgement signalling unit (a.s.u.).

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is the availability of a 64 kbit/s digit rate. Although in principle such a system need be no different from one based on 2.4 kbit/s, advantage is normally taken of the increased channel capacity allowing particularly more comprehensive methods of error control. In addition, with modern p.c.m. transmission systems, a form of common channel signalling is incorporated which is suitable for use with exchanges not incorporating stored program control. This is achieved by reverting back to channel associated signalling at the terminating relay sets.

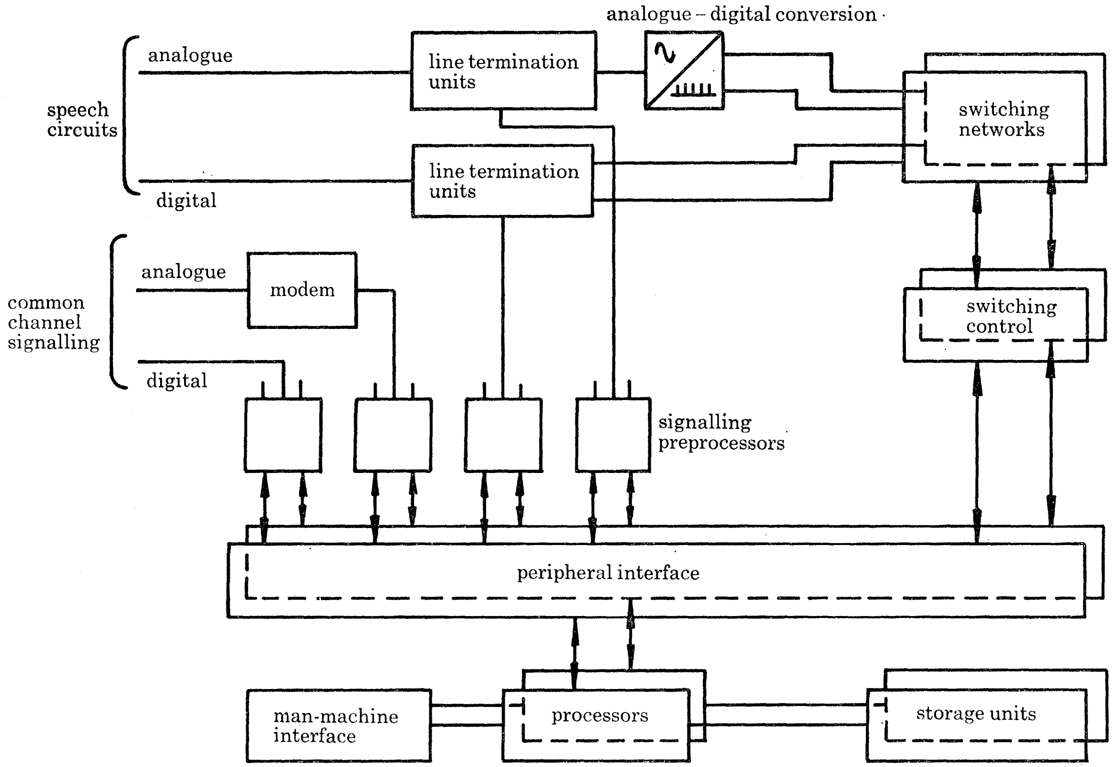

Figure 11. Digitally switched, processor controlled trunk exchange for a mixed transmission and signalling environment.

Complete exchanges

Whereas processor control, digital switching and common channel signalling can be incorporated individually into exchange systems, a new generation of exchange systems is now being designed which incorporates all three approaches. Nevertheless, such exchanges will still have to interwork with existing equipment where more conventional signalling and transmission arrangements are employed. This interworking problem introduces economic penalties, and hence the application of these new techniques is commencing in areas where, either the advantages are overwhelming, or the interworking problems are fairly minimal. In the first category, large digital trunk exchanges are being actively pursued, even for use in analogue environments, since the digital technique offers large economic savings in the realization of switching arrays for trunk exchanges carrying in excess of 20000 erlangs.

A typical processor controlled digital trunk exchange is illustrated in figure 11. Equipment is included to permit operation in an analogue or a digital transmission environment, with or without common channel signalling. Since control signal formating and error control represent a considerable load on the controlling computer, these functions have been shown as off-loaded onto preprocessors. The switching network is shown duplicated to provide security of service in the event of a serious switching failure.

It is interesting to note in such an exchange the relative floor area taken up by the constituent parts. Normalizing the size of the exchange to be 100 for the electromechanical equivalent, the digitally switched, stored-program controlled exchange might occupy 25 racks of which 10 racks would be the actual exchange and 15 racks would be the signalling interface equipment assuming no digital transmission and no common channel signalling. If complete conversion to digital transmission and common channel signalling were achieved, virtually all 15 interface racks would be unnecessary, giving an overall rack saving of some 10:1.

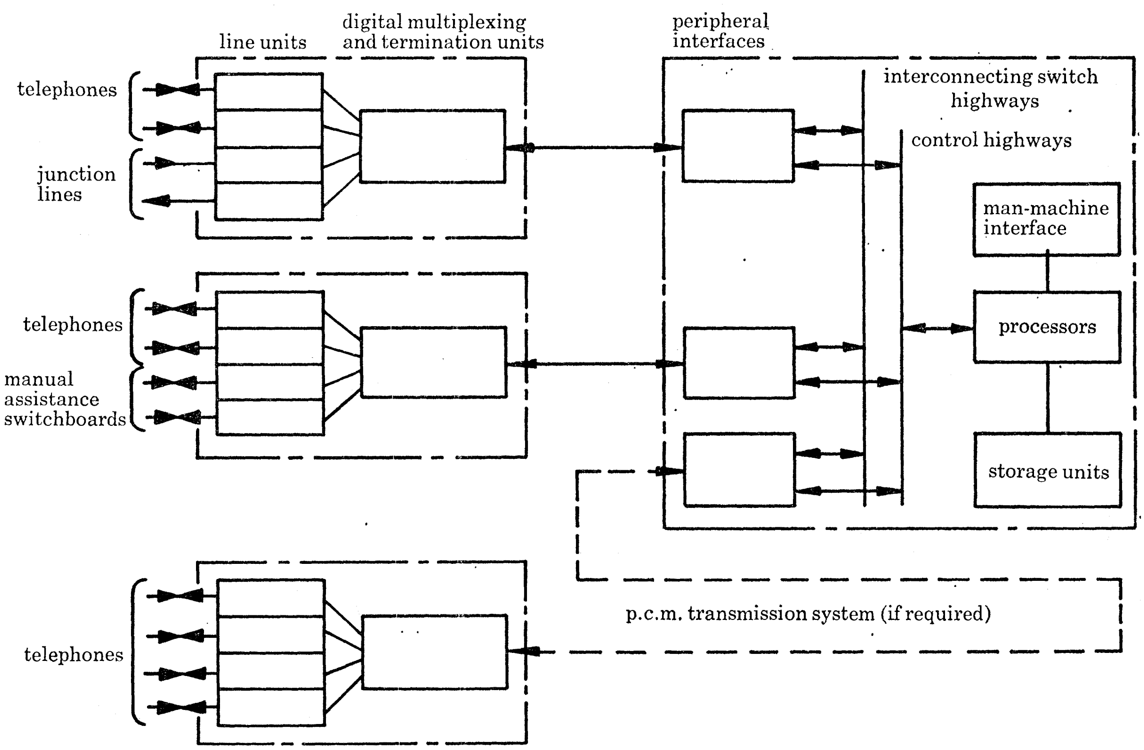

FIGURE 12. Digital p.a.b.x. with provision for remote subscriber units.

With reference to subscriber exchanges, at present the main advances are taking place largely in the private automatic branch exchange (p.a.b.x.) area, where interface problems are less serious. A typical example of a digitally switched processor-controlled p.a.b.x. is shown in figure 12. The standard time–space–time switching configuration is used, and, even with a modest number of channels on the highways (32), exchanges of up to 5000 lines can be constructed. However, a most important feature of such exchanges concerns the ability to locate much of the equipment remotely so that the subscriber wiring requirements are reduced. Although this is possible even with space-divided analogue exchanges, the convenience of the digital approach in this respect is very marked. In the figure a subsystem of 200 subscribers' line units and the associated time switches are shown remote from the main p.a.b.x. This subsystem could be connected to the main exchange over two 30/32 channel p.c.m. systems carried on 4 pairs of wires providing 60 bothway speech channels. Assuming 2 pairs per subscriber telephone, this would represent a decrease in wiring to the main unit of 100:1.

Further benefits accrue from the use of stored program control. Firstly it is possible to treat the individual concentrators all as part of one integrated exchange, or alternatively it is possible to treat some units either individually or collectively as completely separate exchanges as far as the subscribers are concerned. Indeed the central equipment can now form part of the local main exchange, thus reducing the administrative and maintenance problems by concentrating the main hardware at one centralized location.

Conclusions

Current and medium term developments in switching are characterized mainly by the introduction of digitally switching, stored-program control and common-channel signalling. Although these techniques have obvious technical attraction, in the ultimate it is the practical advantages they offer which will ensure their success. In terms of basic exchange parameters, these advantages may be summarized as follows:

(*a*) Physical sizes of exchanges can be reduced by at least 50 %, and possibly 90 %. Such reductions more readily permit the mounting of equipment on shorter racks suitable for normal office accommodation, thus reducing the need for special exchange buildings.

(*b*) The exchanges should be very much easier to plan, manufacture and install. It may be possible to reduce the whole cycle from requirement identification to a working exchange to something like 18 months for large exchanges, with the actual installation time being reduced to less than two months. For small exchanges the corresponding time scales should reduce to weeks and hours.

(*c*) The exchanges should be extensible by pure addition without rearrangement of existing equipment.

(*d*) Maintenance costs should be reduced by virtue of the powerful fault diagnostic arrangements that can be incorporated. Actual reliability should improve, but it must be remembered that existing electromechanical equipment can be made very reliable even by electronic standards.

(*e*) Since the exchange hardware is basically general purpose, it should be easier to cater for changing network conditions brought about by the evolution of the network and improvements required in both administration and subscriber facilities.

At this time certain other potential advantages are not necessarily being realized to the same extent. They include mean power consumption, which is still comparable with electromechanical equipment; capital costs, which have yet to show the big reduction promised; and heat dissipation problems, which have become more acute due to the reduction of physical size not being accompanied by a similar reduction in power consumption. However, by the further incorporation of low power l.s.i. devices, and the gradual decrease in interworking equipment, these limitations should be overcome.

Special subscriber facilities have not been mentioned other than as a passing comment. This was deliberate since it is considered that they represent possibly the least significant advantage to be gained from the introduction of the new systems. However, for those who require more than a good basic service, the following subscriber facilities will probably become the most useful:

abbreviated dialling (shortened codes for frequently used numbers);
automatic alarm calls (early morning calls);

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call waiting (indication of an incoming call while the subscriber is already engaged);

ring back when free (automatic ringing of called and calling lines when both are free);

three-party service (ability to connect a third party into an existing call and establish various combinations of connection);

transfer of calls (automatic diversion of incoming calls to another line).

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