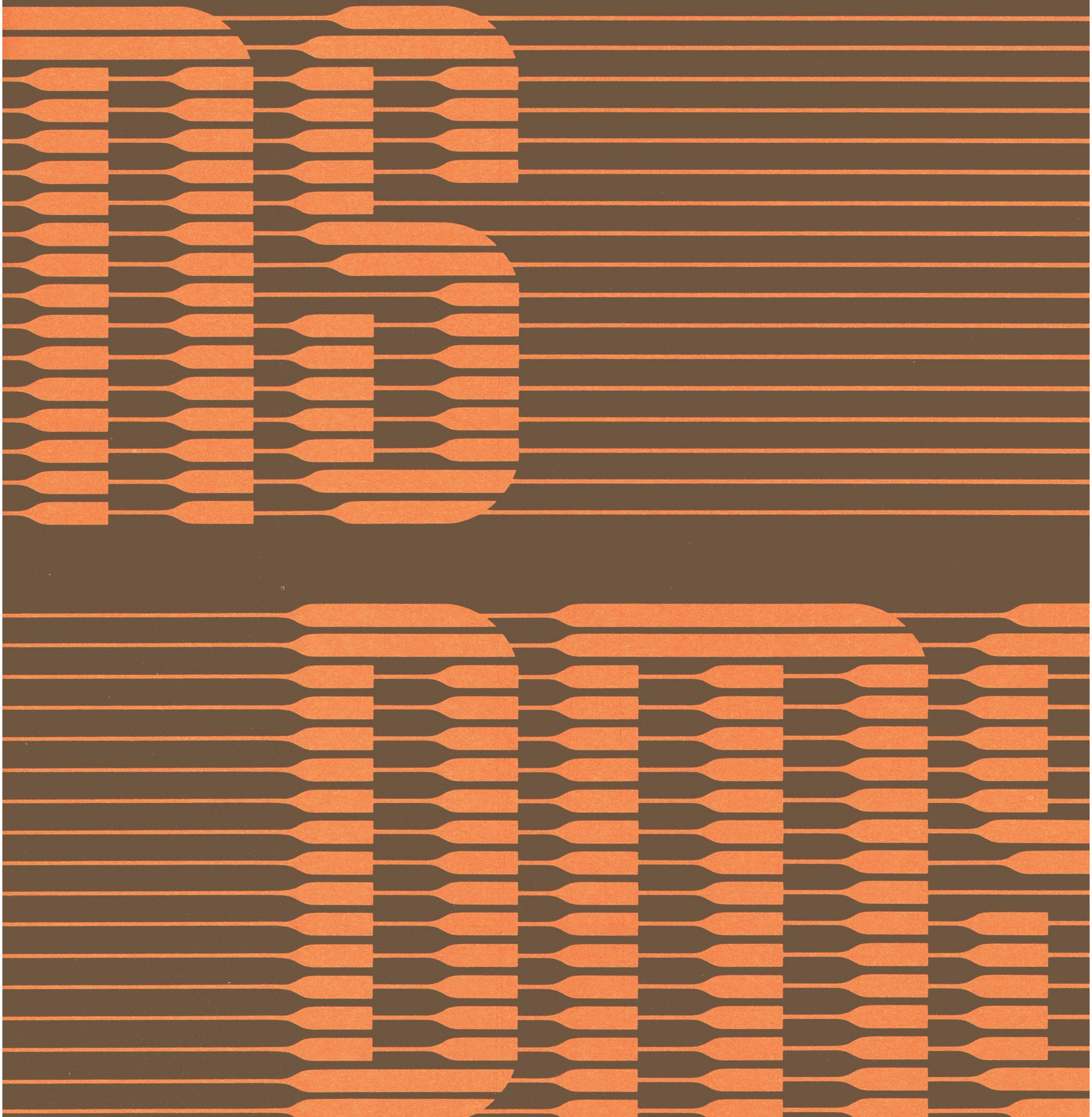
telesis

August 1978

Special issue:
DMS-10 Digital community dial office



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Cover: Digital technology is moving fast into prominence within the telephone industry. BNR and Northern Telecom are in the forefront with DMS, a digital switching family.

Editorial

This special issue of Telesis focuses the spotlight on the DMS-10, a local digital multiplex switching system of small to medium size, and the newest member of Northern Telecom's digital switching family in full production. Other members of the digital family — DMS-1, a subscriber carrier/remote switch, and SL-1, a digital private automatic branch exchange — have preceded DMS-10. The DMS-100, a medium to large size local digital switch, DMS-200, a digital toll switch, and DMS-300, a digital gateway switch, will follow shortly. The integration of digital switching systems and digital transmission facilities paves the way for operating economies and improved network performance.

The DMS-10 is a stored-program-controlled system suited for use in local switching centres in the size range of 300 to 6000 lines. It offers a wide range of service features for subscribers and provides the telephone operating companies with improved maintenance and administrative features.

The impetus to develop the DMS-10 was provided by planners at Northern Telecom and Bell-Northern Research. They recognized the market need and the availability of a technology base to satisfy the commercial requirements. Designing the right product, at the right time and cost, are well known fundamentals for the successful introduction of a new product to the marketplace. The development of the DMS-10 system is based upon field proven technology selected from the SL-1. The use of proven components, such as the custom large scale integrated circuits, processors, memories and the high level software language, was a key factor in minimizing the design risk and the system cost, and shortening the development and introduction interval. As applicable technology evolves, the flexibility of the DMS-10 design will allow the system to be kept current.

Planning for the DMS-10 began in October 1975, and by January 1976 hard development was underway at BNR, with assignment of key resources to assemble and build up the required staff. Development proceeded rapidly, through the lab model stage to the first production system, which was shipped in July 1977. The system was installed and successfully cut into service October 17, 1977, at Fort White, Florida, as a class 5 digital office for the North Florida Telephone Company. This was a major milestone for Northern Telecom, Inc., the US subsidiary of Northern Telecom Limited, as DMS-10 represents the first switching product for which it has had the prime responsibility to manufacture and introduce to the North American market. The NTI digital switching division in Creedmoor, North Carolina, is responsible for the manufacture, marketing, installation and engineering of DMS-10 systems and is supported by the division's West Palm Beach facility in Florida where the circuit packs and hybrid circuits are manufactured. Sales are headquartered in Nashville, Tennessee, with sales personnel in every major US city. Following the first verification office in Fort White, a second office was successfully put into service by Continental Telephone Company in Wakefield, Virginia, in February 1978. Other systems have followed, with 18 in service as of the end of August. The first Canadian DMS-10 office was turned over to Bell Canada in August 1978.

The six articles presented here document the development of the DMS-10, its position in the historical evolution of switching, the major parts of the system, and the implementation program, from product development through manufacture and installation, to the service introduction of the verification offices. The success of DMS-10 was only possible because of the dedicated effort and close cooperation of many people involved in the project from inception to market introduction. BNR and other organizations from Northern Telecom and various operating companies worked together to produce the system which not only met but exceeded its objectives in a very short time frame.

W. J. Ives

Walter Ives
Director, Technology, Digital Switching Division
Northern Telecom, Inc.

The future arrives for the small switching office

Brian Voss
Brian Watkinson

DMS-10 brings to small and rural telephone systems an economical means of matching the performance and features of the rapidly evolving large urban switching machines.

Since the early days of the telephone, customers and operating companies have benefited from the continual march of technology but, economic factors have prevented small telephone exchanges from keeping pace with the changes and improvements in large urban centres. This disparity can now be eliminated with DMS*-10 providing modern switching and associated exchange services for central offices with capacities between 300 and 6000 subscriber lines.

The economic and service objectives for DMS-10 were achieved by using the latest in modern technology, combining new stored program control techniques with digital switching to provide 'big city' services. Equally important, telephone companies can now evolve a more efficient and higher performance telephone network by integrating digital transmission systems with digital switching equipment.

In order to see where DMS-10 fits in the evolution of the telephone network, we must briefly examine some history.

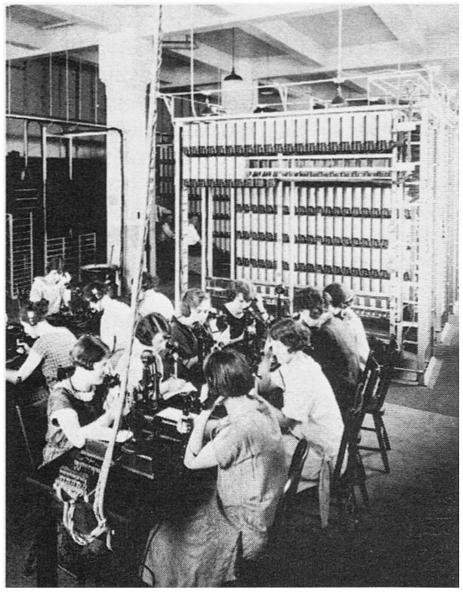

Figure 1. While styles change, telephone switching systems linger on. Step-by-step switches, like those in the background of this photograph, were introduced over 50 years ago and are still widely used in applications where DMS-10 is intended to be used.

A little history

Widespread use of dial telephone service began over 50 years ago with the installation of step-by-step, automatic switching equipment, see Figure 1. The step-by-step switches (devices with rotating 'wipers' which 'step' one position for each pulse received from a dial telephone) were assembled into switching systems where routing was directly controlled by a subscriber's dial.

Step-by-step equipment survived into the 1950s when it began to be displaced by the crossbar switch, see Figure 2. Crossbar switching systems provided 'common control', that is, subscriber dials did not directly control the routing of a call as in step-by-step systems. Control functions were handled by a common pool of specially designed equipment (functions such as receiving and storing dialled digits, translation for routing, and billing) shared by all the subscribers on the system. The combination of common control techniques and crossbar switching networks paved the way for automatic alternate routing and direct distance dialling. In addition the common control equipment could also automatically test and report faults allowing centralized maintenance and administrative procedures to be developed by telephone companies, thus improving both productivity and service.

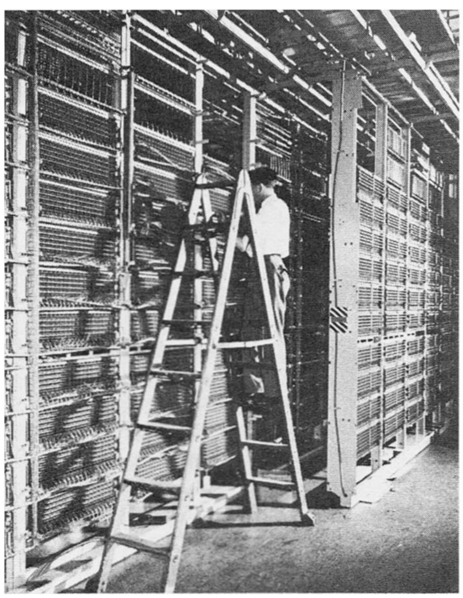

Figure 2. The crossbar switch heralded a breakthrough in switching system flexibility. This resulted from the application of common control techniques to separate the switching and control functions. Shown here is part of an early crossbar switching network.

During the 1960s, the trend to more sophisticated and flexible control technology accelerated with the introduction of stored-program control switching systems. These systems continued to use electromechanical switching but a special computer performed call processing, maintenance, and administrative tasks.

During the last two decades, virtually all new large switching systems have been manufactured with either common control or stored-program control equipment. But high initial costs for control equipment has slowed application of these technologies in the smaller switching systems used in many low population areas of North America. This has produced a curious anomaly in the telephone network by leaving most community dial offices equipped with old step-by-step systems, or similar limited direct control equipment.

Bridging the gap

The DMS-10 system was developed to bridge the technology gap between the community dial offices and large urban centres. Major design objectives included:
— minimizing common equipment costs to permit economic application for small communities,
— compactness, to avoid building extensions when replacing obsolete electromechanical switching equipment, see Figure 3,
— integrating digital transmission facilities to provide equipment and operating economies, and to permit overall network performance improvements,
— flexible design to allow evolution of technology to keep the system current and to maximize performance advantages for the owner
— dependable service, with emphasis on economic, unattended operation at locations remote from urban centres.

The last objective is particularly important for small switching systems because frequent service and maintenance visits can rapidly escalate telephone company expenses. DMS-10 offices are expected to be largely unattended since subscriber requests for new service orders or changes are relatively infrequent. However, while a typical maintenance or administrative task might require less than 30 minutes effort in an attended office, a visit to a remote office to perform the same task might include dispatching and round trip travel time of four hours! Thus, to achieve the twin objectives of dependable service with economic, unattended operation, great emphasis has been placed on reliability. This was accomplished with built-in automatic diagnostic and recovery features that permit telephone companies to defer repair actions for improved operating efficiency. Similarly, administrative tasks, such as traffic measurements and service orders, can be performed at remote centralized locations convenient to the operating company.

The execution

The following articles in this issue describe in more detail, the features, design, intelligence and hardware of DMS-10. Before delving into some of these details, it will be helpful to quickly outline the DMS-10 system.

The basic DMS-10 equipment organization and associated functions are illustrated in Figure 4. The diagram identifies three basic equipment assemblies: control, network, and peripheral. DMS-10 equipment consists of mechanical assemblies or shelves designed to accommodate standard printed circuit packages or 'packs'. Both packs and shelves are plug-in units to facilitate extensions and repairs.

The smallest DMS-10 system requires four shelves of common control and switching equipment — two control and two network. For larger systems, network shelves are added in pairs up to a maximum of six shelves. Each control shelf is equipped with a central processing unit (CPU) one of which operates in a 'hot', standby mode. Active/standby CPUs are changed over on a scheduled basis (usually daily) to ensure the standby unit is always operating correctly. If an active CPU should fail, the system automatically switches to the standby one.

Each control or network shelf will have a maximum of two memory packs with one shelf always equipped with redundant, standby memory. If an active memory pack or its associated shelf should fail, the system automatically recovers by substituting the standby memory. This is a novel approach to memory architecture since most stored-program-controlled switching systems double memory equipment by duplicating the entire memory system. By contrast, the DMS-10 approach only requires an increase of 1/3 to 1/7 of the memory equipment to provide automatic recovery. Initial equipment is minimized to permit economic application at small sizes. Also, dependable service is enhanced by reducing the repair rate in the sensitive common equipment area. Experience with earlier stored program switching systems has shown that procedural errors are important contributors to system failures. By reducing equipment, system 'down time' attributed to procedural errors is correspondingly reduced.

The primary function of the network shelf is to establish connections between digital channels (actually pulse code modulated (PCM) channels). Thirty PCM voice channels plus two signalling channels are carried on a five-pair cable called a multiplexed loop. A network shelf can accommodate up to seven network packs, with two multiplexed loops each. These shelves are always equipped in pairs, and multiplexed loops are also paired across the two shelves. In the DMS-10 network telephone service is automatically retained despite a loop or shelf failure. While one loop is 'down' during a repair interval the second multiplexed loop of the pair serves twice the number of lines. This service protection technique was utilized instead of full network equipment duplication to, once again, minimize initial costs, equipment failure rates, and associated maintenance action. The network normally provides excess traffic capacity, and subscribers are not likely to notice any change of service during repairs.

DMS-10 analog peripheral equipment converts voice frequency signals from telephones and trunks into digital pulse code modulated signals. The associated subscriber loop and interoffice signalling data are also converted to digital messages for subsequent communication with the CPU. The peripheral equipment can connect or digitally switch the PCM signals associated with any one of 112 analog terminals to any one of 30 digital PCM channels.

Digital peripheral equipment converts digital signalling of the DMS-10 multiplexed loop to bipolar signalling required by the standard DS1 interfaces.

When digital transmission facilities are integrated with a digital DMS-10 central office, dramatic reductions in costs are made possible by eliminating analog terminal equipment and the associated expenses for floor space, power and distribution facilities. Transmission and signalling impairments which would be introduced by terminal equipment are also avoided, thus providing overall network performance improvements. Some interesting application possibilities arise with the combination of digital transmission and switching.

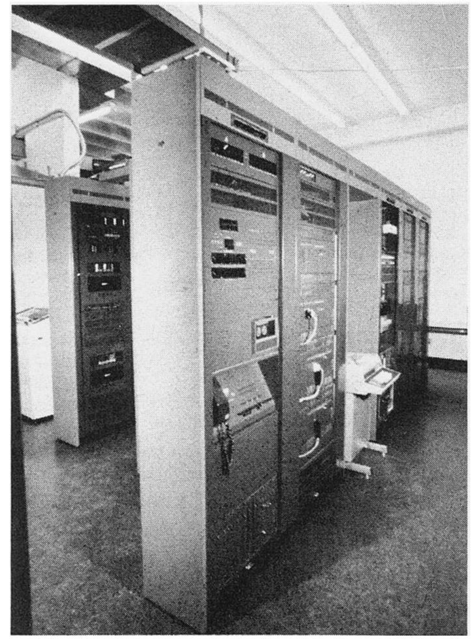

Figure 3. *Digital switching systems provide a forward step in equipment design, combining clean, functional packaging with compact size. This is a photograph of the first commercial DMS-10 during installation at Fort White, Florida in 1977. Only five bays of switching equipment are required to serve up to 500 subscriber lines.*

Digital interoffice trunks

Digital trunking between analog central offices is illustrated in Figure 5 (a) and the corresponding situation when one office is a DMS-10 in Figure 5 (b). At the analog office 24 trunk circuits cross-connect, through distribution facilities, with 24 channel units of a D3-type channel bank which terminates the digital transmission line. In DMS-10 the same interconnection could be provided, but a more economical alternative is to use fully digital connecting circuits, called digital carrier modules (DCM), instead of the trunk circuits, distribution facilities and channel bank. A standard DMS-10 shelf can accommodate up to six DCMs — capacity for 144 digital trunks — compatible with D3, D1D, or D2 channel banks in connecting offices.

When both central offices are digital, the situation shown in Figure 5 (c) arises. No analog transmission is used in either switching machine or on the interoffice transmission facility. However, the digital switches should operate synchronously to avoid 'slip' impairment: loss of information when one office transmits digital signals faster than the other is arranged to receive them. DCMs enable DMS-10 to operate asynchronously, in which case slips will occur, or to operate in the more desirable synchronous mode. When operating synchronously the DCM at a 'slave' DMS-10 can extract a synchronizing signal from the 'master' office clock and use this to adjust the slave office clock frequency to maintain synchronization.

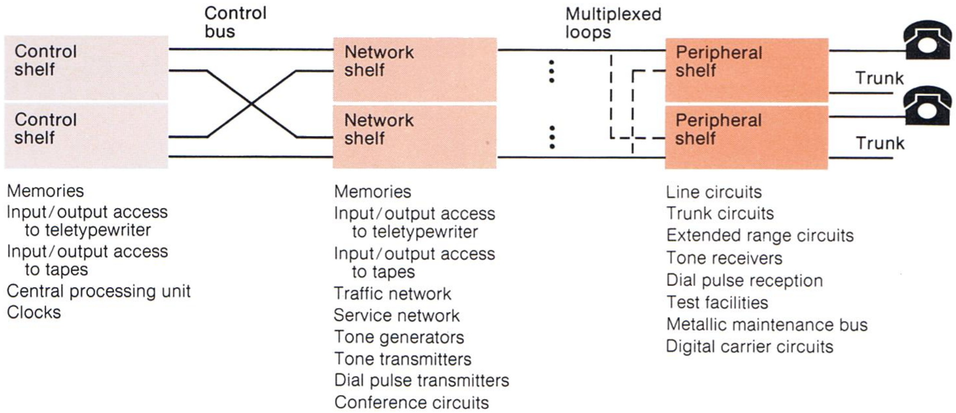

Figure 4. *DMS-10 is assembled from three types of equipment: control, network and peripheral. Control architecture requires certain functions to be distributed over both control and network shelves in order to maximize performance reliability, therefore the functional lists above show some duplication in these areas.*

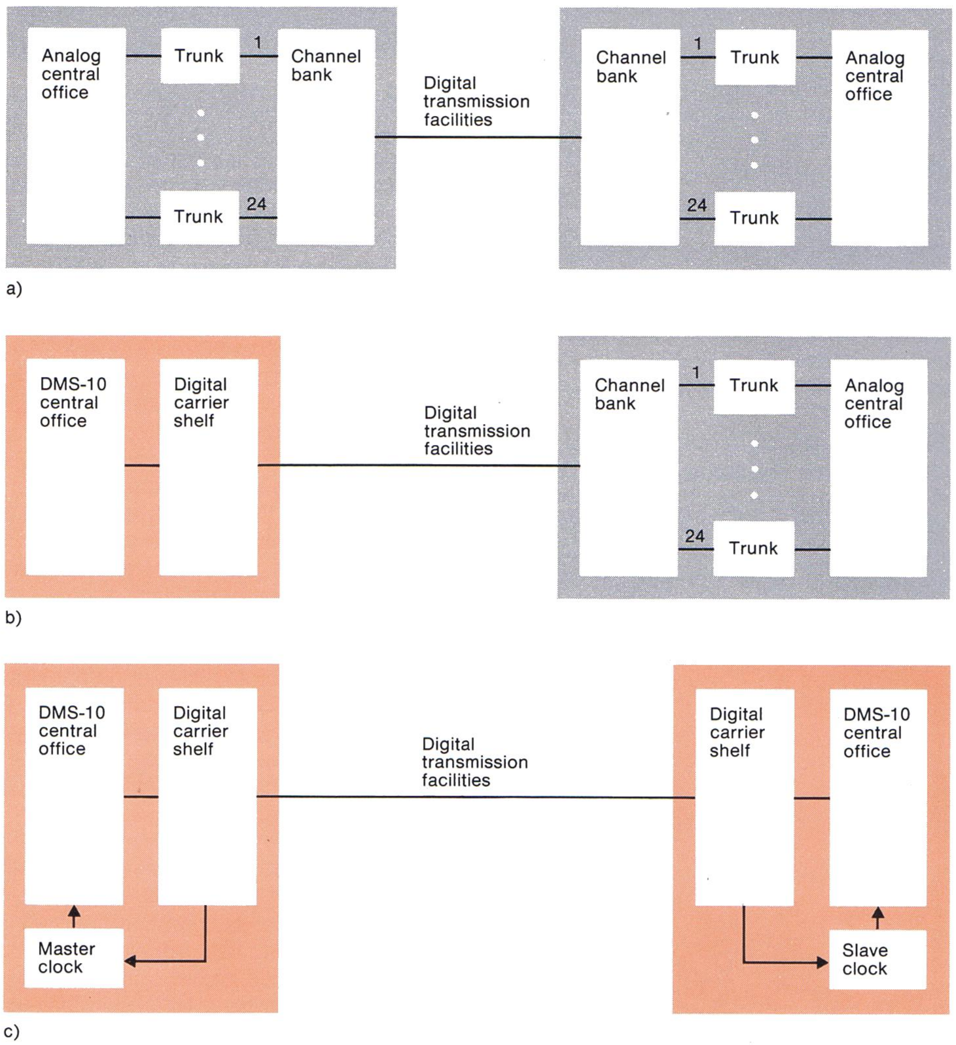

Figure 5. *Analog to digital conversion functions are necessary when two analog switching centres are connected by digital transmission facilities (a). Integration of digital transmission and switching, with improvements in economy, reliability, and performance becomes possible when at least one of the switching centres is a digital switch (b and c). One sixth of a digital carrier shelf in DMS-10 takes the place of two or three shelves of trunk circuits and channel bank equipment in the analog central office.*

Pair gain systems

Conventional subscriber carrier or pair gain systems are configured typically as shown in Figure 6 (a). An office terminal performs like a channel bank to connect line circuits in the central office to channels of digital transmission lines. At a remote terminal, channels are connected to corresponding lines to complete the circuits. Pair gain is achieved because the remote terminal may be located close to served subscribers and a large reduction in digital lines compared with analog lines is possible between office and remote terminal.

Equivalent pair gain is obtained with DMS-10 by arranging for standard analog peripheral equipment to be located remotely, as shown in Figure 6 (b). An office carrier module connects via two digital transmission facilities to a remote carrier module, in order to extend two DMS-10 multiplexed loops to the remote site. This allows standard peripheral equipment to be located remotely and, in addition to pair gain, allows the remote equipment to have the same maintenance and administration as the main DMS-10. Two office carrier modules can be housed on a standard DMS-10 shelf; the remote carrier module occupies spare space on a standard bay equipped with four peripheral shelves. A few spaces on the shelves are dedicated for maintenance circuits, leaving capacity for 212 lines on the bay.

In addition to conventional pair gain applications, remote peripheral equipment provides several other interesting opportunities for connecting central offices equipped with older switching systems.

Feature additions

Adding new service features to older switching equipment is often prohibitively expensive or impossible. However, it is possible to provide a connecting office with the full range of DMS-10 services by installing remote peripheral equipment. Services such as speed calling, call waiting, Digitone* dialling, and many business offerings become immediately available in the connecting central office to those subscribers served by remote peripheral equipment. The telephone company can offer uniform services between the DMS-10 and its connecting exchanges, while retaining existing directory numbers and traffic arrangements. Investments in new equipment additions to older switching exchanges can be avoided indefinitely.

Capacity extensions

Adding line and associated traffic extensions to satisfy customer growth demand can be particularly expensive in older community dial offices. To add capacity, telephone companies must frequently rearrange equipment and cabling patterns on old fragile systems. The additional

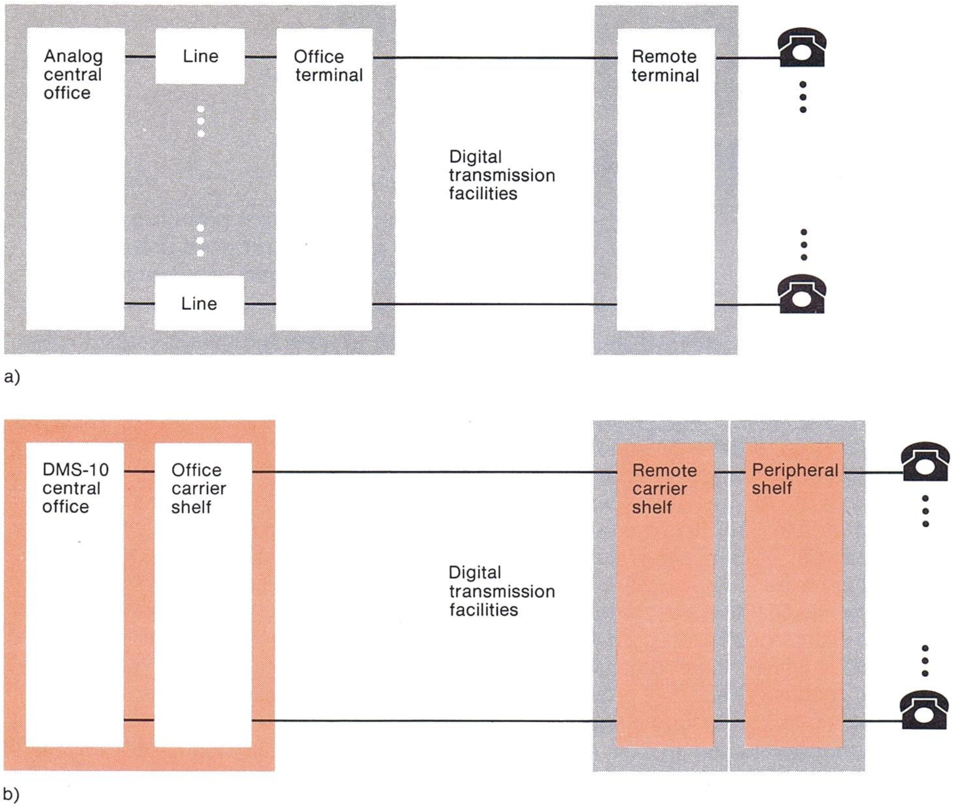

Figure 6. The advantages of integrated digital transmission and switching are readily apparent in subscriber carrier systems (a). In DMS-1, half an office carrier shelf at the central office replaces four shelves of line equipment and approximately eight shelves of subscriber carrier office terminal equipment, while at the remote terminal the DMS-10 remote carrier shelf and up to four peripheral shelves are roughly equivalent in size to a subscriber carrier remote terminal (b). Besides equipment reduction, uniformity of local and remote peripheral equipment in the DMS-10 is convenient for telephone company maintenance and administrative staff, and ensures uniform service for their customers.

terminal and switching equipment may even require a building extension, or extensive floor plan changes. When the remaining life of the existing switching equipment is limited, telephone companies are reluctant to invest in these equipment additions. An alternative for DMS-10 connecting offices is remote peripheral equipment. Incremental line and traffic capacity can be added in relatively small amounts as customer demand grows. The DMS-10 compactness can provide building floor space relief, and rearrangements to existing equipment can be minimized. When the time comes to replace the old switching equipment, a new DMS-10 system is immediately compatible with the equipment installed as growth extensions.

Combined trunk groups

The connecting central office can be equipped with interoffice trunk facilities, complete with D-type channel banks as illustrated in Figure 5(b). An alternate plan is remote peripheral equipment with DMS-10 trunk circuits. The remote peripheral equipment and its digital transmission line can be dedicated to trunk traffic, or to a combination of local, extended area service, and toll traffic. For small offices, the savings possible with combined trunk groups are often attractive, and digital line facilities and terminating equipment can be minimized.

By integrating digital transmission facilities with the DMS-10 digital network it is possible to locate DMS-10 lines and trunks remotely using digital carrier facilities. Conventional subscriber carrier or pair gain applications can be accommodated with significant reductions of terminal equipment in the DMS-10 central office. The same capability can be applied to connecting central offices with older and more limited switching equipment. New service features increase traffic and line capacity, and combined trunk groups offer telephone companies new, flexible planning alternatives to incremental investments in older and more limited switching equipment.

This article has briefly shown the position of DMS-10 in the historical evolution of the telephone network and some of its exciting application possibilities have been introduced. For more complete discussion of what DMS-10 is, and how it came to be, the reader is referred to subsequent articles in this issue.

°Trademark of Northern Telecom Limited

Brian Voss has worked for Bell-Northern Research since 1965. He has been involved with the development of several switching systems, ranging from electromechanical central offices, through military and business application digital switches, to the past two years' assignment with DMS-10 development. He received a BEng in 1962 from McGill University, Montreal, Quebec, and a MEng in 1968 from the University of Toronto, both in electrical engineering. Currently Brian is manager of DMS-10 system development, with responsibilities for present system hardware and future system evolution.

Brian Watkinson was awarded his BASc in electrical engineering by Queen's University at Kingston in 1962. From that year until 1965 he was a design engineer with Northern Telecom in Montreal, working on manual and toll systems and key telephone systems. He then transferred to Bell-Northern Research as an engineer and then supervisor of local crossbar systems design. In 1971 he became manager of a group involved in business communication systems design, and subsequent product development for the digital business communication system, SL-1. From 1976 to 1977 he was manager of DMS-10 system development. He is currently manager, product planning.

The DMS-10 program: increasing the pace of development

Tony Stansby

Innovative program planning speeds a major new product from concept to service in less than two years.

The DMS*-10, developed by Bell-Northern Research, is a key member of Northern Telecom's family of digital switching machines. Digital technology has already found extensive use in transmission facilities, bringing about reduced costs and superior service, as was demonstrated in 1977 with the successful introduction of DMS-1, a digital rural subscriber carrier[1]. Now DMS-10 fills the need for a competitive switching product for local exchanges from approximately 300 to 6000 lines and in combination with its larger relative, DMS-100, provides complete digital product coverage of the local exchange market.

Until recently, it has been impractical to design a cost-effective common control switching system for small offices with only a few hundred lines. The high fixed cost for central control computer and switching network equipment strongly favoured large systems. However, the introduction in 1975 of Northern Telecom's SL-1* business communications system[2] proved that an economically viable small system could be designed using fully digital techniques for both control and switching network. A feasibility study in 1975 showed the same digital techniques could be applied effectively to the design of a small central office switching machine.

Planning the program

Development of DMS-10 commenced in January 1976, to a commercial specification prepared by Northern Telecom. Achievement of a 1977 product introduction date was established by marketing as a primary strategic objective of the development program. Thus much of the time spent in program planning was devoted to meeting the challenging goal of a development to in-service interval of less than two years.

The overall program plan required the preparation of four subsidiary plans, for the development of

- product hardware and software designs
- hardware manufacture and testing facilities
- an automated process for system configuration, software manufacturing and job documentation preparation
- installation and on-site checkout facilities and procedures.

In order to meet the desired introduction date the plans had to operate in parallel throughout the development period, coordinated through a single master program schedule.

The first attempt at the master schedule, using critical path scheduling techniques, showed clearly that the schedule objective could not be achieved with the conventional development approach; ie, design—development—technology trial—field trial—production. Overlapping of consecutive program phases was ruled out since this would have resulted in losing in each phase many of the benefits of preceding phases. Shortening of individual phases was not realistically possible. Accordingly, it was decided to take advantage of the high confidence level in the basic technologies established by the SL-1 field performance to eliminate the technology and field trial phases, and to proceed directly from laboratory development to first production.

This approach had several desirable attributes, as shown in Figure 1. First, it reduced the minimum product introduction interval from 29 to 20 months. Second, by deferring the date of initial connection to live subscriber traffic, it allowed an additional 3 months for software development, integration and testing. Third, it permitted more extensive design testing at the laboratory prototype stage than would otherwise have been possible. Its success, however, was critically dependent on an effective process for the rapid translation of hardware design changes from the laboratory testing program into production of the early systems.

To minimize the risks associated with this approach, the initial DMS-10 feature set was limited to essentially the subscriber features available in the older systems which DMS-10 would replace, plus most of the maintenance and administrative benefits made available by the new system. Many of the more advanced features, items such as direct digital trunking, custom calling services, LAMA (Local Automatic Message Accounting) and remote digital line connection, were scheduled for market introduction at a

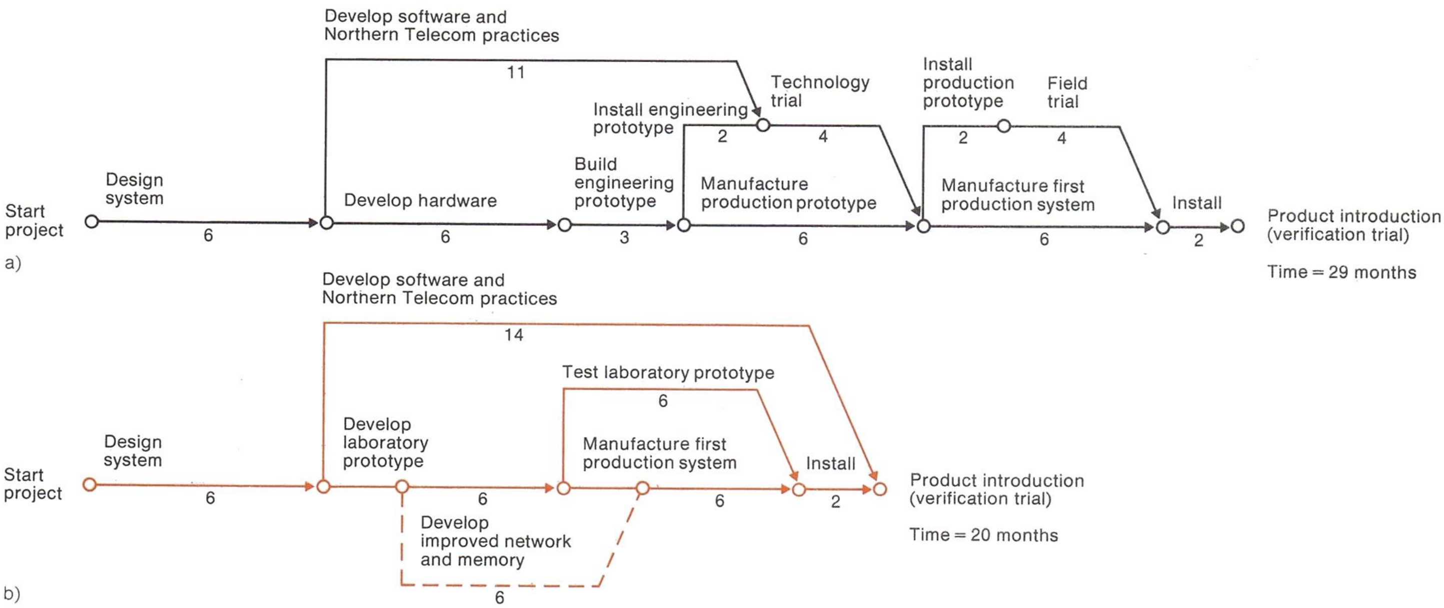

Figure 1. A conventional development program for a switching system (a) includes a technology trial of a handmade engineering prototype in a 'live' (though frequently captive) environment, followed by a field trial of a soft-tooled production prototype, leading finally to manufacture of the first production system. There are four cycles of hardware design: laboratory breadboards, engineering prototype, production prototype, and production. Software and operating documentation (Northern Telecom practices or NTPs) usually have three cycles of which only the first is shown for clarity. The activity intervals shown (in months) are typical for a product of the complexity of DMS-10.
The use of proven hardware technologies enabled the DMS-10 development program to be shortened by more than 25 percent (b). By enlarging the hardware development phase into a full laboratory prototype system with more extensive testing, it was possible to reduce the total project interval while in fact increasing the development time available.
The dotted line portion of (b) shows the subsidiary development program introduced between August 1976 and May 1977 to incorporate design enhancements in the digital network and memory architecture which were conceived mid-way through the development phase.

later date. In addition, experienced Bell Canada support was obtained to provide planning and on-site guidance for the operating companies during the installation and initial in-service periods of the first several offices.

Having thus established the basic program outline, hardware and software availability dates could be predicted with some confidence, and commitments made to customers for the verification offices. With the cooperation of the Mid-Continent Telephone Company and one of its subsidiaries, North Florida Telephone, a first verification site was selected in Fort White, Florida, some 80 km west of Jacksonville. The Fort White community was served by a 20 year old electromechanical switch of some 300 lines, which was overdue for replacement. A second site was established, for a 900 line office of the Continental Telephone Company, in Wakefield, Virginia, about 40 km west of Norfolk. To ensure adequate support of these two offices during the trial period, two further offices for in-house use were included in the program plan, to be manufactured concurrently with the Fort White system. The first, located at BNR Ottawa, would be used for initial software verification, simulation of any field problems identified during the trials, and testing of solutions prior to field application. The second, at NTI Creedmoor, North Carolina, would support manufacturing testing and aid in the training of operating company personnel.

Program highlights

The key milestones established in the final program plan were as shown in Table 1.

Committed in-service dates for both systems were 6 weeks later than the earliest possible dates established by the program critical path. These contingency periods were allocated to the installation phases (the intervals between system delivery and in-service). The success of the program then depended on meeting the system delivery milestones, and on being able to resolve any residual problems on-site in the time available prior to the in-service dates.

As events transpired, this strategy proved very successful. Only one major change was made during the execution of the plan; this was in August 1976, when an opportunity arose to make substantial improvements in the architecture of the digital switching network and processor memories. After an analysis of the potential performance benefits versus the schedule risks involved, the proposed changes were approved, without change to the key milestones. This necessitated a subsidiary development plan in the areas affected, which rejoined the master schedule in May 1977, only two months before delivery of the first system (see dotted line portion of Figure 1b.).

In spite of this, manufacturing started on time, and both verification offices were delivered and entered service on schedule. The contingency interval proved invaluable in the case of the Fort White system, permitting the resolution of the numerous minor problems which inevitably accompany the first field installation of a new product. A week before the planned Fort White in-service date, all potentially service-affecting problems had been identified and solutions developed. For the few instances where the final solution could not be applied immediately, temporary back-up procedures were established to prevent loss of service if the problem should occur.

Verification planning

Northern Telecom designated the period October 1977 to April 1978 as a verification period for DMS-10. This period covered the first six months of in-service operation for the Fort White office and the first three months for Wakefield. The objective of the verification trial was to evaluate the ability of the new product to meet its predicted performance levels in a normal operating company environment. The following details refer specifically to the Fort White office; however, procedures for the Wakefield office were very similar, except for the shorter trial duration.

Fort White is an unattended office, administered and monitored remotely from the North Florida Telephone toll centre in Live Oak, some 50 km distant. Prior to the trial, North Florida Telephone personnel attended the initial series of DMS-10 training courses offered by Northern Telecom to all DMS-10 customers. During the trial, these personnel administered and maintained the office in a normal manner. System documentation provided to North Florida Telephone for the trial consisted of regular NTPs (Northern Telecom practices), as provided to all DMS-10 customers.

Reporting procedures were set up with the operating company through which BNR received copies of all Fort White customer reports, and of all DMS-10 teletypewriter printouts. In addition, for each problem identified during the operation of DMS-10, whether arising from a customer trouble report, or from a hardware failure, software error or documentation error, the operating company craftsperson prepared a field failure report which was sent to BNR. By analysis of these data, BNR engineers were able to monitor key performance parameters of the system and to detect and correct any hardware and software design problems. Resulting changes to the system were first tested on the DMS-10 captive office at BNR, and then applied to the Fort White system.

Results

On 17 October 1977, with the agreement of North Florida Telephone management, it was decided to attempt a trial cutover of Fort White, with provision to cut back immediately to the old switch in the event of trouble. The cutover commenced shortly after 10 pm on the evening of the 17th. Within fifteen minutes the first DMS-10 was in full service, five days ahead of the schedule established some 20 months earlier[3]. The operation was so successful that it was not deemed necessary to cut back to the old switch. A two week period of intensive on-site monitoring by BNR engineering personnel followed, after which the system was proclaimed 'sane' and healthy, and the BNR engineers returned to Ottawa. The office was provided with dial-up teletypewriter access, permitting remote monitoring from BNR in the event of problems, and a member of the Northern Telecom installation team remained on standby for a further six weeks in case immediate on-site assistance should be required.

Table 1

Event	Date	Time from start date
Project start	January 1976	0 months
Start manufacture	January 1977	12 months
First system delivery	July 1977	18 months
First system in service	October 1977	21 months
Second system delivery	October 1977	21 months
Second system in service	February 1978	25 months

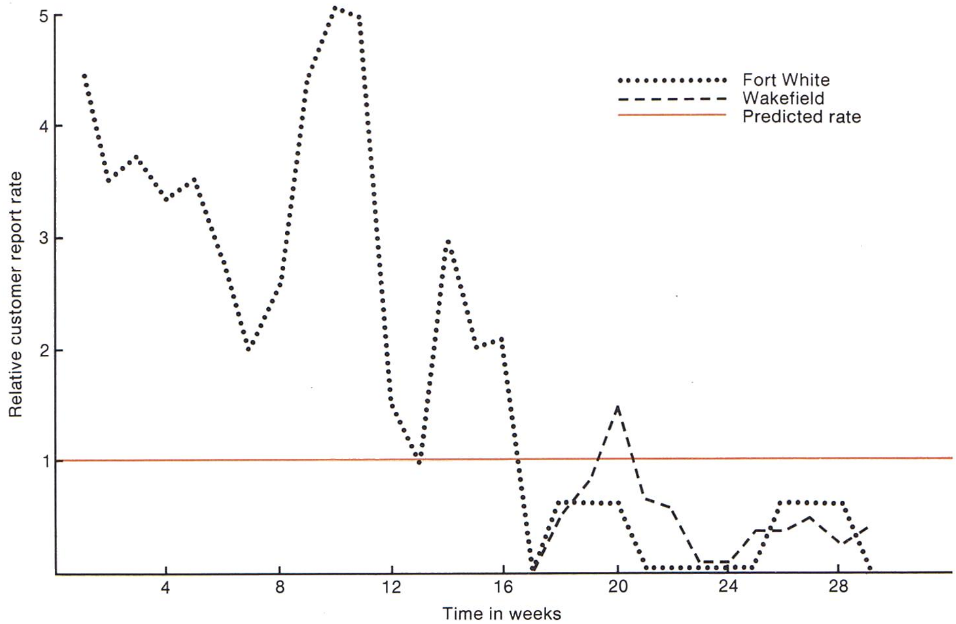

Figure 2. The customer report rate for DMS-10 related items is shown. The report rate is measured relative to a normalized prediction which includes an allowance for early-life performance derived from actual results from previous Northern Telecom products. This graph shows how the DMS-10's performance improved to the predicted level well within the planned verification period. The elimination of the trials adversely affected the performance of the Fort White office for some 16 weeks following in-service, after which it met and maintained its expected service performance levels. The Wakefield office — which was placed in service 16 weeks after Fort White — met performance expectations through almost the entire verification period.

Figure 2 shows the customer report rate of the two offices throughout the trial period. As the figure shows, the performance of the Fort White office reached the predicted level well within the planned verification period. The Wakefield office met performance expectations through almost the entire verification period. Other performance parameters measured during the trial period, including hardware failure rate, software and procedural (ie, human) error rates, transient call store initializations and system reloads, showed similar results to that of Figure 2. During the final two months of the trial period, both offices consistently exceeded their expected performance levels.

One significant success of the Fort White verification trial was the resolution of a design problem which caused the system, under certain conditions of ac electrical power fluctuation, to initiate an automatic reload of program and office data from the backup tape into the system memory. This problem was identified during Fort White installation testing, but defied all attempts at simulation in either the BNR or NTI captive offices. Evaluation of system output messages over the first three months of Fort White operation, during which time the problem recurred on three occasions, led to diagnosis of the probable cause, and its subsequent elimination in January 1978 by application of a simple hardware design change. No other automatic reloads of the system occurred during the trial.

Both verification trials met the primary objective of demonstrating the ability of DMS-10 to meet its predicted performance levels in a normal operating company environment. In addition, the trials have provided large amounts of operating data to aid in further refinement of the design, and have demonstrated the viability of the methods described in this article for reducing the development interval on this project.

Looking ahead

By the end of the verification trial period in April 1978, four more offices had entered service in addition to Fort White and Wakefield, and all six were providing excellent results. A further four systems were in various stages of on-site installation, and new systems were entering the test and burn-in chamber in NTI Creedmoor at a rate of close to one per week. With the basic product thus established, the emphasis of the BNR program is moving to the evolution and enhancement of the system, including the addition of the advanced features referred to earlier. Most of these features were under active development even before the Fort White office went into service and a program of continuing additions to the product's capability into the early 1980s is moving ahead rapidly.

The development of new features, which either offer new subscriber services (and thus new revenue opportunities to the operating company), or permit reductions in capital or operating expense, is only one aspect of the ongoing DMS-10 program in BNR. Of equal importance is the continuing evaluation of new technology opportunities. The current rate of evolution in the digital electronics field is such that several generations of technology will come and go during the life of a digital central office, each offering new possibilities for improved performance and lower costs. This is a radical departure from the situation in the electromechanical switching era, when the same technology applied throughout the operational life of a typical office. In this new environment, the products which will survive in the long term will be those which can most effectively apply the evolving technologies not only to new offices, but also to the upgrade of existing installations.

There are two keys to success in this endeavour, both of which are emphasized in the DMS-10 program. The first is the modularity of the system design. True modularity goes much deeper than the simple use of plug-in circuit cards and connectorized shelves and bays. It involves meticulous attention to the partitioning of system functions between and within the hardware and software elements of the system, such that software functions are independent of each other and of the hardware technology within which they operate. Hardware functions must be similarly partitioned, with technology-independent interfaces. Only through such attention to detail in the basic system design is it possible to selectively upgrade parts of the total system without destroying the system integrity.

The second key is the anticipation of future technology trends to permit optimization of the system configuration to accommodate them. To this end, exploratory studies are currently in progress on the application to DMS-10 of technologies which will not achieve commercial viability until the mid-1980s. These long-range activities will ensure that, though future DMS-10s will be much different from the DMS-10 of today, the advances embodied in later systems will be available to earlier systems to the maximum extent possible.

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*Trademark of Northern Telecom Limited

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He became a manager in the aerospace development group in 1965, and participated in the initial space segment studies of the Canadian domestic satellite system, later becoming Northern Telecom project manager for the Telesat satellite communications repeater and antenna subsystem definition study contracts. From 1970 to 1972, he was project manager for the highly successful SG-1 (Pulse) electronic PABX, followed by two years in Northern Telecom corporate marketing, and a year with NT (Europe) NV in Amsterdam as technical director. He returned from Europe in January 1976 to become project manager for DMS-10. His spare time interests are skiing, flying and carpentry.

Sophisticated features for the smaller switching centre

Las Lovas

DMS-10 offers a variety of sophisticated, yet economical operational and service features for the small switching office.

DMS*-10 is a digital switching machine suited for use in a small local switching centre with a capacity ranging from 300 to 6000 lines. Previous articles have stated that the prime objective of DMS-10 is to provide dependable service, with emphasis on economical, unattended operation in a variety of suburban and rural locations, sometimes far from urban centres. DMS-10 achieves this objective with a carefully chosen combination of principle and practice. It uses high quality components and advanced hardware and software technologies. It is equipped with automatic fault detection and correction capabilities, as well as remote maintenance and administrative features, that allow the machine to supply data about its operations and to respond to requests for information about its general health from a monitoring point in a 'remote' centre any distance away. The following articles in this issue describe these features more fully. However, it will be helpful to describe them broadly here, see Figure 1, before looking at the engineering details.

Choices for the subscriber

A prime requirement for DMS-10 was that it should offer a comprehensive range of features, so that subscribers in smaller communities or rural housing developments could enjoy the same degree of choice as their counterparts in larger settlements. Service features are, after all, the primary elements of telephone service as seen by the subscriber, whether private resident, government agency or business enterprise. An idea of the scope of these features can be gained from the partial list in Figure 2.

The methods of providing these features vary from one switching system to another, but the features themselves have become standardized throughout the telephone industry. This uniformity is, of course, the key to the compatible operation of thousands of switching offices over a large geographical area such as the North American continent.

The large group of service features is subdivided into line, originating, and terminating features. The line features offer a variety of types of line to choose from: typically, individual and party lines for the residential customers, and individual, private branch exchange and message metered lines for the business subscriber. Coin lines, better known as public telephones, are usually provided by the telephone company for public use in shopping centres, hotels, airports, etc.

Depending on the type of line provided, the subscriber has a wide choice of originating and terminating features. These include the choice between rotary dial or the pushbutton type telephone, or a telephone with no dial at all (denied originating). The so-called custom calling services, such as speed calling and three-way calling, are increasingly popular.

With speed calling, the subscriber can make a call to any one of up to 30 predetermined destinations by simply dialling one or two digits instead of the usual 7 or 10 digits. The three-way calling feature is used to set up a common connection to two destinations, allowing three subscribers at different places to confer. Custom calling services also include two terminating features, namely call waiting and call forwarding. When a subscriber equipped with the call waiting feature is engaged in a telephone conversation the DMS-10 system will alert him of any other incoming call. He may even answer the new call and switch back and forth between the two conversations in complete privacy. The call forwarding feature is useful in minimizing lost calls when away from home or office. A subscriber who expects to be temporarily absent from his usual phone can instruct the DMS-10 to forward calls to a friend's house or to a branch office, for example, while he is away.

Another terminating feature widely used in the business community is directory number hunting. This allows business subscribers to have many telephone lines but to publish only one number in the telephone directory. When an incoming call to the published number finds that this line is busy, the hunting feature re-directs the call to the other lines in a predetermined order until an idle line is found.

Some of the service features shown in Figure 2 are not as apparent to the average subscriber as those described above. They are, however, significant in that they determine the selection of required trunk routes (translation and routing) and automatically record billing information (line charging). Features listed under office signalling and supervision, together with those designated by the heading 'digital interfaces', provide versatility and make the DMS-10 compatible with the wide variety of existing switching systems and future digital switches. For further details on how these features are implemented the reader is referred to the next two articles.

Choices for the operating company

The DMS-10 operating features enable a telephone company to monitor and evaluate the switching system's performance, to rearrange and expand the hardware as necessary to cater for growth in service demand, to change subscriber and office

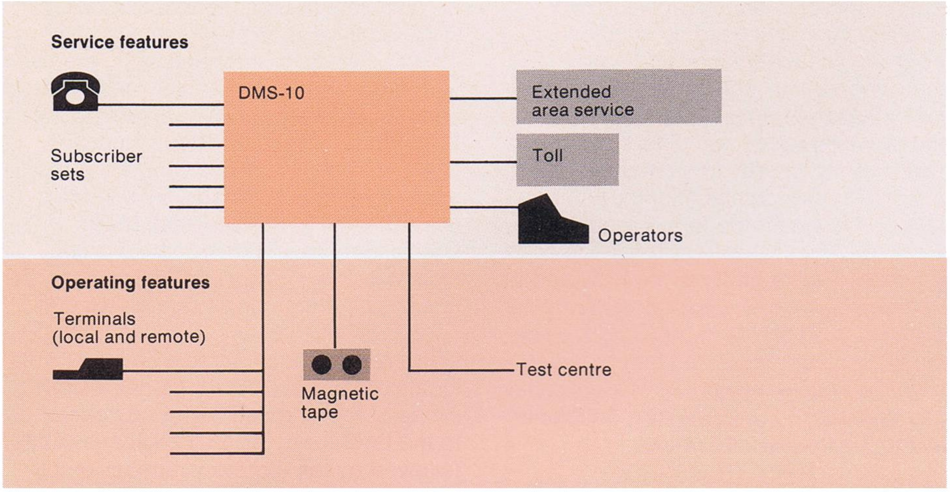


Figure 1. *A software-controlled digital machine for a small switching centre, DMS-10 offers a wide range of service features for subscribers and an equally comprehensive set of operating features for the telephone company. This block schematic sets the scene for the discussion of these features in this article. Service features provide telephone service to the subscribers by linking them to other switching centres (and their subscribers), to telephone operators and to the toll centres of the long distance network. Operating features relate to the operation and maintenance of the switching centre itself.*

Service features

Types of line
Individual
Two-party
Four-party
Eight-party
Coin, prepay, coin first
Coin prepay, dial tone first
Coin semi-postpay
Private branch exchange
TWX
Loop start
Ground start

Terminating line features
Free number terminating
Denied terminating
Inward wide area telephone service (Inwats)
Directory number hunting
Call waiting
Call forwarding

Originating line features
Rotary dial
Digitone
Flat rate
Message rate
911 emergency service
Denied originating
Toll denied
Toll diversion (private branch exchange only)
Outward wide area telephone service (Outwats)
Hotel — motel private branch exchange
Revertive calling
Speed calling
Three-way calling
Manual line
Automatic line

Digital interfaces

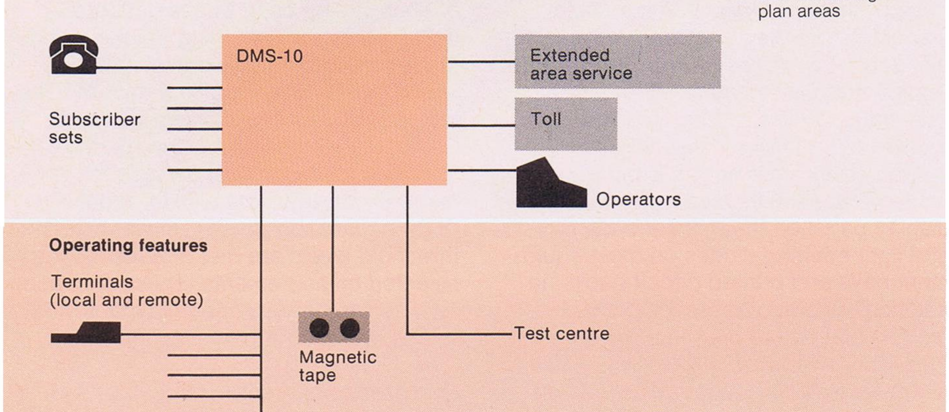
Types of ringing
Ac-dc single-frequency ringing (bridged or divided)
Fully selective frequency ringing
4-party, bridged or divided
8-party, divided
Continuous ringing (105 volt)
Coded ringing (10-party)

Interoffice signalling and supervision
Outpulse multifrequency and dial pulse
Detect delay dial, wink start, immediate dial
Receive multifrequency and dial pulse
Send delay dial, wink start, immediate dial

Line charging
Automatic number identification (1, 2-party)
Circle digit identification
Operator number identification (4-, 8-, 10-party)
Direct distance dialling through centralized automatic message accounting (CAMA), and operator positions such as TSPS, and the Northern Telecom TOPS
Local automatic message accounting

Miscellaneous features
Fire alarm service
Line lockout (100%)
Suspended service
Alarm sending and checking
Malicious call tracing

Translation and routing
Local class 5
North American numbering plan format
Local tandem
Operator 0−, 0+, 1+
Service codes (N11, 11N)
International dialling
Digit deletion, substitution, prefixing
Alternate routing
Multiple rate centres, extended area service region and North American numbering plan areas



Maintenance overlay programs
Network and signalling
Network repair
Control equipment
Service circuit
Peripheral equipment
Input-output device
Conference circuit

Data modification overlay programs
Configuration record
Loops, shelves, packs
Routes and destinations
Home numbering plan area, rate centres, local calling area
Thousands groups
Prefix, address, screening translators
Directory number hunt group
Trunk group
Trunks

Figure 2. *Service features, many of which are familiar to subscribers, are emphasized in the upper part of this diagram. The first three columns denote the different types of line, and originating and terminating features that the DMS-10 can provide, while the other columns relate to the ways in which calls are signalled to other switching centres, and how billing information is recorded. The lower part of the diagram illustrates DMS-10's comprehensive range of operating features for the telephone company. These are implemented through overlay programs, which are loaded into memory from magnetic tape as required. The first set is concerned with maintenance of the switching machine, and the second with modifying the data that list all the subscriber lines, trunks, type of service for each subscriber, and so forth.*

data to keep pace with subscribers, and to perform maintenance functions (tests and repairs) on the switching equipment. Consequently, several broad categories of operating features are provided: operational measurements, data modification, diagnostic programs, maintenance and alarm facilities, see Figure 2. Most of these features are implemented through the man-machine interface, often called the input-output system.

This input-output system is a vital part of DMS-10, providing effective communication between telephone company personnel and control equipment. It employs two basic types of equipment: magnetic tapes and terminals. The terminals can be installed either at the DMS-10 site, or at the 'remote' centre, allowing for the remote monitoring required in many small community dial offices. New devices can be added as required: (for instance, the facility has been developed to add on a nine-track standard computer tape for billing long-distance calls). The entire DMS-10 system is secure, in that terminal access is controlled by passwords, and selected messages can be restricted to certain channels. Such controlled flexibility greatly enhances the capabilities of the system for remote administration and maintenance.

A crucial part of the input-output system is the primary cartridge tape drive (one of those just mentioned), which contains a complete duplicate of all the office data and programs on a backup tape. In the event of a memory failure affecting the program store or data store, the programs and data are automatically reloaded from this tape. The primary tape also contains programs called overlays, which are executed infrequently and which would otherwise occupy expensive resident memory locations. Overlay programs, which contain the bulk of the data modification and fault analysis software, can be loaded into the main memory manually or automatically as they are required.

Keeping the machine running smoothly

Because the telephone company needs great reliability in a switching machine for community dial offices, the BNR designers gave considerable thought to the most cost-effective way of achieving this aim in DMS-10. The maintenance features are central to this aim. The DMS-10 maintenance scheme employs equipment redundancy (the provision of standby units for critical equipment), fault diagnosis through resident and overlay programs, and alarm reporting, complemented by an interactive maintenance capability.

Equipment redundancy provides two benefits. First, it is used by diagnostic programs to locate faulty equipment by analyzing various combinations of redundant equipment units. In other words, if one combination of equipment modules responds incorrectly to a diagnostic test, then alternative combinations using duplicate or redundant modules are tested in succession until a correct response is obtained. Thus a fault can be localized to a particular module. Second, automatic recovery procedures can be used, since the system can switch to standby equipment if it finds a faulty unit. Manual repair may be deferred until the next scheduled visit to the unattended office.

In order to keep a close check on the health of the switch, two types of diagnostic programs — resident and nonresident (overlay) — are provided. The resident programs are used for fault detection and isolation, while the overlay programs contain full fault analysis procedures and extended diagnostics. Any failures detected by these programs are reported via output messages, which may be accompanied by alarms, depending on the severity of the problem found. The various output messages become the starting points for trouble-clearing procedures, as prescribed in the procedure-oriented practices, a set of detailed manuals that set out the steps to be followed to determine the cause of each output message. These procedures are based mainly on tracking down and replacing faulty printed circuit packs, so that field maintenance is kept as simple and speedy as possible.

Operating personnel are warned of equipment problems by visual and audible alarms so that they may take quick remedial action to restore normal operation. Alarms are classed as minor or major, depending on the service degradation caused by the failure. Visual indicators can be easily seen on the front of most equipment, such as an alarm status display panel on the maintenance bay, and light emitting diodes on most equipment bays and printed circuit packs. In addition, all output messages accompanied by alarms are preceded by one (minor) or two (major) asterisks. Visual alarms are always accompanied by an audible signal such as a bell or tone. In addition to these local alarms, DMS-10 can be set up to send alarm indications to the remote centre, and to have alarm messages printed on terminals in that centre.

To complete the maintenance package, DMS-10 is equipped with test lines and special circuits to interface with standard test gear, such as the Noller remote test unit, the No 3 local test cabinet and the No 14 local test desk. The test lines, which can be used for a variety of functions, such as noise and one-way transmission testing, are associated with special directory numbers that can be dialled locally or from another office. (Two test lines can be used in a loop-around configuration to check two-way transmission.) Maintenance personnel in a remote location can also test the transmission properties of a subscriber loop connected to the DMS-10 by dialling an access code, followed by the directory number of the loop. The loop can then be tested with the aid of test gear at the remote location.

Measuring machine performance

An important part of the telephone company's job is to monitor and evaluate switching machine performance. DMS-10 helps this analysis by gathering the necessary operational measurements, and printing them on local or remote teletypewriters, see Figure 3. Operational measurements consist of three basic types of data: peg counts, block or overflow counts and usage measurements. Peg counts are the number of times a particular event (such as a subscriber making a call that requires an outgoing trunk) is observed to take place. Block or overflow counts are the number of times a particular event is prevented from taking place due to an error condition, or the shortage of resources, respectively. Usage measurements, on the other hand, indicate the total time associated with a particular event (for example, the time of an outgoing call). These data are collected by the switching machine and printed according to a preset schedule which can be changed by a data modification procedure to suit requirements. Data can also be obtained on demand from designated output devices, either manually or automatically. In addition, DMS-10 will alert personnel when certain threshold levels are met or exceeded on selected measurements. These exception reports can be very useful in identifying trends in machine performance.

One area of particular interest to the telephone company is the pattern of distribution of telephone traffic throughout the network, over the various trunk groups and among different types of calls. This information can be obtained from the DMS-10 traffic measurements. Originating and incoming service measurements indicate the number of permanent signal,

OPMØØ1 TRAF THUR 11:ØØ:ØØ HRHR	PEG	BLK	USE	
ORTM	ØØØ32	ØØØØØ	ØØØ65	Calls originating and terminating in the DMS-10 area
ORDG	ØØØ56	ØØØØØ	ØØ146	Calls originating in the DMS-10 area for other locations
ORNC	ØØØØ3			Calls originating in the DMS-10 area and not completed
RVRT	ØØØØ2		ØØØØ1	Revertive calls — calls made to other subscribers on the same party line
INTM	ØØØ49	ØØØØØ	ØØØ67	Incoming calls that terminate in the DMS-10 area
INDG	ØØØØØ	ØØØØØ	ØØØØØ	Incoming calls that are routed to another switching machine
INNC	ØØØØØ			Incoming calls that are not completed
RCVR	ØØØ43	ØØØØØ		Number of times DMS-10 receivers are connected to handle incoming digits
SVCE	ØØ329	ØØØØØ		Number of times DMS-10 service circuits are connected

Figure 3. *Traffic measurements show the peg, block and usage data for the entire office in categories of originating, terminating, incoming, outgoing and revertive call types. This is a comprehensive account of the total call processing load carried by the switching machine in a given period.*

####		
#	ovly dn	Load overlay program 'dn' to modify office data
REQ	new	Request: add new data
TYP	stn	Type: information about a subscriber's station apparatus
DN	292 1101	Directory number: 292 1101
TN	1 2 5 4	Terminal information: the subscriber's line is to be found on bay 1, shelf 2, card 5, circuit 4
OPT	1fr	Option: implement 1fr — single party, flat rate service
REQ	ado	Request: add an option
TYP	stn	Type: option is to modify data for the subscriber's station equipment
DN	292 1101	Directory number: 292 1101
OPT	spb 596 5184	Option: implement special billing so calls are charged to 596 5184
REQ	del stn 292 1101	Request: remove station 292 1101 from the data — ie, remove service to that number
REQ	end	Request: end input session
#		

Figure 4. *This printout from DMS-10 shows how authorized telephone company personnel can readily change the data about subscriber services stored in the machine. At the top, the instruction is to add a new subscriber with the directory number 292 1101. Centre, the order adds a feature to this number that allows the subscriber to be billed at another number, 596 5184. Bottom, the order is to terminate service to the number 292 1101. Lower case letters (colour) denote the telephone personnel input, while the machine's responses are in capitals.*

####		
#	ovly ntwk	Load overlay program 'ntwk' to alter the hardware configuration of DMS-10
REQ	new	Request: add new data
TYP	pack	Type: data involving a circuit pack
PACK	1 2 6	Location of pack: the new pack is to be located on bay 1, shelf 2, as card 6
PKTP	2t00	Type of pack: 2T00, serving a single party line
REQ	end	Request: end input session
#		

Figure 5. *Data modification orders are also employed to handle changes in the switching machine's equipment. Here, a telephone company employee instructs the machine to modify its data to recognize a line circuit pack that has been added to serve a new subscriber line.*

####		
#	ovly hunt	Load overlay program 'hunt' to retrieve information about a hunt group
REQ	que	Request: use the query function to retrieve information
TYP	dnh	Type: information about directory number hunt group 2
HTGP	2	
TYP	DNH	The DMS-10 confirms that information is being requested about hunt group 2; then it produces the information that the numbers in that group are searched sequentially, and that if all the numbers are busy the caller is routed to overflow (route 6). It then lists the first directory number in the group, and the others in the order in which they are searched.
HTGP	2	
SRCH	SEQ	
OVFL	ROUT	
OVRT	6	
DN	292 2121	
	292 2122	
	292 2123	
	292 2124	
REQ	end	Request: end input session
#		

Figure 6. *The DMS-10 query command can be used to retrieve information about a wide variety of features or data in the machine. Here, it is employed to produce information on a directory number hunt group used by a business subscriber.*

partial dial time out, abandon and false start conditions encountered during the given period. These measurements also indicate the percentage of incoming and originating calls that had to wait for initial service for three seconds or longer (receiver and dial tone delay tests). Another area of interest is the performance of the switching machine, in particular, how often and for how long various items of equipment are used or are out of service. This information can be readily obtained from DMS-10 plant measurements.

Finally, another set of measurements indicates the demand on various software resources, such as call registers, device registers, message buffers and network message queues. Analysis of DMS-10 operational measurements can reveal trends that point to the need for rearrangement of equipment or software resources. Well timed reassignments and planned extensions ensure good service while eliminating the possibility of costly over-engineering.

Keeping up with subscribers

The population served by a telephone switching centre is constantly changing. Only a small portion of the changes are caused by long range trends, such as increasing urbanization of the population. More significant are the rearrangements caused by subscriber movement. In some offices as many as 20 percent of the subscribers change their telephone service in a particularly active month. They buy new service features, change their directory number, or simply move out of the area.

One of the reasons for constructing the DMS-10 software architecture in the way described in the article on p 309 is to handle this constant change activity without having to make extensive software changes. Thus, the DMS-10 software is split into two parts. One comprises the generic programs that provide the telephony call processing logic which seldom need changing. The other consists of office data that reflect the office characteristics in minute detail. Changes to the office data portion are made easily, and without altering the call processing programs, by means of a data modification package, which contains several overlay programs, as shown in Figure 2. The programs are listed in the sequence in which they are executed when initially generating the entire office data. Overlay programs can be executed in either free-running or conversational modes: some in both. Once loaded into memory, free-running overlay programs are executed without further manual intervention. At the end of execution a diagnostic message is printed out and is interpreted by means of a trouble clearing procedure. Interactive overlay programs operate in a conversational mode and can be executed step-by-step under the control of commands input by operating personnel.

Once the office is operational, any segment of the data can be modified by loading the appropriate overlay program and then entering a few commands. Figure 4 shows examples of data modification orders that would add a new subscriber, change his options (at a later date) and finally terminate his service (when he moves away).

A new subscriber can be added to the office data only if there is an available terminal number associated with an unassigned line circuit pack. If this is not the case, then an appropriate circuit pack is added first and defined in the office data, as shown in Figure 5.

The data modification overlays also have a data retrieval capability that can be invoked by the query command. Figure 6 illustrates how this command can be used to list the pertinent characteristics of a directory number hunt group belonging to a business subscriber.

The few examples given here indicate the power of the data modification overlays, and more important, the simplicity of the input commands, which helps to eliminate human error. Indeed, these programs can cater to personnel of various levels of experience by communicating with them in the so-called interactive mode, as in the first two requests in Figure 4. The third request, deleting a station, is the way an experienced person would enter the command in one line, compared to an inexperienced person using the interactive mode, and relying on 'prompts' from the machine. Both methods, of course, result in the same information being recorded in the office data.

This overview of service and operating features demonstrates that DMS-10 meets both subscriber requirements and operating company needs. On one hand, subscribers expect reliable, high quality service, and on the other hand telephone companies seek economy, convenient operation and ease of maintenance. The following articles will describe the engineering details, the technology and innovative ideas that enable the DMS-10 to realize the objectives set for it.

*DMS is a trademark of Northern Telecom Limited

Las Lovas, a native of Hungary, obtained his BASc in electrical engineering in 1962, and his masters in the same field in 1964, both from the University of British Columbia. On graduating, he joined BNR and was involved in exploratory development and then hardware development of the SP-1 electronic switching system. In 1969, he moved into software development for SP-1, specifically the design of a data modification package and the call processing software for custom calling and centrex features. He was made manager of centrex generic development for SP-1 in 1974, and manager, SP-1 systems verification, later that year. He was appointed to his current position as manager, DMS-10 field support and system verification, in 1976. Las is a member of the Association of Professional Engineers of Ontario.

DMS-10 system organization

Les Rushing
Gino Totti

A novel approach to system architecture, combined with modular components, has produced a flexible and economic system.

A well thought out system architecture is one of the most important aspects of DMS-10 design. It needs to be optimum both for hardware and software as well as meet a demanding economic challenge—a digital switching system economical for small to medium size offices where the equipment is often unattended. It is vital to hold down both capital costs and operating expense for the small office, and at the same time, allow smooth and economical growth to the maximum capacity.

These problems are solved by designing an efficient and flexible system architecture, by employing modular construction in all the equipment, and by using state-of-the-art commercial and custom electronic components. The result is a very compact digital system which is flexible in terms of operational, maintenance and administrative features. Compared to conventional offices, it is substantially smaller, easier to manufacture and requires less time to install, while providing unattended operation with remote administration and maintenance.

Modular design is employed throughout; every printed circuit pack, shelf and frame has connectors for easy and rapid additions or changes. Unique circuit capabilities and significant cost reductions accrue from Bell-Northern Research's in-house design and packaging experience for generating custom LSI (large-scale-integrated) circuits, thick film hybrid integrated circuits, staked-pin printed circuit backplanes, and associated connectors. These capabilities were built up over the years through the development of similar items for other switching systems which are now well established Northern Telecom products. The experience gained from the development of other common technology switching systems has proven invaluable not only in the case of advanced circuits but also in system hardware and software development, as well as manufacturing methods.

In the hardware area, some very important elements of proven performance were readily available: for instance, a fast, special purpose telephony processor specifically designed to handle up to 6000 lines, and a single channel pulse-code modulation (PCM) encoder-decoder (codec). Also available were MOS memory packs and suitable input-output devices.

Advantages of digital technology
Switching and controlling digital information can be done with relatively straightforward, low-cost logic circuits. Techniques such as the use of time-division, multiplexed links allow the system network to be small and flexible. Speech is converted to digital form in the peripheral equipment so that all operations in the network are digital. Other functions normally carried out separately by analog means can therefore be performed digitally in the network and can share circuits with speech. Functions performed in the network, beside switching speech information, consist of scanning, signal distribution, tone generation, dial pulse (DP) and multifrequency (MF) signalling, conference calling, and test functions. Since digital paths can be easily monitored and divided into sections, fault detection and diagnosis are simple and economical.

Digital technology lends itself to a modular format. Thus, with increasing demand for more subscriber lines, the system can grow simply by adding modular plug-in units. While network, memory and peripheral equipment can grow with the line size, the processor's capacity is sufficient to cover the entire line range of the DMS-10.

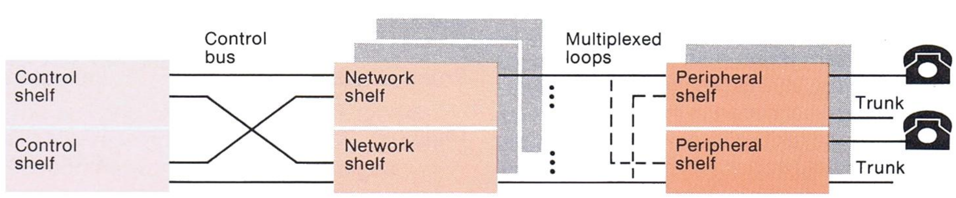


Figure 1. The system functions are provided in three shelf types: control, network and peripheral. For reliability, the control shelf is duplicated and network shelves are always provided in pairs. The network can grow from two to six shelves by adding more pairs of network shelves. A peripheral shelf can be switched and controlled by either network shelf.

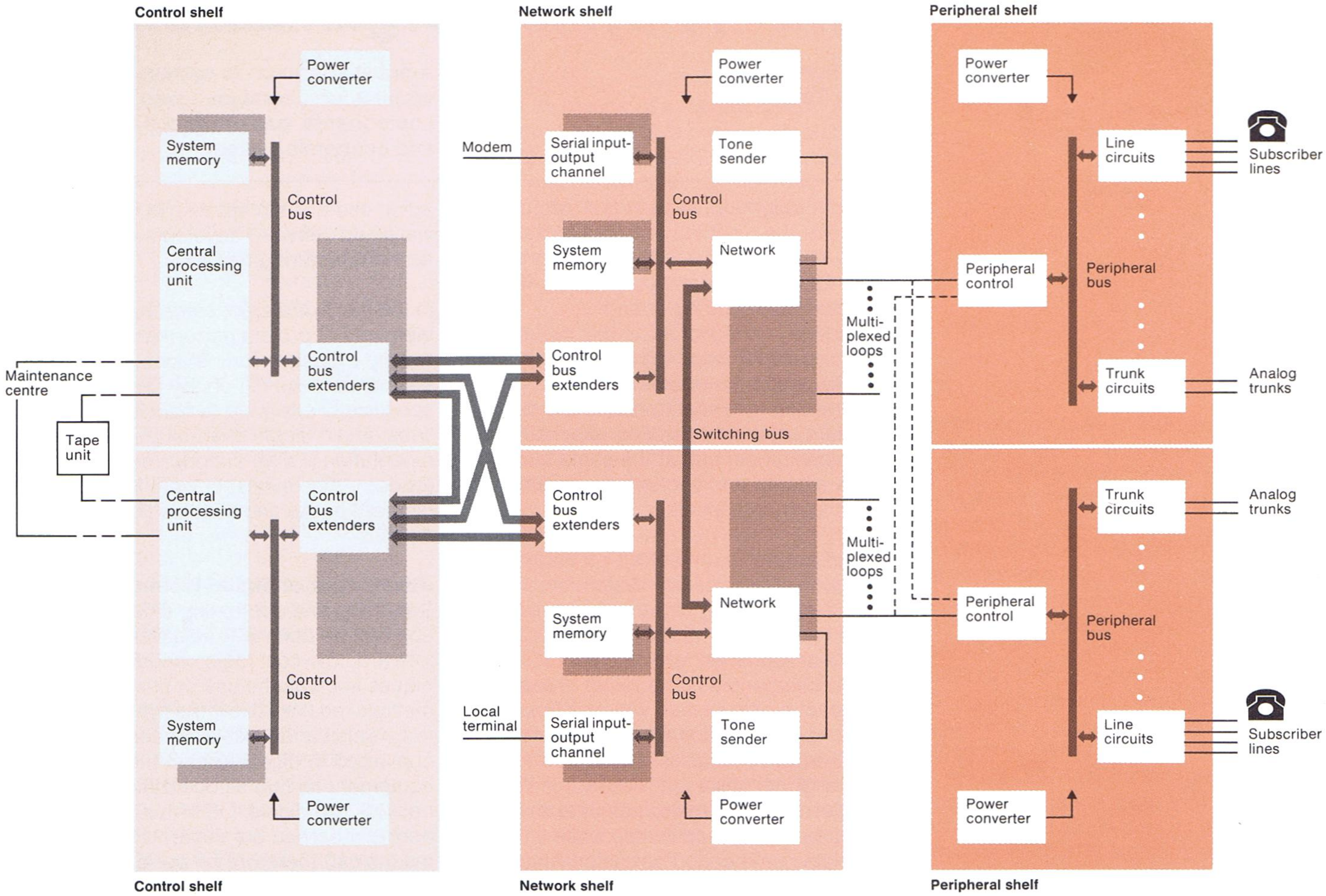


Figure 2. This block diagram gives an overview of the system architecture and of the functions provided within each shelf type. Each processor in the duplicated control shelves communicates with system memory, network and input-output devices via a common control bus which extends across the backplanes of both control and network shelves. The system memory is subdivided into blocks and is distributed over both control and network shelves. One memory block is designated as standby. Network shelves interface with peripheral shelves via multiplexed loops, and carry both control and speech information. Two network shelves, constituting one group, can switch up to 32 multiplexed loops. A pair of multiplexed loops can be connected to up to four peripheral shelves.

The system consists of control, network and peripheral shelves, see Figure 1. It is designed to be very reliable and fault tolerant, providing uninterrupted service in an unattended office. In some areas of the system, this high reliability is ensured by providing redundancy or duplication of equipment which is critical to the operation. This is especially true in the common equipment where failures affect a large number of lines. However, some equipment is expensive, making duplication prohibitive. Therefore, some functions do not have dedicated shelves, but share shelves with other equipment. For example, the system memory and input-output device interfaces, which would be normally concentrated in the control section, are distributed among both control and network shelves. This arrangement is made possible by using a common bus to link the processor

Table 1 Optional peripheral equipment circuit packs — analog shelf

Circuit pack	Function
Single-party line circuits	Signalling and transmission interface for 4 single-party lines
Multi-party line circuits	Signalling and transmission interface for 2 to 4 multi-party lines with provision for divided and/or frequency selective ringing and automatic number identification
Public coin box line circuits	Signalling and transmission interface for two lines serving public coin-operated telephones
Trunk circuits	Includes several types
Digitone* receiver	Decoding of pushbutton dial signals received from subscriber telephones for line connection setup
Multi-frequency receiver	Decoding of inter-office signals received from connecting offices for trunk connection setup
Line and trunk test circuit	Automatic testing of line and trunk circuits as part of the automatic maintenance routines

memory, network and input-output devices. Bus extender packs and cables interconnect the two control shelves and extend the same bus to part of the network shelf backplanes. This arrangement allows memory and input-output device control packs to be distributed over both control and network shelves. An overview of the system architecture is shown in Figure 2.

Control equipment

The system's processing power is in the control equipment. It has two main elements: the central processing unit (CPU), which directs the operation of lower level subsystems in the hierarchy, like network and peripheral equipment, and the system memory, which stores the operating instructions (programs), office information and customer data. Other elements include a magnetic tape unit to load programs and data, and to serve as a 'backup' for system memory; direct serial links to the alarm system and to maintenance terminals; and a network clock generation circuit.

For reliability, the CPU is fully duplicated, with one operating in the active mode, and the other on standby, ready to take over call processing immediately should any serious failure occur in the other. A change-over control pack monitors the state of the two processors. Each processor communicates with other control shelf elements via the common high speed bus which extends over part of the backplanes of the network shelves.

The system memory is subdivided into blocks of 64 000 words each. One block, mounted in a network shelf, is on standby and can be switched in to replace any other faulty memory block mounted on other shelves. Standby memory can be loaded from the backup tape unit if necessary and fault recovery is automatic. In fact, enough redundancy is provided for the system to be able to reconfigure itself automatically following fault detection. Self checking capability is built into both the hardware and software. Bootstrap programs are stored in non-volatile read-only-memory (ROM), so that even in the event of a drastic failure in the control equipment the system can build itself up to a working configuration. Following fault detection and recovery, fault isolation is performed by diagnostic programs which either reside in memory or on tape. These are called in automatically to diagnose the fault and the result is displayed on the maintenance terminal.

Network equipment

Network shelf circuits provide the transmission links required between peripheral equipment shelves, and the supervisory links between control and peripheral equipment. Two network shelves, the

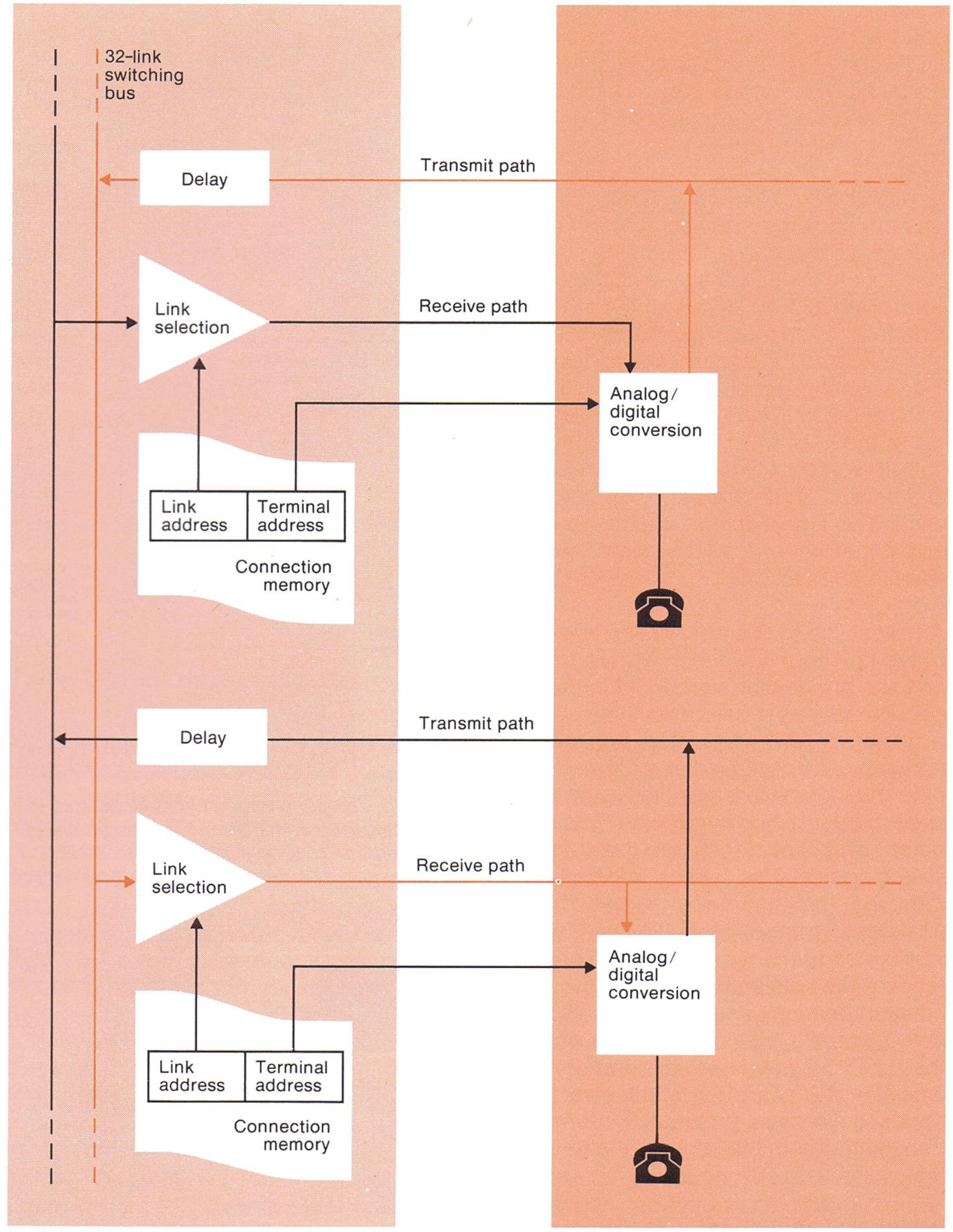


Figure 3. This diagram illustrates the speech path of a connection between two subscribers. The analog voice signals from a subscriber's telephone are converted to digital signals and passed to the network over a multiplexed loop. The network logic delays the speech data and switches them to the receiving multiplexed loop. A connection memory associated with the receiving loop controls both the switching and the analog to digital conversion logic.

minimum required, can switch up to 2500 lines, plus 330 trunks and service circuits. The digital network can grow from one to three groups (two shelves per group), thus providing a maximum of 7500 line terminations, plus 1000 trunks and service circuits.

The building blocks for network growth are the network circuit packs contained in each network shelf: two for digital service circuits, one for signalling, one for conferences, from one to seven for network switching, and two for intergroup switching.

The digital service circuit packs provide call progress tones, test tones, and outpulsing of dial pulse and multifrequency signals, as instructed by the CPU. The signalling packs perform the scanning, signal distribution, updating of speech connection memories, and the setting up of test connections for network maintenance programs. Each conference pack allows up to ten three-way conferences, or five six-way conferences, or any combination of the two. And finally, the intergroup switch packs and associated cables provide switching between network groups.

A network shelf interfaces with the control equipment using the common control bus and with the peripheral equipment using digital multiplex loops. Network circuit packs and shelves are paired for reliability, see Figure 2.

Two multiplexed loops, one on each network pack in a pair, can control up to four peripheral shelves. Each loop is prime on two shelves and is capable of controlling all four shelves if the other loop fails. Each multiplexed loop consists of five twisted pairs, carrying clock pulses, frame synchronization, terminal address, signalling and speech information into and out of the network. The data bit streams on the loop are transmitted at 2.048 Mb/s and consist of 32 time slots of eight bits each. Two time slots are used for control and signalling, and 30 time slots for speech connections.

A typical line to line connection is illustrated in Figure 3. Speech signals from one line are converted to PCM in the line circuit and multiplexed onto the loop to which that line is connected. Logic in the network pack controls the multiplexing onto the loop and delays the digital speech information by 16 time slots before retransmitting it onto the network switching bus. This speech information is retrieved from the bus by the network pack that controls the multiplexed loop connected to the receiving line. To recover the speech information, the connection memory of the receiving loop activates the link select logic and enables the receiving line during the appropriate time slot. A similar path is followed, in the opposite direction, for speech information transmitted from the second line to the first.

Peripheral equipment — the outside world interface

The peripheral equipment (PE) is the hardware that interfaces with the 'outside world'. These circuits provide the supervisory and transmission functions needed for the various types of links involved in using the total telecommunications network. In addition to communication interfaces, a number of service and maintenance circuits are provided in the peripheral equipment frames.

Analog equipment is provided in a 'universal' analog shelf in which various types of circuit packs may be mounted on an optional basis, see Table 1. Up to six shelves can be mounted in one PE frame. Cables, fitted with connectors, run between the shelf and the switching centre's main distributing frame, providing the essential connections between the PE packs and lines or trunks. A functional diagram of the shelf appears in Figure 4. Essential functions common to all line circuits are described in Table 2.

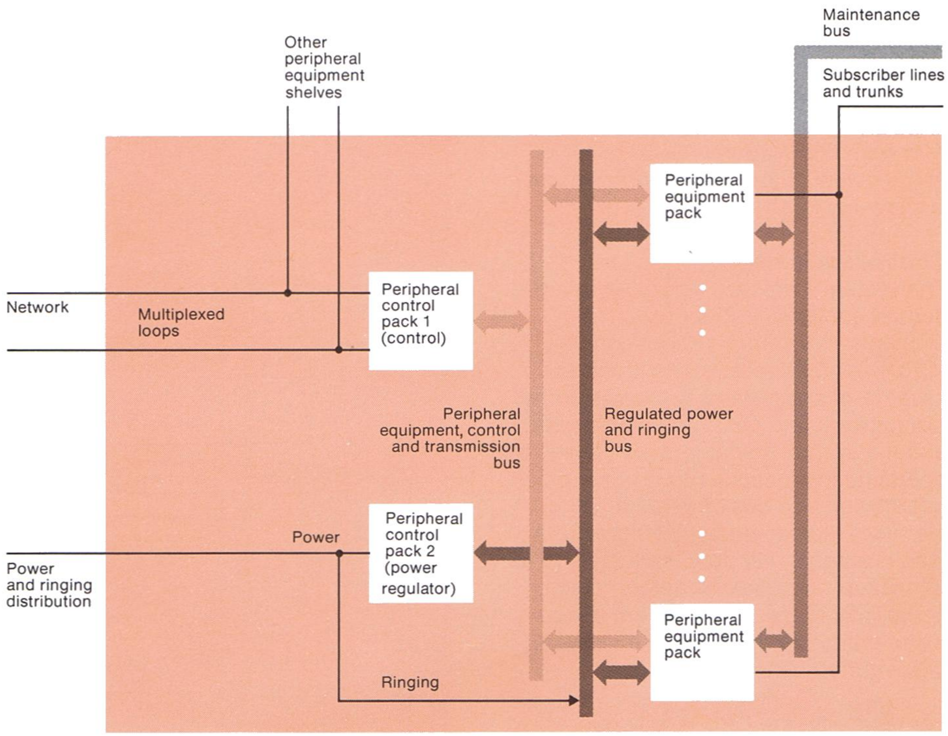


Figure 4. The peripheral equipment acts as the interface between the DMS-10 common equipment and the 'outside world'. Digital signals from the common equipment are connected to the peripheral equipment via the multiplexed loops of the network, whereas the analog signals come from the subscriber lines and trunk circuits.

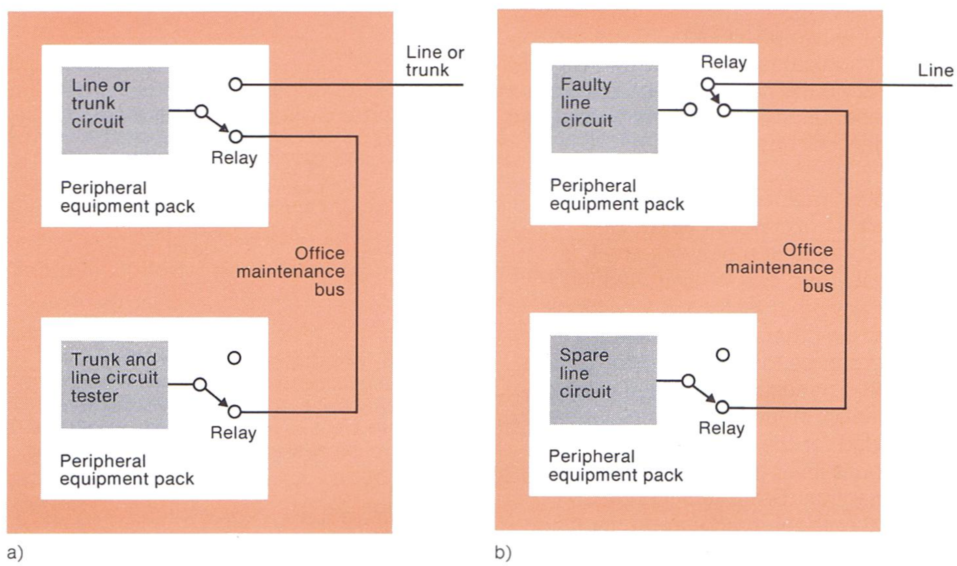


Figure 5. (a) Testing subscriber lines or trunk circuits is made easier with one of the peripheral equipment packs. Under software control, individual lines and circuits are accessed and tested via the office maintenance bus either automatically or manually. (b) If a faulty line circuit is detected, a standby unit can be switched in.

The transmission and signalling features of each line and trunk circuit are tested daily as part of the DMS-10's automatic maintenance routines. Routines can be performed under central control, or on demand by manual requests via a local or remote terminal, see Figure 5. Tests are applied by a circuit pack which has access to any line or trunk through a maintenance bus.

If a faulty line circuit is detected, a spare circuit can be switched in to the affected line, as shown in Figure 5b. For unattended offices, both detection and switching of the spare circuit can be performed automatically while the restorative action is reported to a remote maintenance centre. Maintenance personnel can therefore postpone a trip to the switching centre to replace the faulty circuit until a convenient time, as the spare circuit maintains service to the affected line.

The maintenance bus also provides access to lines for local or remote loop testing, and allows remote maintenance centres to make tests over special incoming test trunks. It can also be used for testing outgoing trunks with portable test equipment plugged into jacks located on the DMS-10 maintenance bay.

Because of the large numbers of line and trunk circuits in DMS-10, the components in these circuits — including the codec and associated filters, the line circuit control logic, and the loop interface — have a large influence on the cost and size of the switching machine. Thus considerable attention has been paid to the design and implementation of these circuits. The components used in the codecs are the same as those employed in the DMS-1 system[1], so DMS-10 benefits from the extensive cost reduction and development work done previously. The codecs use state-of-the-art components and a custom large-scale integrated (LSI) circuit designed at BNR.

Another BNR-designed custom circuit is represented by the control logic LSI which provides control functions as well as the interface to the PE control and transmission bus. It would require more than 50 standard small-scale and medium-scale integrated circuits to perform the functions of this single LSI circuit.

The loop interface provides voice transmission coupling between the codec and the subscriber loop. The key item here is the loop detection circuit which utilizes thick film microcircuit technology to provide line supervision; it provides a dc compensation current to the line transformer to neutralize the magnetic flux, thus allowing the use of a smaller and more economical transformer.

Interfaces for the digital world

The environments in which DMS-10 found initial applications are analog. However, a significant economic advantage exists for a number of digital interface applications. There is an increasing trend in the telecommunications industry to use digital carriers for trunking, although digital channel banks[2] have to be installed where digital carrier lines enter an analog switching centre. Recent increases in the number of digital switching machines bring new importance to the digital links and to remote digital line concentrators. The use of these concentrators makes possible a variety of applications, from the simple extension of local line concentrators to essentially independent remote units.

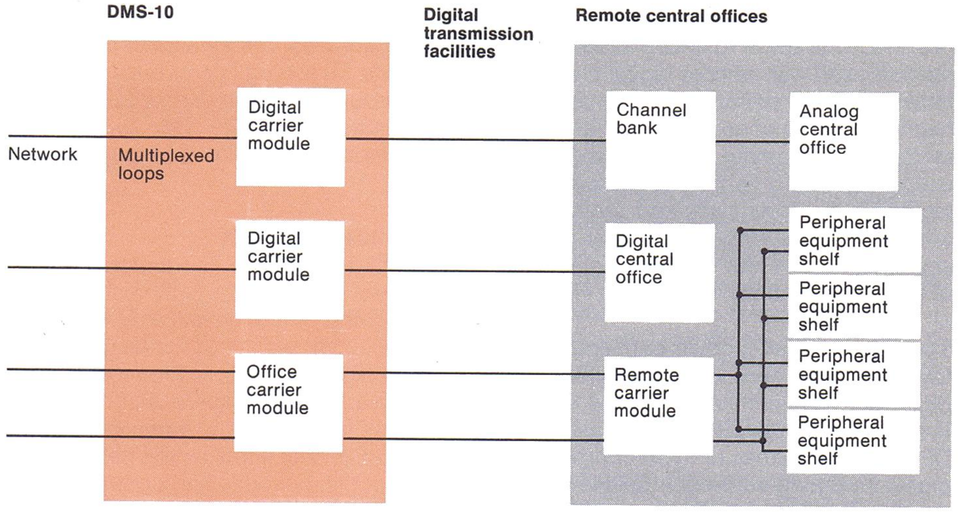


Figure 6. DMS-10 has several ways of interfacing with digital transmission facilities. A digital carrier module allows operation with both digital and analog central offices. (A digital channel bank is required at the analog central office.) For remote DMS-10 equipment, an office carrier module at the local office works with a remote carrier module at the distant office.

Table 2 Line circuit functions

- **Loop-current detection** — depending on the sequence of events, the state of loop current may indicate request for service, numbers dialled, identification of particular subscribers on some multiparty lines, special requests (flashing), or termination of the call. This loop current is supplied from the line circuit and is controlled at the subscriber's telephone by the hookswitch and dial. A detector reports changes in loop current (above or below a specified threshold) to the common equipment via the digital multiplex loop. These changes are interpreted by software in the common equipment which initiates the required actions.
- **Ringing** — the high voltage analog signal required to operate the 'ringer' in a conventional telephone set cannot be transmitted through the digital transmission paths provided for voice communication. Ringing is therefore supplied to the line circuits via dedicated ringing buses and applied directly to the loop, under commands received from the common equipment via small relays mounted on line circuits.
- **Transmission** — the two-way transmission of voice frequency signals through the line circuit requires conversions between the analog signals on the loop side and the digital signals on the common equipment side. The analog-to-digital and digital-to-analog conversion circuit (referred to as the codec) is provided as part of the individual line circuit. This single-channel codec[1] is in contrast to the group-channel codec utilized in systems where the codec is shared by a number of voice circuits (for example, the DE-3 channel bank shares a group-channel codec between 24 circuits[2]). Another transmission function required in the line circuit is conversion between the two-wire transmission on the subscriber's loop (analog signals carried in both transmit and receive directions on the same two wires) and the four-wire transmission on the multiplex loop (digital signals with separate transmit and receive paths). This is provided by a single-core transformer circuit.
- **Logic control** — a custom LSI logic circuit provides the control interaction between the line circuits and the common equipment. This interaction includes the exchange of messages relating to control functions (loop current detection, ringing, etc) and the time-multiplexing of speech signals (the transmission and reception of digitized speech samples in specified time slots).

Two types of digital interfaces are provided with DMS-10: a digital carrier module used with remote digital channel banks or digital switches, and an arrangement consisting of an office carrier module and a remote carrier module for use with DMS-10 peripheral equipment located in a remote switching centre. Both are designed to work with standard DS1 signals[3] at 1.544 Mb/s. A block diagram of these applications is shown in Figure 6.

The digital carrier module connects a DMS-10 multiplexed loop to a 1.544 Mb/s digital line. It is primarily intended for synchronized applications such as with DE-3 channel banks or synchronized digital switching centres. A built in slip control circuit permits the use of nonsynchronized remote equipment such as DE-2 channel banks when slips can be tolerated. The major features of the digital carrier module include:

- detection and generation of carrier-group alarm signals consistent with DE-2/DE-3 channel bank features;
- bipolar violation detection to monitor DS1 errors;
- time-slot-interchange for matching DS1 time slots to available connecting time slots;
- digital loop-back for locating faults;
- standard DMS-10 multiplex loop interface to the switching centre, and DS1 office repeater interface on the facility side.

For remote applications, two DMS-10 multiplexed loops are connected to four remotely located DMS-10 peripheral equipment shelves over two standard DS1 rate facilities. This arrangement is consistent with local peripheral shelves, where each loop normally serves traffic on two shelves, but is capable of serving all four in the event of any failure associated with the other loop.

The remote PE shelves provide the same features as the local shelves, including line, trunk, maintenance, and service circuits. The hardware is consistent between remote and local shelves, removing the need for special call processing software for remote shelves. Since both trunk and line circuits can be provided in a common peripheral shelf, the remote unit can be utilized as an add-on for growth to an existing switching centre, or as a remote extension to a DMS-10 centre.

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As a measure of the effectiveness of digital interfaces, the same size PE shelf that holds 56 analog line circuits or 28 trunk circuits (or some combination of the two) can accommodate up to six digital carrier modules, providing 144 digital trunks.

A technical evolution

The DMS-10 common and peripheral equipment are part of a technical evolution, drawing on the development and experience gained in both analog and modern digital communication systems. This evolution will continue with new advances in technology, particularly in such cost critical items as the peripheral equipment line circuits and control memory circuits.

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3. G Marshman, F Mills, The LD-1: a second generation digital line, Telesis, Vol 3 No 6, March/April 1974.

Les Rushing received his bachelors and masters degrees in electrical engineering from the University of Illinois and New York University, respectively. He joined BNR in 1966, working initially in various aspects of the SP-1 central control complex, and becoming manager of the SP-1 program store development in 1968. Les contributed to the initial BNR exploratory program on digital switching in 1970 and the DMS-100 development project in 1972. Since 1976, he has been involved in the DMS-10 project and is currently manager of DMS-10 digital interface development.

Gino Totti graduated with a BSc in electrical engineering from the University of London, England, in 1963. For the next four years he was a development engineer with English Electric Leo Computers near Manchester, designing magnetic disk file controllers for the computer systems under development by that company. In 1967 he came to Canada to join the SP-1 design team at BNR in Ottawa. He was involved in the design of input-output device interfaces for the SP-1 common control test centre for about a year. Subsequently he carried out the exploratory work which formed the basis for development of the Pulse* EPABX. He was one of the main designers of the wired logic control unit for Pulse throughout its development. In 1972 he joined the DMS-100 group and shortly after became manager of a small team designing remote digital line concentrators. After a brief period spent in France on loan to Northern Telecom Europe, he joined the DMS-10 team in Ottawa in February 1976 as manager for common equipment and maintenance development. His current function within DMS-10 is of a planning and exploratory nature in the common equipment area. Gino is a member of the Association of Professional Engineers of Ontario.

Software: source of DMS-10 intelligence

Greg Mumford
Dick Swan

Using proven hardware and language, the DMS-10 software is sophisticated and flexible, while remaining economic over the range of office sizes.

The heart of a digital switching machine is its software — its 'intelligence'. Software provides the instructions and routines for all of the machine's activities, from handling a call to maintenance, trouble shooting and administration.

Computer-controlled switching machines, such as DMS*-10, need the maximum possible call handling capacity and must still retain software flexibility to accommodate an ever increasing diversity of subscriber features. However, trade-offs between flexibility and throughput must be achieved to assure the product's cost competitiveness. Small community dial offices are particularly sensitive to high start-up costs which can result from excessive flexibility and capacity at the low end. Cost-effective flexibility and expandability were achieved in DMS-10 by careful choice of modularity in the design of both hardware and software, as explained in this and other articles in this issue.

Ideally, systems would be cost competitive across an entire market range and be ready for sale as soon as the market need was identified. Realistically, marketing and technology inputs must meld to produce a successful product. For DMS-10, the major marketing requirements which influenced the software design were emphasis on cost effectiveness at small line size ranges and an introduction to the market in 1977, less than 21 months after the start of the project. One technology response to these marketing requirements was to employ a flexible architecture which permitted initial design of software for a basic range of standard telephony features, with the ability to easily add sophisticated features in the future. Another response was to make use of the proven central processing unit of the Northern Telecom SL*-1 business communications system, and the associated high-level language and assembly language for software development[1]. These responses, along with the use of proven hardware technology, plus a control hierarchy adapted from SL-1, strongly influenced the definition of the software architecture.

Substantial benefits were gained from using the SL-1 language, which is employed in a number of Northern Telecom's existing products (eg, SL-1 and SL-10[2]) as well as in others currently under development at BNR. Inherent in this language are the modern structured programming concepts which facilitate modularity, improving both maintenance and readability. Previous computerized switching systems were coded in low-level (that is, machine-oriented) assembly languages; SL-1, on the other hand, is a high-level language which results in faster code implementation. The powerful high-level commands are translated by a compiler into longer sequences of intermediate object code, and these in turn are interpreted as hardware commands by a collection of digital logic circuits following fixed operating routines and known as firmware, because it lies between hardware and software. Thus one SL-1 command stored in the DMS-10's memory can generate many instructions at the hardware level, resulting in significantly smaller memory requirements over direct production of machine code.

Scanning — hardware and software working together

One important fact about DMS-10, unlike many other stored-program-controlled switching systems, is that scanning is performed by hardware logic circuits, not by software. (Scanning is the searching by central control for changes in state — such as a handset being lifted by a subscriber — throughout the line and trunk circuits it serves.) This arrangement,

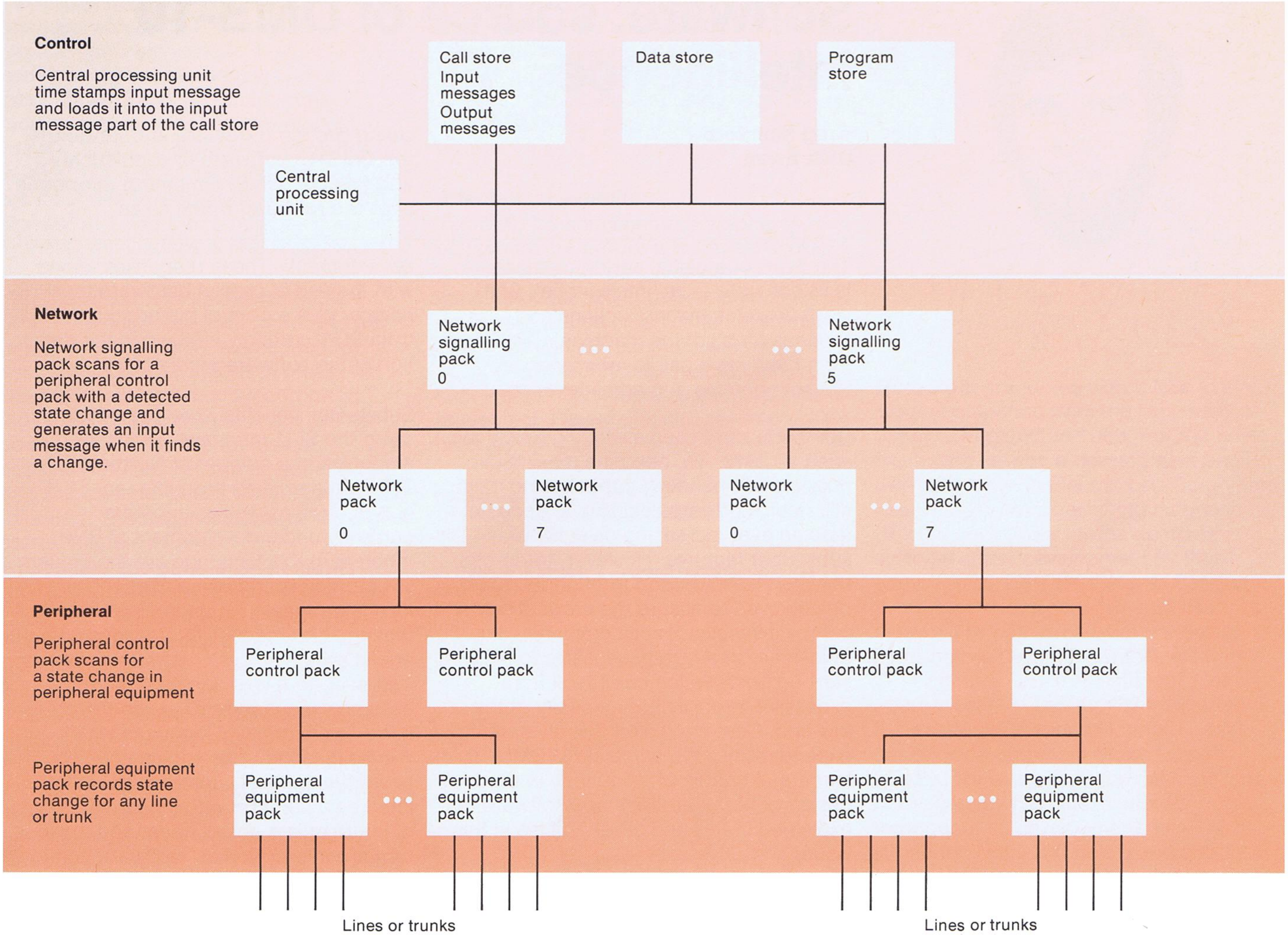

Figure 1. The DMS-10 is a software-controlled digital switching machine in which hardware logic is employed to reduce the percentage of time that the software spends in attending to 'housekeeping' tasks such as scanning all the line and trunk circuits that the machine serves. This scanning takes place at two levels in the hardware, as shown here, before any notification is sent to the central processing unit for action. Events on any line or trunk — such as a subscriber lifting the handset — are registered by one peripheral control pack for all the lines or trunks on that shelf. At the next higher level, network signalling packs search for change information from any of the peripheral control packs. The central processing unit is notified only when a state change is detected by this two-level hardware scanning process. When notified, it issues a message, which bears the time of origination, to the scheduler to initiate follow-up action by the call processing programs.

which is known as autonomous scanning, reduces overhead time significantly. (Overhead time is the time allocated for the software to run the switching machine when no calls are being processed: it is therefore unproductive as far as call processing is concerned.) In DMS-10, this scanning is done by circuit packs in the digital network. State changes on subscriber lines are concentrated by two-level scanning in the control hierarchy, see Figure 1. The first level is in the peripheral equipment shelf, where peripheral control packs scan for state changes from any of the lines or trunks on that shelf. At the second level, the network signalling packs search for change information on any of the control packs. Only when a network signalling pack detects a state change (an event) in the peripheral equipment of

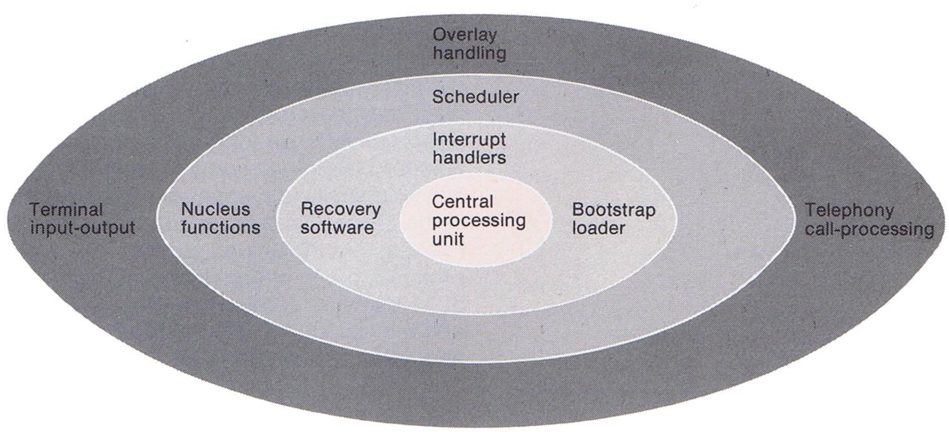

Figure 2. DMS-10 software is arranged in 'layers' around the central processing unit. Each layer functions more or less independently, communicating through well-defined interfaces, and 'hiding' the outer layers from the inner ones. Within each layer, programs are organized into modules, each with a well-defined task. In this way, the software remains flexible, versatile, and easily adaptable for new features as the telephone company requires them.

DMS-10 is the central processing unit notified. This division of scanning responsibility allows DMS-10 to be an event-driven system in which a 'time-stamped' message (produced when the central processing unit is notified of a state change) is simply queued for later processing (see box on this page).

One of the alternative techniques (common in many switching systems) involves software control of the scanning. Changes are detected by scanning every circuit periodically. This leads to increasing overhead as the number of lines increases, and to a reduction in call processing time available the more subscriber lines there are to scan. The DMS-10, being an event-driven system, has the advantages of a fixed overhead because scanning is performed autonomously in hardware. Also, critical real time response requirements associated with scanning on a short cycle are eliminated. New input is picked up by call processing at its convenience, thus minimizing the effect of real time interruptions from the outside world. Interrupt handling is described further in the box on p 312.

The software organization

The DMS-10 software can be viewed as forming self-contained 'layers' on the central processing unit, see Figure 2. Software in the outer layers builds upon the capability provided in the inner layers, and functions independently, interacting with adjacent layers only through messages. The inner layer thus 'hides' many aspects of the processor hardware from outer layers, allowing their logic to be simplified. The inner layer contains a group of programs most necessary for the central processor, including the interrupt handlers, the bootstrap loader (which is used to start the system from scratch), and the recovery software, which is required if external events cause the system to close down temporarily. The next layer contains the scheduler, which arranges the machine's working schedule, and a number of nucleus functions, such as the logic required to add and delete items from lists in memory. As a result, the next level is again simpler because it can utilize well defined function interfaces without knowing any implementation details (that is, how they work). The outermost layer contains the modules for terminal input-output, overlay handling, and telephony call processing.

Each layer is composed of modules that partition the layer and hence the software into self-contained and virtually autonomous units. For example, the modules that implement the call processing logic in the outer layer communicate with the

The organization of the DMS-10 software

The DMS-10 software is divided and functionally separated into modules, each one responsible for a particular function or set of functions. Each module consists of submodules. Some of the modules process calls: others comprise the interface with peripheral circuits (ie devices) within the switching machine. The first section is known as call processing logic, and the second as device driver logic. This separation of the call processing logic and device driver logic is intended to provide a software modularity that minimizes overhead, reduces development effort in the designing company, and retains flexibility for evolution of the system. Device drivers allow call processing modules to be independent of hardware. Figure 3 illustrates the principle of modularity as applied in the software organization.

The software operation of DMS-10 is based upon the reception of messages stimulated by 'events' in its peripheral circuits, such as subscriber handsets being lifted or replaced. Event messages are routed by the input message handler to the appropriate device driver for processing. There is one device driver for each type of device (eg lines, trunks, receivers, and tone generators). The device driver bases its interpretation of the event on the current state of the device (eg ringing current applied) and the device's hardware characteristics (eg line circuit). Events can cause a change in the device state (eg from 'apply dial tone' to 'receive digits'), transmission of control functions to the device, and/or notification of the event to the higher control software, see Figure 4.

A common driver function is the collection of hookswitch events (that is, dial pulses) into a dialled digit. Call processing logic is notified by the driver only upon reception of a complete digit.

Another typical device function is to screen out 'hits' on the line during conversations — that is, transient voltage spikes caused by lightning, power line signals, etc.

Associated with any active device is a device register in the software. This register is a memory area used to retain a record of the current state of the device. Call registers are another type of register. They contain the state of a particular call — for example, whether the call is in the ringing or talking state. During the processing of a call, device registers are linked to the appropriate call register by software. Device registers are manipulated by device driver modules, while call registers are manipulated by call processing modules.

Call processing logic uses events received from device drivers, eg dial pulses, based on the current call state stored in the call register, eg dialling interval. The processing may result in changing the call state, analyzing digits, and/or sending control commands to device drivers. Control commands include ring line, check for the presence of a coin, switch from digit recognition to hit screening, and send wink.

Both device driver and call processing modules have a similar organization. Each is composed of several submodules, one for each value of the software state stored in the applicable register. Device drivers also contain another set of submodules, one for each type of circuit. Thus a new line can be introduced into the DMS-10 with the simple addition of a single new module.

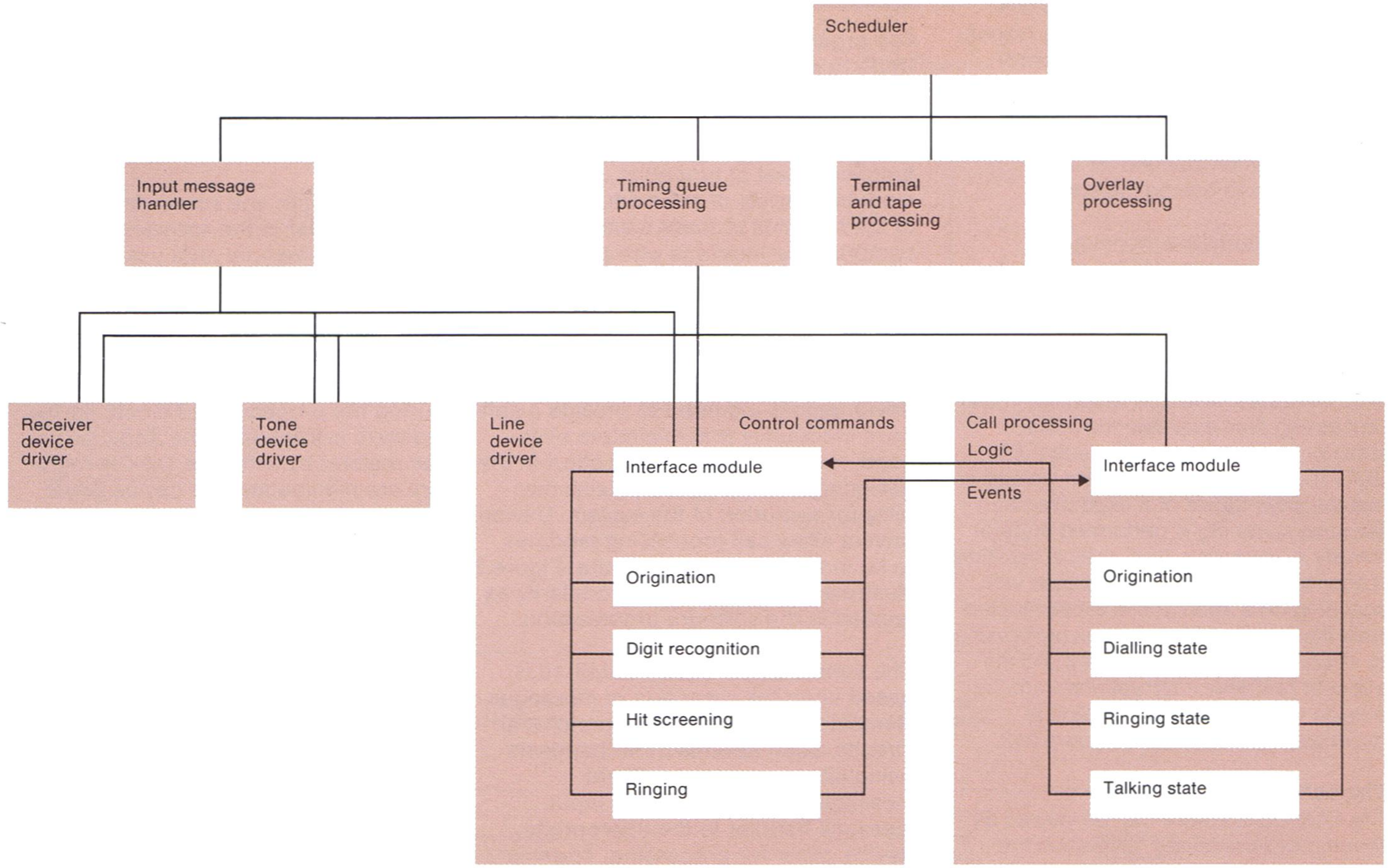

Figure 3. A modular software organization, as illustrated here, is adopted for DMS-10. The scheduler controls the sequence in which the processor's tasks are handled. The call processing logic module handles the setting up and disconnection of calls, while the line device driver module interfaces with electrical circuits that are linked to lines and trunks.

line-trunk processing module through a single interface sub-module. This allows call processing software to be independent of the types of lines or trunks involved in a call. New devices can be easily added without changing the call processing logic. Separate sub-modules within the line-trunk module are provided for each type of line or trunk circuit.

Another aspect of DMS-10 modularity is the distinction made between the execution of critical call processing functions and the diagnostic and human-machine interface functions. Call processing programs, together with some maintenance and diagnostic tasks, always reside in the system's main memory. Other functions which are required infrequently, such as fault clearing and data modification, are contained in overlay programs on tape and are loaded separately into the main memory when they are required, 'overlaying' the memory space occupied by previously executed and now unneeded programs. This overlay concept allows DMS-10 to minimize memory requirements while still providing comprehensive maintenance and administration capabilities.

Benefits from DMS-10 modular design
The modular design of DMS-10 software not only provides flexibility and reduced development and maintenance costs, but also makes for a more reliable product in the field. One notable benefit was found during development. Designers could come "on-stream" and become productive very quickly due to the restricted scope of knowledge defined by each module in the system. Further, responsibility for modules could be readily trans-

DMS-10 interrupt system
Various devices connected to the DMS-10 central processing unit 'interrupt' the processor to inform it of events happening in the outside world, but the way in which these interrupts are handled is designed to cause minimum disturbance to the machine's operating schedule. These devices include the printed circuit packs that handle network signalling, terminal input and output, and tape drives. The simple processing scheme used in DMS-10 minimizes overhead and eliminates the interaction of interrupts with all but the inner layer of software.

An interrupt from a network signalling pack passes directly to the inner layer, which inserts a message in the input message queue through which the inner software layer informs the outer layers of interrupts and other events. This message contains the time of the interrupt, the address of the interrupting device (eg line), and the cause (eg hookswitch change). Such input messages form the stimuli for the DMS-10 event-driven software. The processor's scheduler sequentially examines these messages and instructs the appropriate software module to process the message.

Interrupt processing overhead is minimized by the choice of when interrupts are recognized. They are only recognized at times when the processor breaks off from executing the intermediate object codes produced by the compiler from the commands in SL-1 language. At these moments, several of the machine's registers are free and can be used for the interrupt routines.

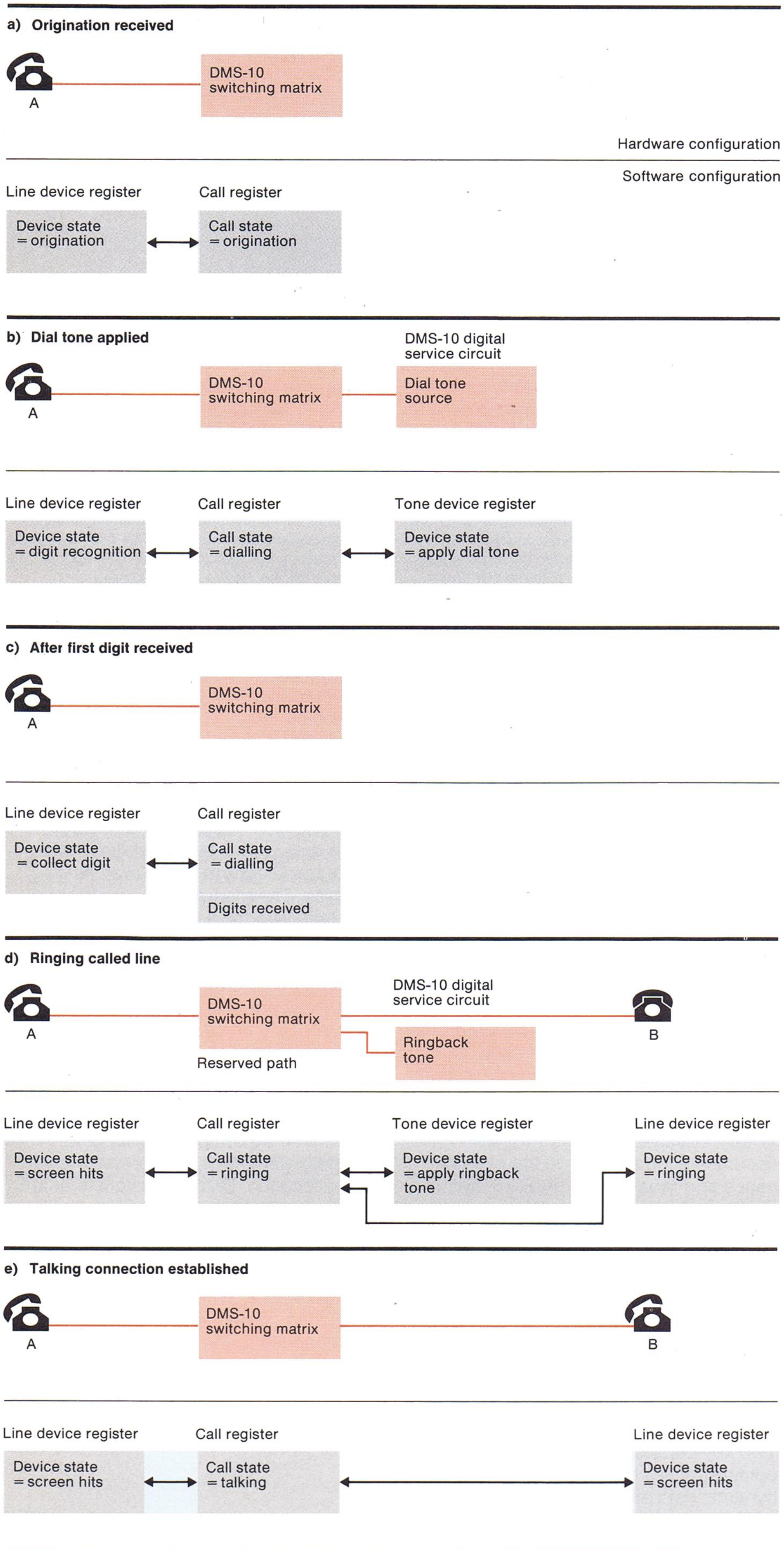

Figure 4. This figure illustrates the placing of a call from one subscriber's telephone to another through DMS-10, from the software point of view. Two main paths are shown — the configuration of the software modules involved in the processing of the call, and the state of each of the device registers in the software.

a) When the caller lifts the handset, it closes contacts in the subscriber loop, and this change of state is detected by hardware and prompts an input message to the central processing unit, via the DMS-10 hardware. The scheduler calls a line driver module to process this input message and obtains a line device register and a call register. Now the call processing logic takes over, informed that the caller has lifted the handset by a message from the line driver. It invokes the appropriate software to handle the origination of the call. A line register is a memory area containing control information and variables for a single line. Assigning a register to a line makes it busy in software and provides the variables needed by the line-trunk module to control the line. A call register is a memory area used by call processing to contain the control variables for a single call.

b) On receiving an origination from the subscriber's line, call processing logic obtains a dial tone source from the digital tone generator and connects it through the digital network to the line circuit. The subscriber can now hear dial tone. At the same time, the line device register is put in a digit recognition state, and the call processing logic waits for dialled digits.

c) The line device register collects the on-hook/off-hook interrupt events that constitute the dial pulses for a single digit. Call processing logic is informed of the dialling information as each digit is completed. On receiving the first digit, call processing logic uses the service driver to disconnect the dial tone generator from the subscriber's line. As each digit is received and stored in the call register, the call processing logic analyzes it against the digit directory stored in the office data table. In this case, the dialled digits are found to correspond to the directory number for the called line B. Digit recognition of the device register is then turned off.

d) If the dialled line is idle, it is busied by assigning it a line register which is then linked to the call register. In addition, call processing logic puts line device register B in a ringing state, which applies ringing current to set B. Audible ringback tone is supplied to line A via a command to the service circuit. A path through the digital network between lines A and B is reserved. The call is now in the ringing state.

e) Call processing logic is informed by the line device register when B's handset is lifted. Audible ringback tone to A is removed by a command to the service network. Line device register B is put in a talking state to remove ringing. A and B are connected through the reserved digital path, and the call is terminated in a talking state. During talking, the line device registers for both A and B are placed in the 'screen hits' state, which means that they are set to exclude external noise such as surges from lightning or power lines.

ferred between designers. This capability was valuable in freeing designers for ongoing development. New or additional features were designed while earlier features matured through implementation, test and production. For example, because of the phased development, such items as the interface to a No 14 local test desk or No 3 local test cabinet, digital carrier modules and the automatic message accounting (AMA) feature were easily added to the software after the basic system was completed. The addition of this new equipment and its controlling software went smoothly.

Another benefit of modular software design comes from well-defined interfaces between the call processing logic and the hardware device driver logic. Device drivers contain modules that are used to control specific hardware types, eg line-trunk module, or receiver module. Rigorous consistency checking can be built in to the software module interfaces, revealing software faults more readily and facilitating software integration and testing. These checks also reduce the number of errors that reaches the field.

The critical interface

The human-machine interface — its keyboard and visual display, the means by which people communicate with it and repair it — is clearly an important aspect of any machine. The cost of running the machine depends partly on how well this interface is designed for the people who will use it. Both administrative and maintenance costs are directly affected.

Requirements for this aspect of a switching machine are very loosely quantified in the telephone industry since there is great variation between different machines in the level of sophistication offered. Nevertheless, the requirements for the human-machine interface are, briefly; that it must be interactive and have explicit responses to faults; tolerate user errors; be coupled with fault clearing procedures; allow fast execution of any task; and allow all machine data to be changed and added on-site.

Sophisticated interfaces are provided for DMS-10 through the use of overlay programs. Selective grouping of associated tasks into one overlay program minimizes the effect of the delay of execution of a task while it is being loaded from tape.

```
REQ   new
TYP   rout
ROUT  32
ALT   33
TYPE  cama
TG    22
OPR   nopr
COS   none
ASTR  ofhk
ATMO  drop
CNTL  clns

REQ

REQ   new rout 32 33 cama 22 nopr none ofhk drop clns
REQ
```

Figure 5. One of the frequent jobs for telephone company personnel is to modify the office data in stored-program-controlled switching machines, based on data modification orders from the company's business office. Assignment and deletion of directory numbers, changes to subscribers' class of service, plus many other modifications, require changes to the data stored in the machine. In DMS-10, such modifications are handled by special software which is designed to increase the speed and accuracy in making these changes by offering a user-oriented, symbolic, interactive procedure. Data are entered on the keyboard of a local or remote terminal. Once the program is initiated, the switching machine prompts the user for the required information, suiting the degree of prompting to the user's expertise. The sequence in the top part of this printout from a DMS-10 terminal record shows how a person can enter the information line by line as prompted by the switching machine. Below, the example shows how a more experienced person can enter all the data on one line.

Separate overlay programs are used for fault analysis of the different hardware subsystems. Some of these programs may be invoked automatically by the system and all can be manually loaded by a craftsperson. When manually loaded, they operate interactively. For example, the system may automatically check the capability of the entire DMS-10 digital switch transmission, identifying any trouble found. This same diagnostic capability can be invoked to enable the craftsperson to interactively control the testing of specific elements of the digital network. The teletypewriter error printouts are used directly as the starting point for the procedure-oriented practices used for fault clearing procedures. This allows rapid and efficient trouble shooting and leaves little room for human error in translating a machine output to a trouble clearing input. Moreover, the teletypewriter messages are integrated with the documentation supporting the maintenance and repair of the DMS-10 switch.

The administrative interface

One of the most important administrative interfaces is that used for controlling data changes and additions. For example, each time a subscriber's phone is added, deleted or moved, data are correspondingly modified. The DMS-10 data modification capability is powerful and user oriented, see Figure 5.

Two key decisions minimized DMS-10 administrative cost. They are the use of dynamic data allocation, and generic program tapes. Let's consider the first one. The configuration of many stored-program-controlled switching machines is enshrined in the sizes of the machine's office data tables at the time of installation. When the configuration of such a machine has to be increased, to cope with a greater number of lines and trunks, the telephone company has to send a magnetic tape containing the existing office data, with the current data table, to the manufacturer of the switching machine. The manufacturer prepares a new tape with the same office data but an expanded table and sends this tape back to the telephone company, which loads it into the switching machine. While this procedure is going on (for perhaps a month), the office data in the switching machine cannot be changed, otherwise there would be a mismatch with the new tape. In contrast, the office data in DMS-10 can be easily expanded on-site at any time by authorized telephone company personnel, thanks to dynamic data allocation. Data extensions that are required with the addition of blocks of hardware are accomplished by simply allocating the required data entities from the switching machine's common free memory space. When this space is exhausted, more memory packs are simply added to the system. Hence the machine's capacity can be accurately matched with growth in subscriber demand, as and when it occurs.

The other point concerns the program tapes that contain the operating programs and the office data for each office. In previous generations of stored-program-controlled machines, such tapes were custom made for each switching centre. In DMS-10, by contrast, the operating programs and office data are kept separate, allowing each to be modified independently. Each tape has four tracks. Operating programs are recorded on tracks one and two, while specific office data appear on the other two tracks. Hence the same operating programs can be simply copied on to the tapes for all the switching centres, and the data for each specific office recorded on the second pair of tracks at little cost, just before the tape is sent to the telephone company for the start up of the digital switching machine. Subsequent tape issues are sent without the data, which are entered on to the tape by telephone company personnel from the switching machine. Office data can be changed by telephone company personnel at the switching office, without returning any tapes to the manufacturer. This brings a number of advantages in controlling the modification and changing of machine data, thus keeping costs down for both the manufacturer and the telephone operating company.

From the point of view of software development, the DMS-10 has been a satisfying project. The chosen development plan has worked well. The initial decisions to use high-level software language and a layered, modular structure have been amply justified by the facts that the first DMS-10 switching machine was installed on time and that numerous additional features are being developed by BNR according to the preplanned schedule and without unforseen problems.

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*Trademark of Northern Telecom Limited

A native of British Columbia, **Greg Mumford** received his bachelors degree in applied science from the University of British Columbia in 1969, and his masters in the same subject in 1971. His work on data acquisition using minicomputers during his masters program led, upon graduation, to a post with BNR in Ottawa working on exploratory studies of digital switching, first in network control, and then in minicomputer software. Later he became involved with the early stages of the DMS-100, the large local digital switching office. In September 1973 he became a manager in the group making a feasibility study of a small community dial office using the technology proven in the SL-1 business communications system. At the end of this study he rejoined the DMS-100 team. When the DMS-10 project started in January 1976, he became the first software manager in the group. His current project responsibility is manager of call processing development. Besides water skiing, which gives way to cross-country skiing in the winter, Greg likes woodworking in his spare time. He and his wife enjoy camping, and are now learning to incorporate a two year old son in their camping trips.

In 1972 and 1973 **Dick Swan** was earning his BMath and MMath respectively in computer science at the University of Waterloo, Ontario. After that, BNR claimed him. From July 1973 to March 1976 he was involved with software administration for generic programs for the SP-1, Northern Telecom's first stored-program-controlled switching family. From then on, he has worked on software for the DMS-10, being promoted to manager in 1977. His current title is manager of systems software development. Tall and lean, with a ginger beard, Dick is a jogger, a marathon runner, and plays soccer and hockey. He is a member of the Association of Computing Machinery and of the Institute of Electrical and Electronics Engineers. Dick has a microcomputer at home which he admits is 'a toy' when closely questioned by his wife, who is an archaeologist, but he says that nonetheless it has taught him a lot about electronics.

Putting it all in a package

Frank Vallo

Careful attention to packaging DMS-10 has produced a digital switching system with a functional, aesthetic and economic design.

Packaging a product like DMS*-10 involves much more than finding a way to fit all the hardware into an appealing 'box'. There is a large variety of practical considerations, many of them characteristic of a digital switching machine. Until recently, many switching machines have been constructed mainly of electromechanical components such as reed relays and crossbar switches. In DMS-10, these components are replaced by printed circuit boards holding discrete semiconductor devices, large scale integrated circuits, hybrid integrated circuits, and other electronic components. This electronic revolution in telephone switching has brought with it new design opportunities for the packaging engineer.

The mechanical design and packaging of DMS-10 is oriented towards application in small community dial offices. The increased demand for more and higher quality telephone service is causing telephone companies to expand or replace old equipment. DMS-10 satisfies this market and provides many new revenue-producing service features. The switch also offers more than attractive features — it is efficient, easy to maintain, and inexpensive to install and tailor (engineer) to the individual needs of each telephone company.

Design requirements

There was a large variety of requirements facing BNR in the design and packaging of DMS-10. The finished product had to be economical, compact and consistent with the rest of Northern Telecom's digital family. Moreover, DMS-10 had to maintain one of the essential elements of the entire switching design: modularity without sacrificing compactness.

DMS-10 is currently economical for a community dial office of 300 to 6000 lines, and flexible in the features it offers. Careful decisions on partitioning, both at the system architecture level and the printed circuit board level, contributed significantly to making DMS-10 economical for small and large offices. For example, a 300 line system requires only three bays: one containing peripheral equipment, one for common equipment and one for maintenance. Growth is easily accommodated by adding individual printed circuit packs as required. DMS-10 software (discussed in the article on page 309) provides the flexibility to permit a telephone company to choose a feature package suited to its needs.

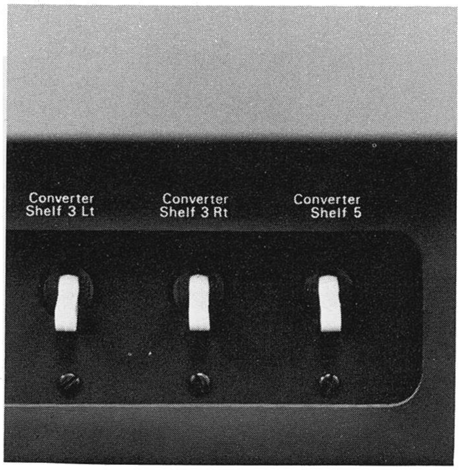
Since DMS-10 is expected to be placed in unattended switching centres, packaging must contribute to the reliability and fault tolerance of the system. Therefore, connectors, cables and cabling hardware were chosen to match the high reliability of the switching equipment. For example, new methods were developed for interconnecting elements of the system. Also some cables could not be longer than 2 m for electrical reasons and cabling had to be designed to accommodate this constraint.

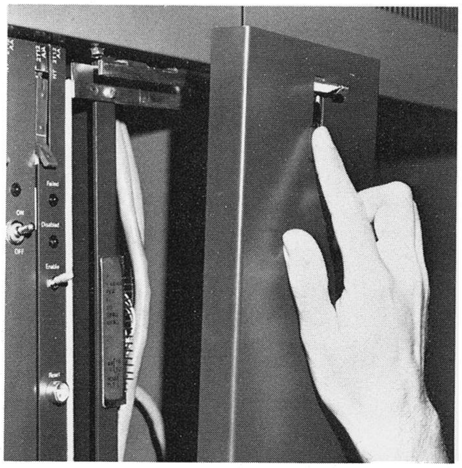
In addition, the hardware had to be easy to manufacture, ship, assemble and install. Once in place, the switching machine must be able to operate under varied environmental conditions. It must be able to do this under the worst conditions: loss of heating in winter and lack of air conditioning in summer. For example, if the office air conditioner fails on a long summer weekend, the system can operate without degradation until repairs are arranged on the next working day.

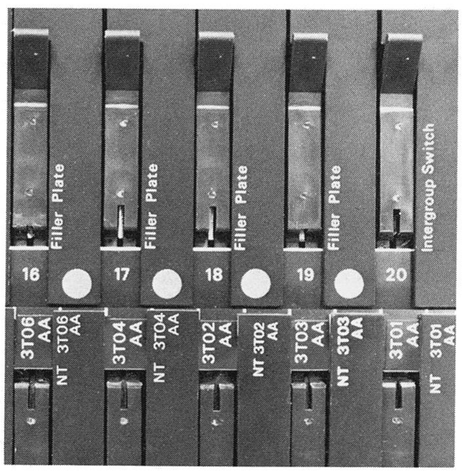
Let's briefly examine how each of these requirements was met.

Designed for use

Early in the discussions of the Northern Telecom family of digital switching machines, a decision was made to integrate the technology of all DMS products. This objective is reflected in the packaging design. The DMS-10 development group worked with BNR's design interpretive group to tackle the project. The task was to simplify the user interface both visually and functionally. The obvious result was a characteristic colour for all DMS equipment — maple brown — and accent colours to identify the different members of Northern Telecom's digital world family. For DMS-10, burnt orange became the identifying colour and has been used for the finish of cabling fascia and trim hardware.







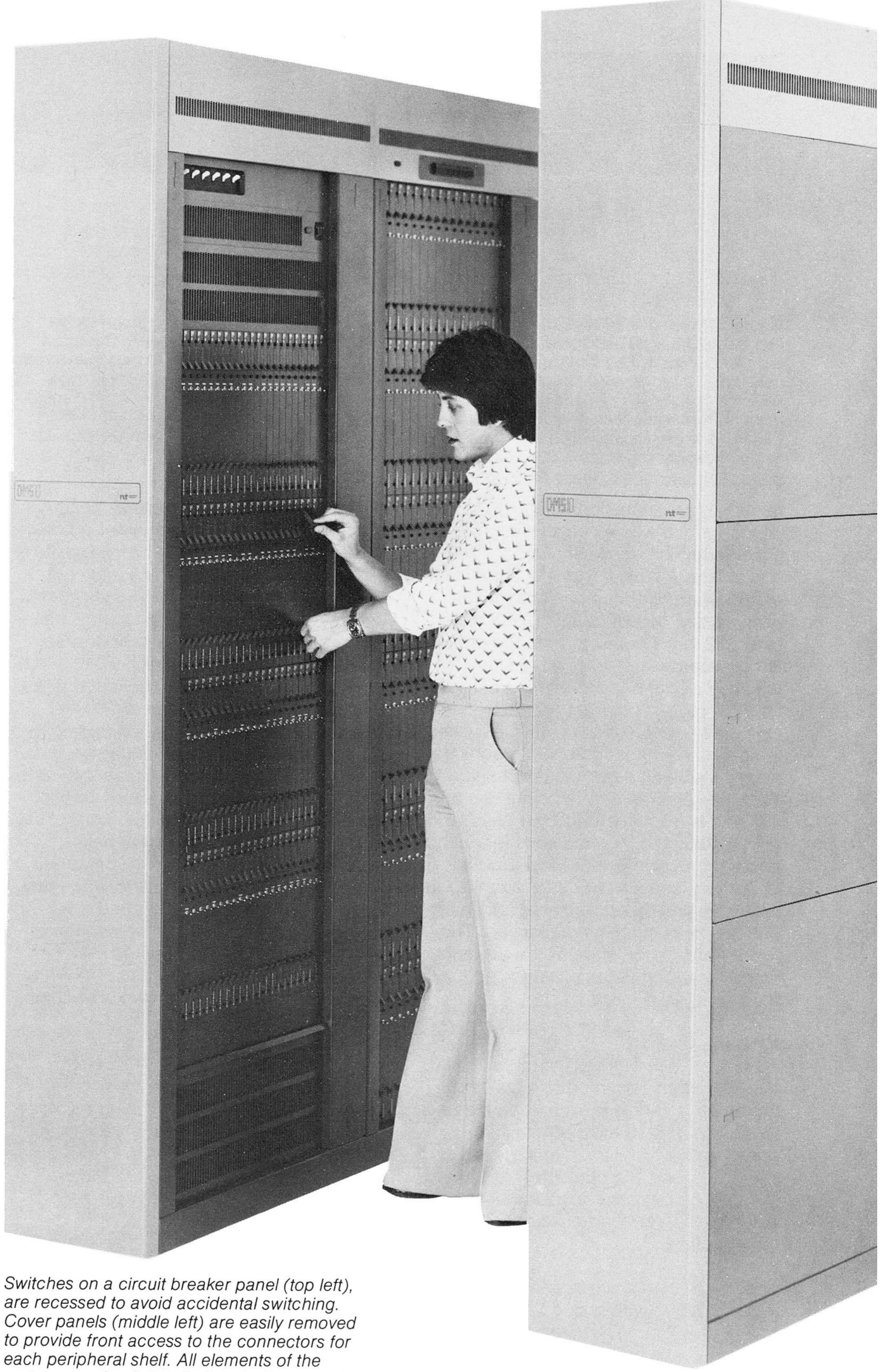


Figure 1. *The DMS-10 switching machine, designed by Bell-Northern Research and manufactured by Northern Telecom, is an example of effective packaging. The photo of the peripheral bays (right), illustrates its clean appearance, with uniform placement of shelves and many features which permit a telephone company to use the machine efficiently. Switches on a circuit breaker panel (top left), are recessed to avoid accidental switching. Cover panels (middle left) are easily removed to provide front access to the connectors for each peripheral shelf. All elements of the system are clearly labelled, including manufacturer's printed circuit code, for quick identification and replacement (lower left).*

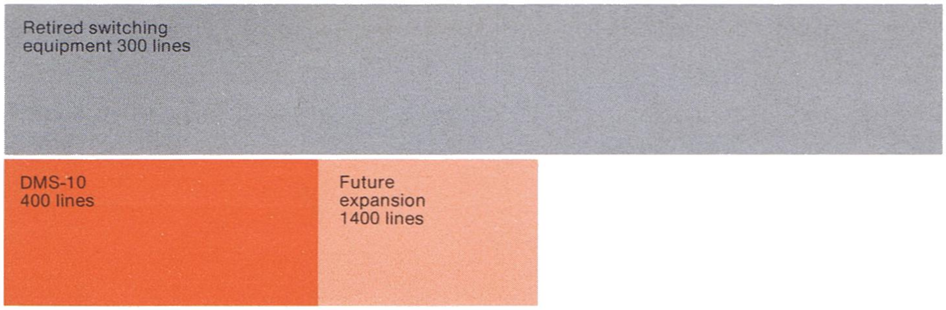


Figure 2. North Florida Telephone Company purchased the first DMS-10 switching machine last October for its Fort White exchange. The new DMS-10 provides 400 customer lines, an increase of 100 lines over the previous equipment, with space reserved for future expansion. DMS-10's larger capacity was easily accommodated in the existing office with no new construction required. The bar graph above illustrates the relationship between the space needed for the old equipment (grey) compared to that for DMS-10 equipment (colour). Note that the total space required for DMS-10 equipment, including a possible expansion to 1400 lines, is just over half the space previously used to provide 300 lines.

Simplifying the functional aspects of the user interface was an elusive objective, considering the sophistication of DMS equipment. A typical frame is composed of 100 or more circuit pack faceplates with graphic details on most, and more than 200 lock latches to hold the printed circuit boards in place. The design employs a uniform layout and a paint finish to reduce contrast between elements — circuit packs, shelves, frames — so that indicator lights and graphics are clearly visible at a glance. A specific design requirement for efficient use of DMS-10 is front access to the bays, and the packaging accommodates this with easily removable panels. The product package creates a user interface with the simplicity and order typical of computer and business machine packaging. This image reflects the state-of-the-art technological development that DMS products represent, see Figure 1.

Keeping it small

Buyers of DMS-10 might want to install it in part of an existing office building; therefore, any new construction needed to house DMS-10 must not have special constraints which would increase its cost. In some cases, the customer might wish to replace obsolescent equipment without extensions to existing buildings, or new construction.

The height of all frames was chosen to fit into a building with a standard ceiling height of 2.7 m. In the past, central office buildings have had ceilings up to 3.6 m in height in order to house the switching equipment, and have required expensive anchoring hardware on the ceiling. DMS-10 has neither of these constraints.

Further economies are possible because of the flexibility of the equipment arrangement. For example, space can be saved by arranging the peripheral equipment bays back-to-back. For large installations (5000 to 6000 subscriber lines) this can mean a 30 percent saving in floor area. At the other extreme is the DMS-10 office providing service for 300 subscriber lines. The space required for this minimum configuration is only 4.5 m^2, including aisle space. For larger switching centres of about 2500 lines, a floor plan with two rows of equipment is suggested. In this case, the first row includes the control bay and two peripheral equipment bays accommodating 540 lines, the recorded announcement bay, and the maintenance bay and its terminal. The second row includes the remainder of the peripheral equipment. Figure 2 compares the DMS-10 space requirement at Fort White, Florida, with that of the previous switching equipment.

For systems larger than 2500 lines, another common equipment bay is required for additional switching capacity. In a switching office with the maximum 6000 lines, there would be five rows occupying an area of about 30 m^2. (Other specifications are given in Table 1.)

Holding it all together

The DMS-10 system is housed in several identical framework assemblies. The framework comprises a series of bays designed to accept a shelf or unit which is mounted on 64.3 cm centres. The size is standard for the DMS family, and was chosen to permit optimal partitioning leading to reduced costs. Also, it matches the frame spacing of DMS-100 (the larger digital switching machine), and SP-1 (Northern Telecom's stored-program-controlled switching system).

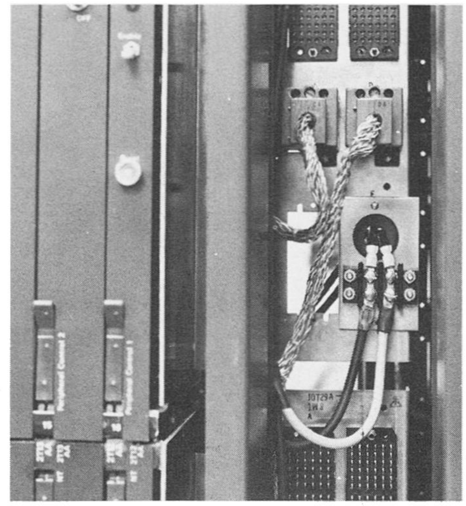


Figure 3. Each peripheral equipment shelf is provided with a wing panel to permit connection from the front of the equipment bay. This feature allows back-to-back lineups of the peripheral equipment, resulting in a considerable saving in floor space. There is an easily removable cover panel which protects the connectors exposed in the photograph.

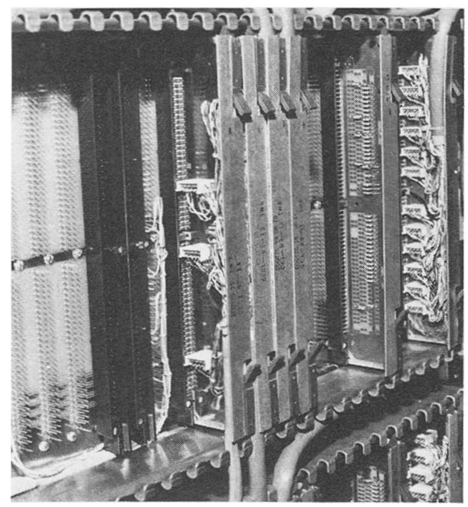


Figure 4. A number of paddleboards are shown protruding from the back of a common equipment shelf. The paddleboards are prewired to cables during manufacture and are easily plugged into the backplane at installation. They allow direct interconnection of various functional elements on the shelf, such as network and memory. The extensive use of paddleboards eliminated the costly development of a special connector. They permit flexibility in the assignment of signal leads — you can rewire or add components in the field, if necessary.

There are four types of equipment bays: common, peripheral, maintenance, and recorded announcement. About 2500 subscriber lines can be handled by the common equipment housed in a single bay. An additional bay containing network shelves covers growth to the maximum

Table 1 DMS-10 critical specifications

		SI units	Imperial units
Equipment frame			
Height		2.4 m	8 ft
Width		81 cm	32 in
Depth		38 cm	15 in
Equipment mounting centres		64.3 cm	25.3 in
Building requirements			
Ceiling height	(minimum)	2.7 m	9 ft
Floor area	(300 lines)	4.5 m^2	48 ft^2
	(6000 lines)	30 m^2	326 ft^2
Floor loading	(standard wiring aisle)	31 kg/m^2	63 lb/ft^2
	(back-to-back lineup)	43 kg/m^2	88 lb/ft^2
Heat dissipation	(standard wiring aisle)	430 W/m^2	40 W/ft^2
	(back-to-back lineup)	537 W/m^2	50 W/ft^2

Table 2 DMS-10 environment

	Transportation and storage	Normal operation	Extreme operation*
Ambient temperature (at sea level)	-50°C — 70°C	0°C — 35°C^{+}	0°C — 50°C^{+}
Relative humidity (at 26°C)	0 — 100%	20 — 80%	20 — 80%
Atmospheric pressure (altitude)	12 kPa min (15 km)	78 kPa min (2 km)	78 kPa min (2 km)
Shock (with equipment on pallet)	30 G		

*For maximum of 72 hours per incident or 15 days/year
$^{+}$Above sea level, the maximum temperature (T) is derated to T_A as follows:
$T_A = T_{MAX} - 2.2A$ where A = altitude (km)

of approximately 6000 lines. The peripheral equipment growth is provided by the addition of single bays, each housing up to six shelves. (Each shelf can hold up to 14 line, trunk or service circuit packs — typically 44 lines, six trunk circuits, four lines or two trunks per pack.) The third type, the maintenance bay, houses the power distribution, the ringing plant, tape shelf, alarm monitoring and other miscellaneous functions. And the fourth type of bay contains recorded announcement equipment. Figure 3 shows a special feature of a peripheral shelf that permits front access for connecting cables.

A special connector — a 'paddleboard' — was developed so that cables could be plugged in and removed from the rear of the common equipment. This was essential to allow for easy office extensions and changing customer needs. The paddleboard is connected to cables by wire-wrapping, and can then be plugged into a printed circuit board backplane, see Figure 4.

Since the majority of the equipment is mounted on printed circuit boards and supported by shelves with plug-in connectors permitting replacement in the field, the system is easy to maintain and extend.

The entire system is connectorized at the circuit pack, shelf, and interframe level with the exception of power and ringing connections. Intraframe cabling is provided in the factory in fixed lengths, thus minimizing the need for assembly in the customer premises.

Ready to ship

The system is assembled and the hardware fully tested in the factory prior to shipment. This procedure and the modularity of the system reduce the installation time of a typical office to one week using two installers. This includes installation of the power plant, main distributing frame, and batteries for backup power. Additional time is used for testing and putting the office into operation with real telephone traffic.

The mechanical structure is rugged to minimize shipping problems. Completely configured and tested bays are shipped with a full complement of printed circuit packs in place. The specially designed skid protects the equipment from damage during shipping. Any additional hardware is shipped with the basic equipment and installed simultaneously.

The entire assembly must meet the varied environmental conditions encountered in the field. Approximately six work-months were spent measuring temperature profiles and characterizing the thermal performance of the equipment. Design changes were made as the system evolved to improve the thermal behaviour so that the equipment could operate under extreme environmental and electrical conditions, and still meet the objectives for reliable service. (Complete environmental specifications are in Table 2.)

The final result of the careful packaging design has been illustrated by the features and successes described in the previous articles in this special issue. Telephone companies of all sizes, with the smallest rural community dial office or the larger urban exchanges, can now benefit from the economies and features of a DMS-10 digital switching machine.

*DMS is a trademark of Northern Telecom Limited

In 1966, **Frank Vallo** graduated from the University of Toronto with a BASc in electrical engineering. After a year and a half with Bell Canada special services in Toronto, Ontario, he went to McMaster University in Hamilton, Ontario, where he obtained his MEng degree in thin film active devices. In 1969, he joined Garrett Manufacturing in Toronto where he was a project engineer in the microelectronics group. In 1971, Frank joined Bell-Northern Research to work on hybrid microelectronics packaging, and later packaging of SL-1 terminals. Frank is currently manager of the DMS-10 equipment development group which is responsible for packaging the equipment as well as providing the interface between manufacturing and design. Frank's interests outside of BNR include furniture refinishing and model airplane construction. He is interested in solar energy for home heating and eventually hopes to build a sun-powered home. He also enjoys cross-country skiing and cycling.

Abstracts

The future arrives for the small switching office

Brian Voss, Brian Watkinson
Telesis, Vol 5 No 10, August 1978
pp 290-293

Switching systems have changed substantially over the last 50 years. Unfortunately, in recent times the small and rural community dial offices have not been able to take advantage of improvements in technology; indeed many of them are still using equipment introduced before 1950. This anomaly is largely the result of economics — modern computer controlled switching machines have been too expensive for small operations. With the introduction of DMS-10, this has all changed. This article outlines the history of switching equipment, and the objectives and features of DMS-10 which bring new cost effective digital technology to community dial offices.

The DMS-10 program: increasing the pace of development

Tony Stansby
Telesis, Vol 5 No 10, August 1978
pp 294-297

The DMS-10 digital multiplex system is a small stored-program digital local exchange covering the line size range from about 300 to 6000 lines. The product was developed from the conceptual stage to an in-service reality in 20 months. The evolution of a program plan to achieve this short interval, and some of the measures taken to reduce program risks, are described and early-life performance results obtained from the first two DMS-10 offices are presented.

Sophisticated features for the smaller switching centre

Las Lovas
Telesis, Vol 5 No 10, August 1978
pp 298-302

A wide variety of service and operating features is provided on the DMS-10 digital switching machine. A prime requirement for DMS-10 was that it should offer a comprehensive range of service features so that subscribers in smaller communities could enjoy the same degree of choice as their counterparts in larger settlements. The article describes the three main types of service features, that is, line, originating, and terminating features for subscribers' telephones. Next it discusses some of the more important operating features provided on DMS-10 for the telephone operating company. These include systems for taking operational measurements, for modifying office data, for applying diagnostics and for implementing maintenance and alarms. Most of the operating features are utilized through the man-machine interface, which is designed to optimize communication between operating company personnel and the switching machine's control equipment.

DMS-10 system organization

Les Rushing, Gino Totti
Telesis, Vol 5 No 10, August 1978
pp 303-308

The overall system architecture is designed for low initial cost and unattended operation. This article describes the essential features of the control, network and peripheral equipment, with both organization and execution briefly explained.

Software: source of DMS-10 intelligence

Greg Mumford, Dick Swan
Telesis, Vol 5 No 10, August 1978
pp 309-315

This article outlines some of the requirements and constraints on the DMS-10 software, and the resulting design decisions made. The software is functionally separated into modules, each responsible for a function or set of functions. Some of the modules process calls (call processing logic) while others comprise the interface with peripheral circuits within the switching machine (device driver logic). This separation makes for a modularity that minimizes overhead, retains flexibility for the evolution of the system, and reduces development effort in the designing company. Operation is based upon the reception of messages stimulated by 'events' in the peripheral circuits (eg an off-hook signal). The processing of a typical telephone call is demonstrated as seen from the software point of view.

Putting it all in a package

Frank Vallo
Telesis, Vol 5 No 10, August 1978
pp 316-319

DMS-10's innovative electronics and system design are matched by economic and flexible packaging. Since the system is designed to serve central offices with as few as 300 subscriber lines, and up to 6000 lines, it was necessary to construct and package it such that it would be economical at all sizes — and still easy to grow. This article discusses the nature of the problems in packaging DMS-10 and how they were solved, producing a flexible, modular design with the pleasing appearance characteristic of the DMS family of digital switching machines.

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Bell-Northern Research Ltd is a subsidiary of Northern Telecom Ltd, the multinational telecommunications manufacturer, and is jointly owned by Northern Telecom Ltd and by Bell Canada, the major telephone operating company in the provinces of Ontario and Quebec. BNR, which is Canada's largest industrial research and development organization, has a wholly-owned subsidiary in the USA, BNR INC. The aim of Telesis, the BNR bimonthly technical journal, is to portray telecommunications progress from the viewpoint of this tricorporate group for an international audience in telecommunications and related industries, the scientific community, and other interested sectors.

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