

The 5ESS Switching System:

Applications Planning

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The *5ESS*[™] system is designed for switching applications in rural, suburban, and metropolitan areas. It can function as a local, local/toll, or toll switch, and has features that make it suitable not only for use in the United States but in almost all countries. The modular design of the switch makes it particularly useful for solving wire center and network problems. This article discusses methods for solving such problems and presents some economic study results demonstrating the savings that can be achieved.

I. INTRODUCTION

The *5ESS* system represents a major step in switching system architecture evolution.¹ Using distributed control, modular hardware and software, and integrated electronics, the *5ESS* system makes possible the integration of digital interoffice trunk facilities, digital carrier subscriber loop systems, and digital switching. Its modular design provides remote switching systems for small office applications. An integrated operator service position system is planned to round out the complete set of switching features.

Figure 1 gives a pictorial description of the various applications displayed over a large geographical area. The applications include

1. Local office growth and modernization
2. Access tandem, and operator services
3. Toll office growth and modernization
4. Small office modernization via remote switching
5. New wire center via remote switching

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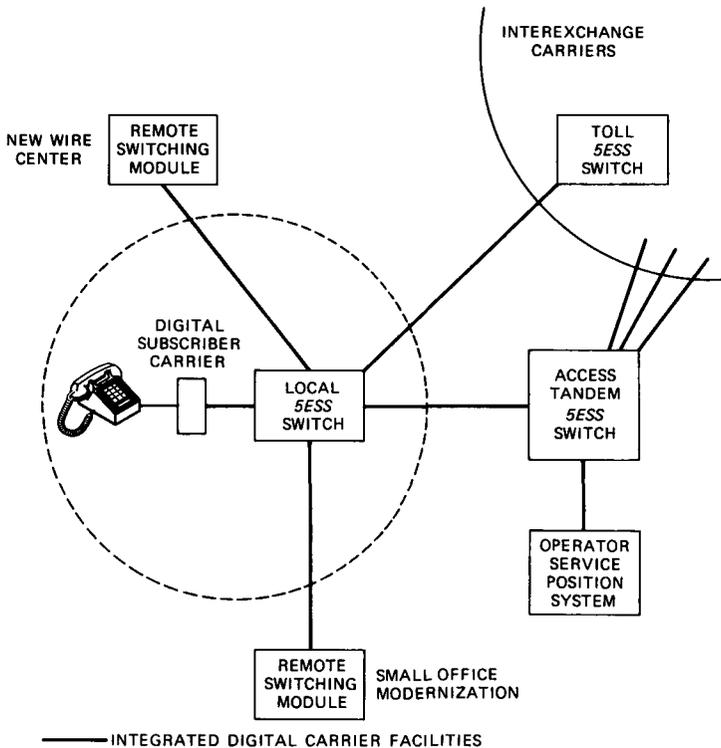


Fig. 1—5ESS switch applications.

6. Integrated digital subscriber carrier systems

7. Integrated interoffice facilities via digital carrier.

Digital synergies between loop, switching, and interoffice transmission technologies are changing network planning methods.² Traditionally, the network planning process was perceived as a collection of related but essentially noninteracting disciplines, each of which was responsible for the evolution of a particular network function (subscriber network, local switching, interoffice facilities, toll switching, or operator services). As Fig. 2 illustrates, the communication among these disciplines was often limited to an exchange of completed plans. Such an exchange would ensure, for example, that a planned rehousing of an end office from one toll center to another was made known to those who were planning for the affected interoffice facilities. The process of developing the plan, however, was typically limited to a single discipline.

Such an approach was justified in an environment where the network technology was characterized by well-defined boundaries among the various functions. However, the advent of integrated interfaces between switching systems and digital loop and trunk facilities has

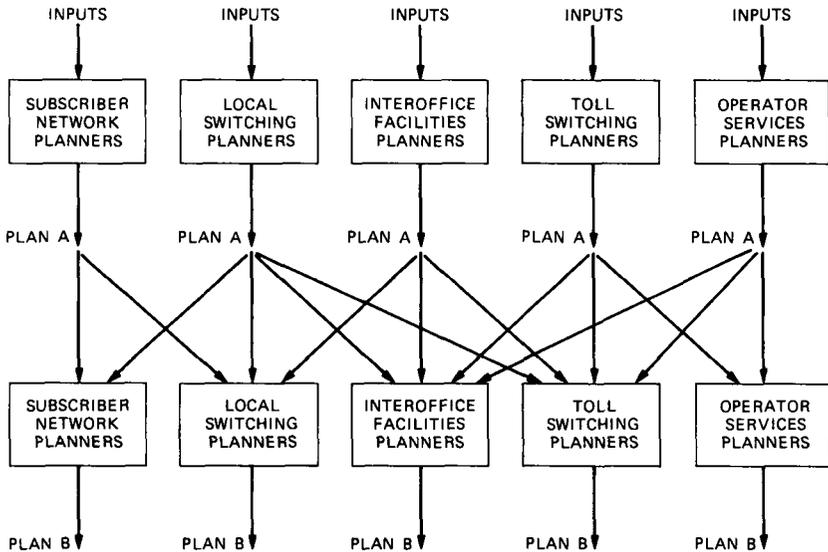


Fig. 2—Traditional approach to planning process.

forced joint-area planning studies. Remote switching, which requires a host office for centralized administration, a change in trunk routing patterns, and oftentimes a change in interoffice facilities, necessitates further joint planning studies. Figure 3 gives a broad overview of the process by which two or more planning disciplines join together for a common study. It is important to point out that most often these

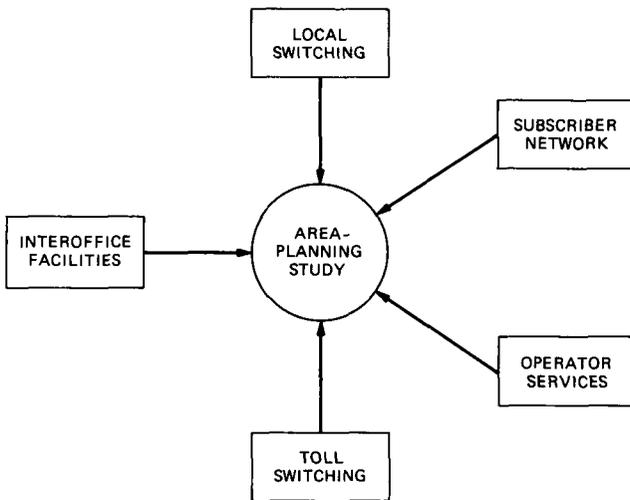


Fig. 3—Area-planning approach to planning process.

studies are made pairwise between disciplines, e.g., local switching and subscriber network, local switching and interoffice facilities, or toll switching and interoffice facilities. This process concentrates on the important interactions between disciplines, avoiding simultaneous study of all disciplines in great detail. The major elements in such a study include

1. Recognizing the problems, formulating alternative solutions, and coordinating assumptions with related disciplines.
2. Assessing which interactions (if any) are likely to be significant
 - a. Performing a conventional, noninteractive study in those cases where no significant interactions are identified, or
 - b. Performing interactive studies involving two or more disciplines as needed, where interactions do exist.
3. Documenting the conclusions and obtaining project approvals, where all affected organizations give their concurrence to the resulting plan.

Joint-area planning studies between disciplines have placed renewed emphasis on estimating total life-cycle costs of various network alternatives over the planning horizon. Not only should the initial cost of equipment be considered, but ongoing growth costs, operations expenses, administration expenses, maintenance expenses, building additions, distributing frame expenses, rearrangement expenses, and revenue from potential new services all contribute to identifying and evaluating the best network solution.

The remaining sections of this paper describe 5ESS switch applications in more detail. Section II covers the application of integrated subscriber carrier and interoffice facilities for a single wire center. Sections III and IV cover the applications and interactions involved in network area planning. Section V discusses the application of the 5ESS system in metropolitan areas.

II. WIRE CENTER AREA PLANNING USING THE 5ESS SWITCH

As previously described, traditional local switching modernization studies were directed at comparing various switch replacement alternatives for individual wire centers. The modeling boundaries separating the local switch from the subscriber loop and interoffice facilities studies are shown in Fig. 4. Important factors included in these wire center modernization studies were switching equipment costs and capacities, maintenance costs, land and building costs, and feature availability.

2.1 Integrated subscriber carrier system planning

When modernization studies involve the 5ESS switch as a replacement alternative, additional factors must be considered. Consider Fig.

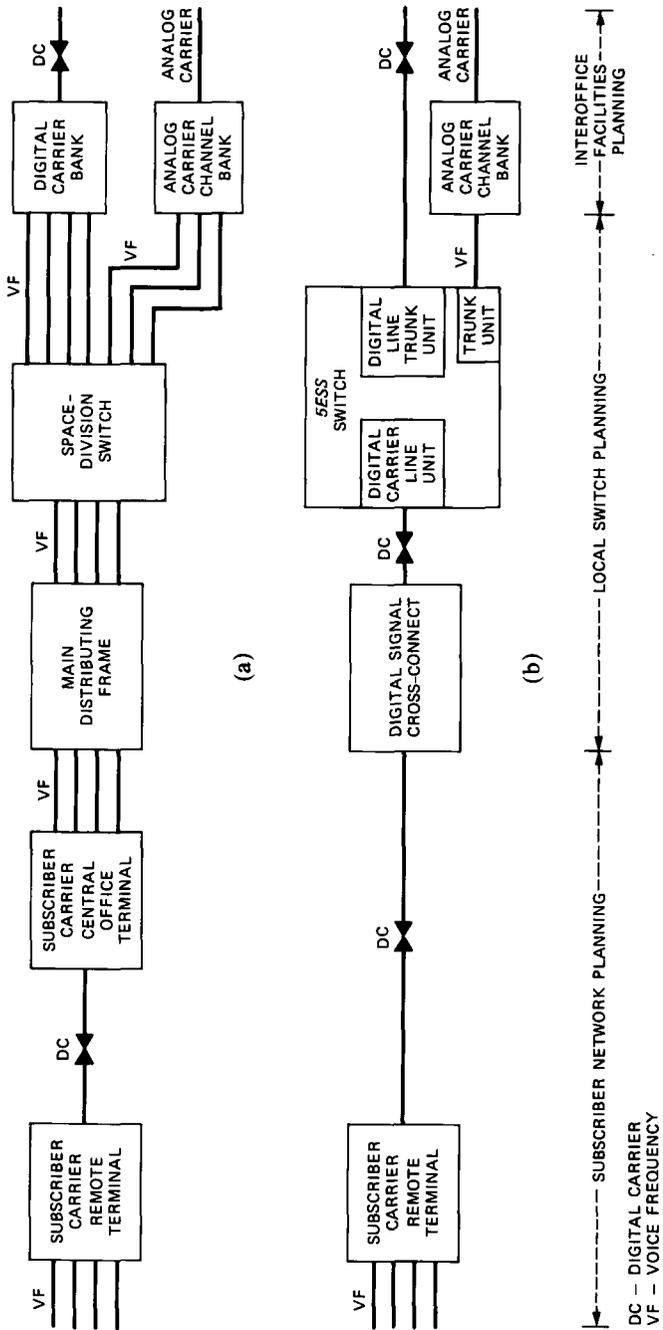


Fig. 4—5ESS switch integrated digital interfaces.

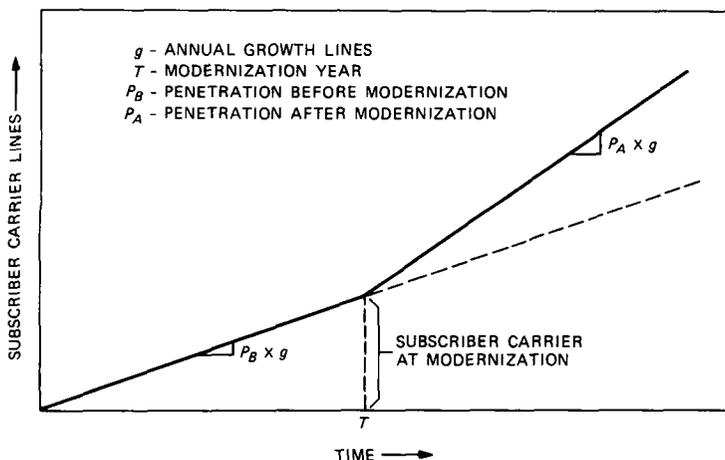


Fig. 5—Increased subscriber carrier penetration after modernization.

4, which shows a comparison of nonintegrated and integrated switching and transmission interfaces. Figure 4a shows that the main components of a subscriber carrier system in a conventional (nonintegrated) interface with an analog switch include the Remote Terminal (RT),* Digital Line (DL), and Central Office Terminal (COT). In contrast, Fig. 4b shows that the need for COTs is eliminated when interfacing a digital subscriber carrier system (such as the SLC® 96 carrier) with the 5ESS system. The digital links from the RT terminate directly on a digital interface called the digital carrier line unit of the 5ESS system. This arrangement obviates the need for individual subscriber line terminations on the Main Distributing Frame (MDF) and line terminating equipment on the switch.

Since the per-line termination cost of a subscriber carrier system is reduced when integrated with the 5ESS switch, application of such systems can be economically justified in more areas. The increased penetration of the subscriber carrier systems illustrated in Fig. 5, at the time of modernization, results in additional savings by avoiding cable expansions and related structure costs. (See Refs. 3 through 6 for a detailed description of subscriber planning methods.)

In summary, the incremental capital-savings-per-growth line realized through termination of subscriber carrier systems directly on the 5ESS switch versus termination on a central office without this capability is made up of the following five components:

1. Analog line termination savings
2. Reduced MDF termination costs
3. Elimination of the COT

* Acronyms and abbreviations used in the text are defined at the back of the *Journal*.

4. Reuse credit for the COTs displaced at the time of modernization
5. Less distribution cable and structure (minus additional subscriber carrier electronics costs).

In addition, opportunities for reducing maintenance costs arise as a result of eliminating the COTs and reducing MDF frame activity for those working lines served by an integrated digital subscriber carrier system.

2.2 Integrated digital facility planning

Similar opportunities for cost reductions exist when terminating digital carrier interoffice trunks directly on the 5ESS system. Referring again to Fig. 4, in the case of central offices with no integrated interface to digital facilities, digital carrier trunks terminate on digital channel banks and analog carrier trunks terminate on analog carrier banks. In the case of a 5ESS switch, analog trunks terminate via analog channel banks and the 5ESS trunk unit. For digital carrier trunks, the need to provide digital channel banks is eliminated and these trunks terminate directly on the Digital Line Trunk Unit (DLTU).

Potential savings from digital carrier integration on the 5ESS system are a function of the facility strategy assumed at the time of modernization. The options include the following:

1. Continue the planned analog and digital trunk penetrations regardless of replacement switch type. This is typical of traditional planning studies.
2. Place all growth on digital facilities after the year of modernization but leave the existing analog plant in place.
3. Place all growth on digital facilities and replace existing analog carrier facilities with digital carrier in the year of modernization. This is the most aggressive digital strategy.

The major savings associated with integrated digital carrier on the 5ESS system can now be summarized as follows:

1. Switch termination savings, i.e., the lower cost of terminating trunks on a DLTU versus terminating trunks on an analog interface.
2. Elimination of the need to buy digital channel banks for growth and the associated maintenance savings.
3. Reuse of the existing digital channel banks at the time of modernization.
4. Elimination of the need to purchase new analog carrier banks and the associated maintenance savings for facility strategies 2 and 3 outlined above. In addition, maintenance of existing analog carrier banks is eliminated under strategy 3.

Other considerations include reduced trunk testing costs associated with integrated digital carrier and additional rearrangement costs

incurred at the time of modernization for segregation of digital special-service circuits that are not integrated with the switch.

2.3 An example wire center planning study

As an example, consider a crossbar local/tandem switching system with the following characteristics:

1. Size: 20,000 lines, 4000 trunks
2. Growth per year: 1000 lines, 300 trunks
3. Twenty-five percent of the growth lines are being placed on subscriber carrier systems each year to handle cable exhausts and subscriber line growth beyond 18,000 feet from the wire center. Ten percent of the lines are presently on the subscriber carrier.
4. Fifty percent of the trunks are presently served by digital carrier and 50 percent by analog carrier.

Consider replacing this entity with the 5ESS local/tandem system in 1985. We want to compare this with the Present Method of Operation (PMO), which involves growing and maintaining the existing equipment to meet the new demands. The cost of the PMO in terms of first cost, life-cycle costs, and revenue requirements is a useful reference for comparing alternative plans.

The lower-cost integrated interfaces with digital subscriber carrier systems drop the subscriber carrier prove-in distance, after replacement, from 18,000 feet to approximately 12,000 feet from the wire center. Sixty percent of the new line growth demand can then be placed on subscriber carrier. Similarly, because of the integrated interface to digital carrier trunks, 100 percent of the new trunk growth is placed on digital facilities (strategy 2, discussed in Section 2.2).

Figure 6 shows an economic comparison of the two alternatives. The modernization plan using the 5ESS switch is approximately 30 percent less costly in terms of life-cycle costs. Note that the integrated interfaces account for almost 80 percent of the net savings when comparing these two plans. Additional revenues result from Custom Calling Services and enhanced Centrex service offerings. In the past, large-scale studies performed by AT&T with the Operating Telephone Companies (OTCs) showed the switching/transmission synergies to be significant. In particular, South Central Bell developed a company-wide modernization plan for 240 step-by-step and crossbar entities in their regions.⁷ The overall results showed that 16 percent of the total network savings were attributable to these synergies. The effect of the digital synergies is largely a function of the subscriber carrier and interoffice facility digital strategies.

2.4 New wire center planning using the remote switching module

The Remote Switching Module (RSM) is a 5ESS switch module that is geographically separated from a host 5ESS switch. The RSM

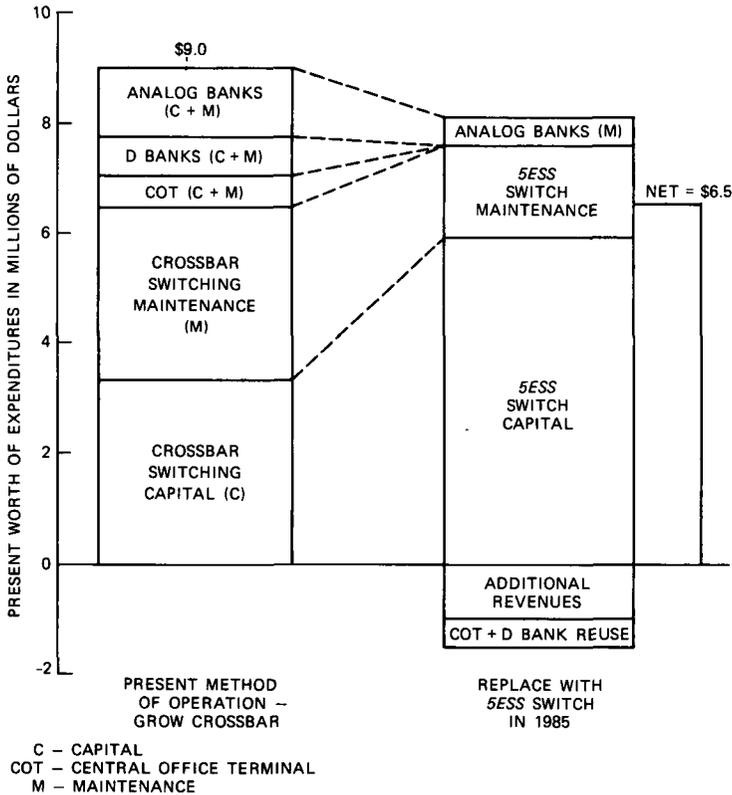


Fig. 6—Twenty-year life-cycle analysis.

module is linked to the host 5ESS switch via digital carrier facilities. Reference 1 discusses the architecture of the RSM. The RSM is an ideal candidate for new wire centers and replacement of small step-by-step or crossbar switches.

When used to switch lines alone, the RSM can currently serve up to 4000 lines. Later in 1985, this capacity will be increased to 12,000 lines. It is possible to switch all traffic not contained completely within the RSM through the host 5ESS switch. This approach is economical for small wire centers with small amounts of traffic to neighboring centers. The cost of the longer transmission path through the host is balanced by the higher traffic efficiency of larger trunk groups, and the elimination of trunk administration and maintenance costs at the RSM site.

However, an RSM can interface with analog and digital lines and trunks in the same way as a 5ESS switch. Terminating analog or digital trunks on an RSM is often important for small offices offering Extended Area Service (EAS), where large volumes of interoffice traffic justify direct trunk groups to many adjacent class 5 offices.

Integrated digital subscriber carrier is also an important feature of an RSM. Subscriber carrier systems are more widely used in the remote locations for which RSMs will often be considered.

The RSM brings to the small office market all of the features offered by the *5ESS* switch, including new business and residence features. The RSM offers the wire center planner the following benefits:

1. The RSM can share the office code (NNX code) of the host office.
2. The RSM is administered and maintained centrally through the host switch. This reduces the staff requirements at the remote wire center.
3. The RSM architecture can grow from a single-switch module (serving up to 4000 lines) to a larger remote system with multiple-switch modules (serving 12,000 or more lines).
4. The RSM can grow into a *5ESS* switch by adding an administrative module and a communications module.
5. A *5ESS* switch can be converted to an RSM if a second *5ESS* switch is located within hosting range (approximately 100 miles, depending on transmission media).

The application of the RSM to a small but rapidly growing community is illustrated in Fig. 7.

III. NETWORK PLANNING USING THE *5ESS* SYSTEM

As discussed in Section II, the *5ESS* switch, coupled with digital subscriber carrier systems and digital interoffice facilities, provides new solutions to wire center evolution problems. The advantages of the *5ESS* switch are equally effective for those planning the evolution of a network⁸ of local switches, tandem and toll switches, new wire centers, operator services, and the operations systems and centers that administer and maintain the network.

The principal benefits that the *5ESS* system offers to network planners are the following:

1. Remote switching. The RSM is a low-cost alternative to small office modernization that offers all the revenue potential of a *5ESS* switch. Because RSMs are monitored and administered through a host switch, the operation expenses of RSMs are much lower than stand-alone switches.
2. A remote switch that can grow into a *5ESS* switch. This keeps the getting-started cost low for small offices with a high growth potential. It provides the planner with a switch that can grow into a stand-alone switch when growth actually occurs, and provides safeguards for areas where growth rates turn out lower than expected.
3. An integrated Operator Service Position System (OSPS). The

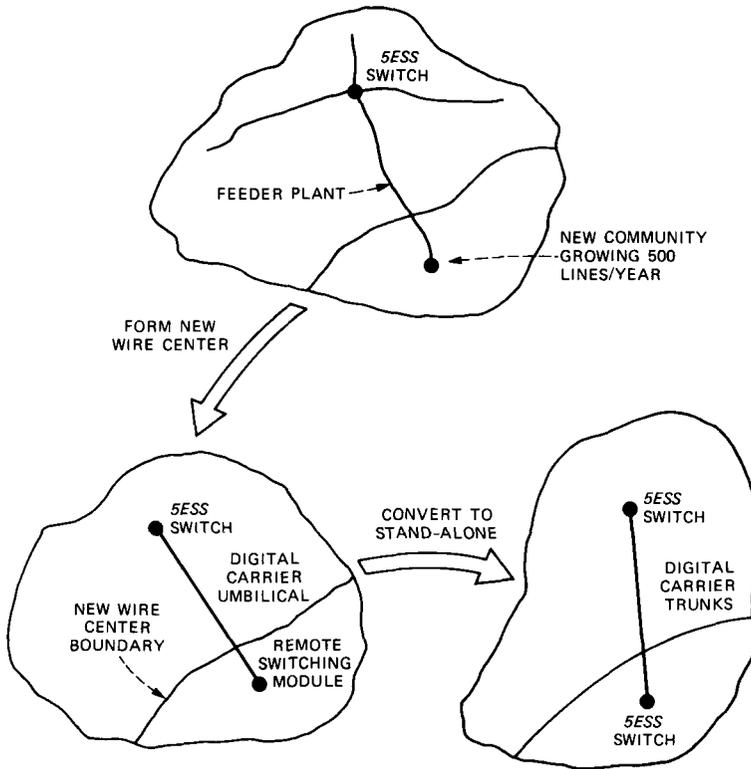


Fig. 7—Application of a remote switching module to a new wire center.

presence of OSPS will allow modernization and expansion of operator services when tandem and toll offices are considered for modernization. Since OSPS will be fully integrated into the toll and tandem 5ESS switch, Operations, Administration, and Maintenance (OA&M) costs are reduced compared to a stand-alone operator system.

4. An integrated digital subscriber carrier (SLC 96 carrier) interface. This lowers the cost of deploying pair gain systems and provides an inexpensive solution to cable exhaust problems. In addition, several integrated subscriber carrier systems can be used to modernize very small Community Dial Offices (CDOs).

5. An integrated interface to digital carrier facilities. This lowers the cost of upgrading Voice-Frequency (VF) and analog carrier systems to a digital carrier.

6. Tandem and toll capabilities that allow the switch to serve as a combined local/tandem, pure tandem, or pure toll switch.

7. Remote toll and tandem switching capability. The RSM can be used as a small toll or tandem switch to serve inter-LATA (Local

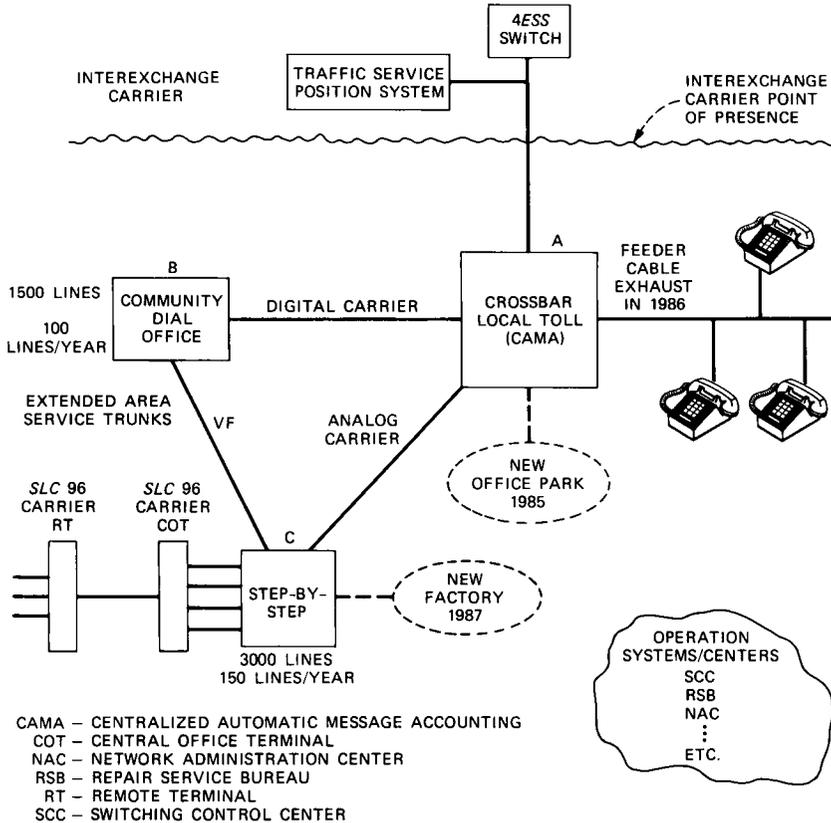


Fig. 8—A sample network planning problem.

Access and Transport Areas) or intra-LATA traffic in those areas where a stand-alone toll switch cannot be economically justified.

8. Integrated Services Digital Network (ISDN) capabilities. Integrated digital interfaces to digital loop and digital trunk facilities are leading to an integrated digital network. End-to-end digital services are being added to the network, providing new voice and data service revenues to the telephone companies.

The complexity of a network planning study varies with the size of the network being considered and functions included in the plan (e.g., operator services or tandem switches.). Such a study can be as small as a network of two or three interconnected switches or as large as the entire telecommunication network for a large city. To illustrate the application of the 5ESS system to network planning, consider the network shown in Fig. 8. Assume that a group of OTC network planners have the responsibility of planning the evolution of this intra-LATA network and have the following objectives:

1. Modernize the entire network to provide new revenue-producing services to existing residence and business customers.
2. Introduce operator services into the exchange network.
3. Provide up-to-date business services to the new office park and factory.
4. Minimize the cost of the projected feeder cable exhaust in 1986.
5. Reduce OA&M costs.
6. Keep the economic impact on the rate payer (revenue requirements) as low as possible.

The network planner is faced with many possible approaches to the network problems in terms of network products and the timing of the network evolution steps. Typically, the network planners must examine many solutions to find the one that comes closest to satisfying all of the objectives. As discussed previously, one plan included in most network studies is the PMO. Although few of the planning objectives can be met with the PMO, the cost of the PMO is included for reference. One solution the planner might consider is shown in Fig. 9. The network is modernized over six years as follows:

1985

1. Replace the crossbar at office A with a new digital switch.
2. Lay a new feeder cable to office A.
3. Add a new operator service system.
4. Upgrade the facility between A and C to digital.
5. Add digital carrier banks at office C.
6. Establish a new wire center and switch at the office park.
7. Expand the operation center to support the new wire center and operator system.

1987

1. Replace the step-by-step at office C with a digital switch.
2. Remove digital carrier facilities from office C and reuse at office B.
3. Convert the VF facility between B and C to digital.
4. Expand the feeder cable to the new factory.

1990

1. Replace the 2000-line CDO at office B.
2. Remove digital channel banks.

Note that two feeder routes had to be expanded, the CDO at office B was too small to justify replacement until 1990, and the operation support centers and systems had to be expanded to support the new operator system and the wire center at the office park.

One possible approach using the 5ESS system is shown in Fig. 10. The network is modernized over three years as described below:

1985

1. Replace crossbar at office A with a 5ESS switch.

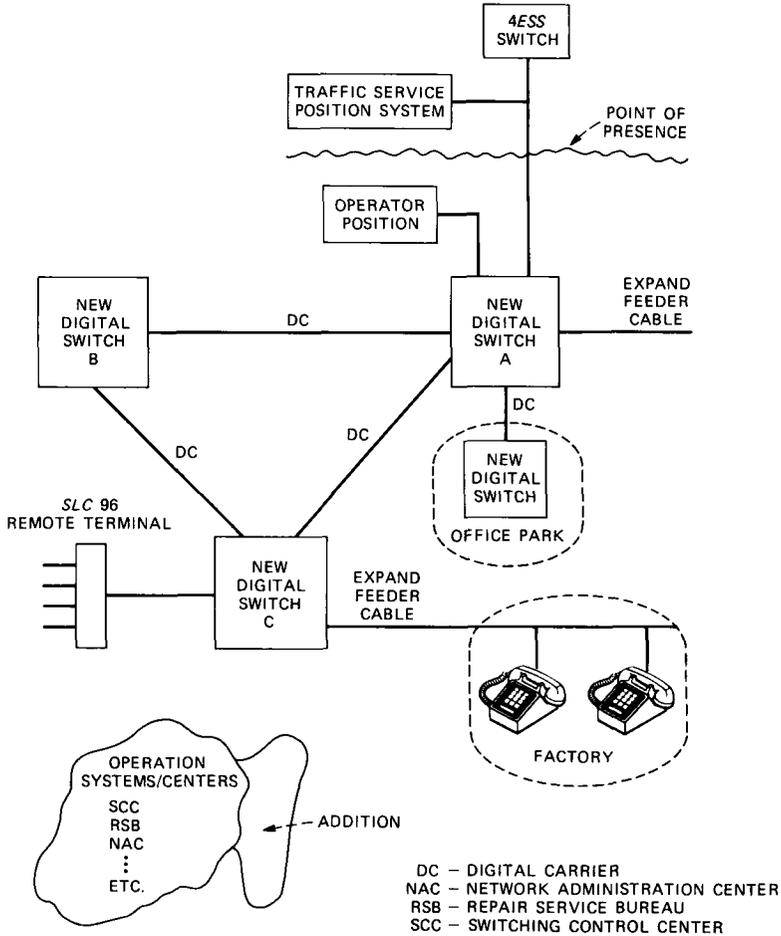


Fig. 9—Network plan 1.

2. Upgrade the facility between office A and C to digital.
3. Replace step-by-step at office C with an RSM (begin collecting new service revenues).
4. Replace CDO at B with an RSM (begin collecting new service revenues).
5. Upgrade the facility between B and C to digital.
6. Add RSM in the office park.
7. Reduce operation center staff due to consolidation of operations support of offices B and C at office A.

1986

1. Deploy integrated SLC 96 carrier from office A to avoid feeder exhaust.

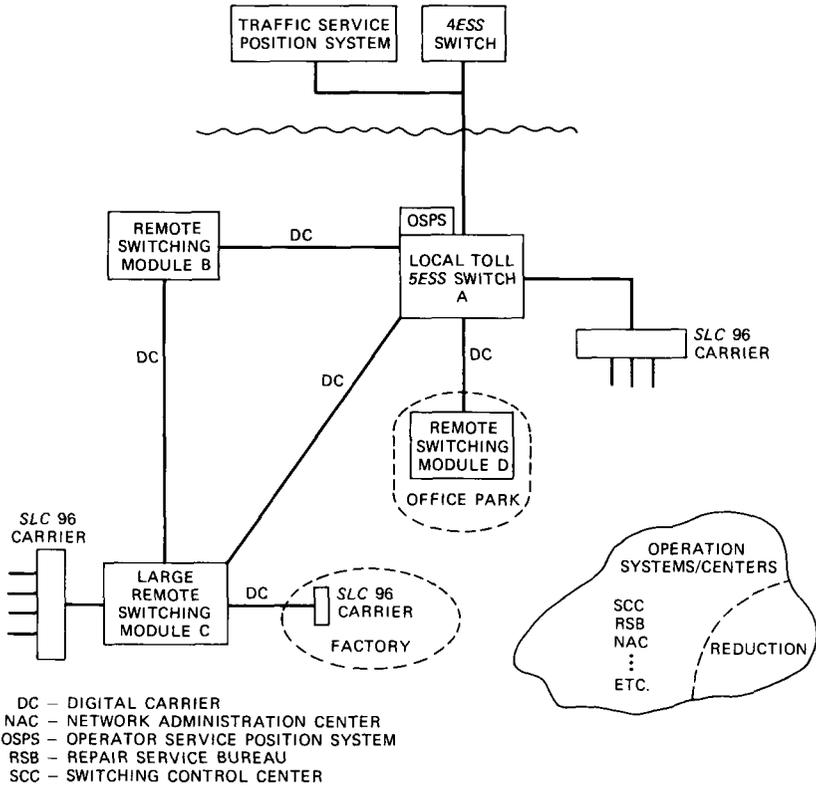


Fig. 10—Network plan 2—applying the 5ESS switch.

1987

1. Deploy integrated SLC 96 carrier at the new factor to avoid feeder cable expansion.
2. Expand 5ESS switch at office A to include operator function.

All offices are replaced in 1985 to achieve maximum new revenue potential and to avoid unnecessary purchases of nonintegrated digital channel banks. If capital constraints in 1985 prevent modernization of all offices in one year, offices B and C could be scheduled in later years. Since the RSMs in B, C, and D, as well as the operator system at A, are operated and administered through the 5ESS switch at A, the load on operation center staff and the operations support systems will be reduced. Feeder exhausts in 1986 and 1987 are avoided by using integrated subscriber carrier systems. The 5ESS system allows all business features to be extended over the subscriber carrier lines to the new factory location. Note that the RSM at offices B and C can either continue to direct trunk the EAS traffic or route traffic through the host 5ESS switch.

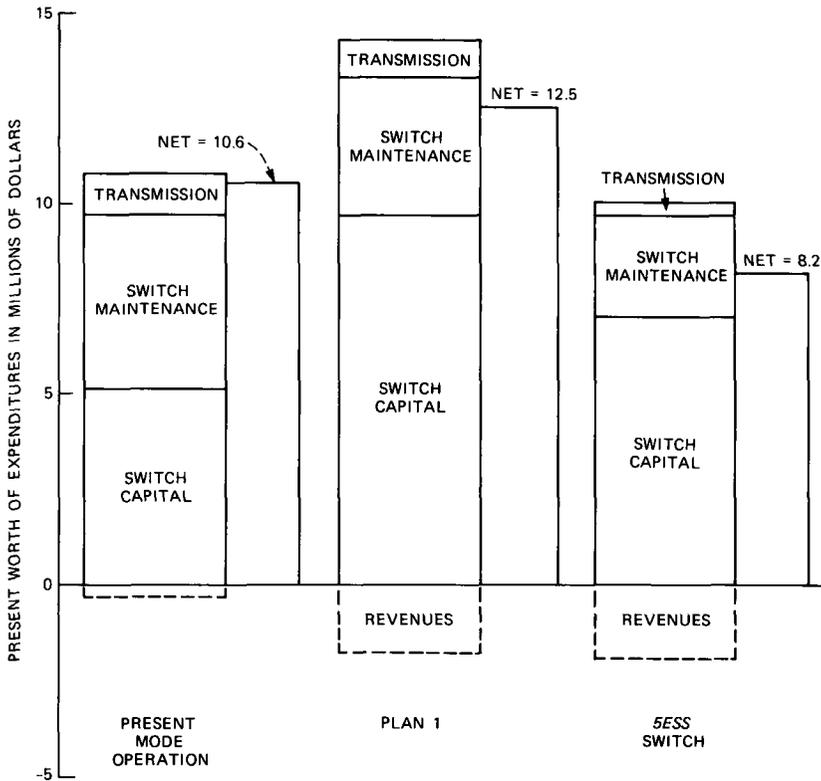


Fig. 11—Life-cycle economic analysis (1984–2000).

To evaluate the alternative network evolution planning strategies, it is necessary to use life-cycle economic techniques together with annual capital constraints. A first-cost analysis could point to solutions that in the long term are far from optimum. As an example, Fig. 11 shows an economic comparison of the three alternatives considered. The 5ESS system alternative is the least costly alternative over the study period. While the switching capital is greater than the PMO, the plan realizes more new service revenues from the earlier modernization of the offices, and significantly lower maintenance and administration expenses. The 5ESS system plan also avoids the capital cost associated with feeder route expansions. Note that the first plan with all stand-alone digital switches is not economically preferable to the PMO.

IV. OTHER NETWORK APPLICATIONS

In addition to solving local network problems as illustrated in Section III, the 5ESS switch can be used in pure toll networks and to implement an access tandem network.

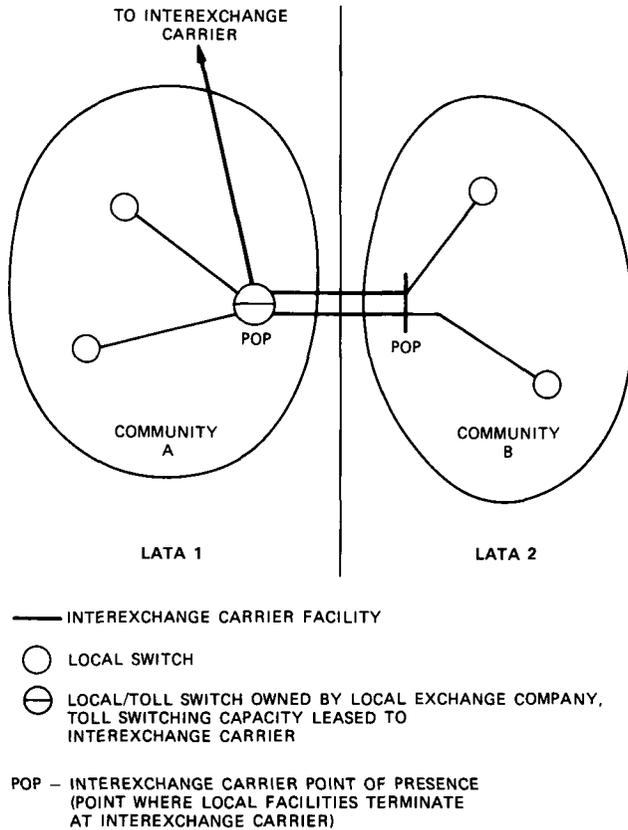


Fig. 12—A sample inter-LATA network.

4.1 Toll networks

Toll switches are used by Interexchange Carriers (ICs) to transport traffic between LATAs. The *5ESS* switch with its complement of toll features and its distributed architecture can provide new solutions to toll switching network problems. As an example, consider the network shown in Fig. 12. As a result of the Bell System divestiture, communities A and B fell on different sides of a LATA boundary. An IC is therefore required to provide service between them, according to divestiture rulings, and is leasing toll switching capacity and facilities from local exchange companies. Communities A and B are forecasted for continued growth and the local/toll switch is planned for replacement by the local exchange company. The IC wishes to establish a separate toll switch to handle larger forecasted toll traffic volumes. However, current traffic levels do not justify a large switch. An RSM serving as a small toll switch is a good candidate and is shown in Fig. 13. This need for small toll switches is common along LATA boundaries and along

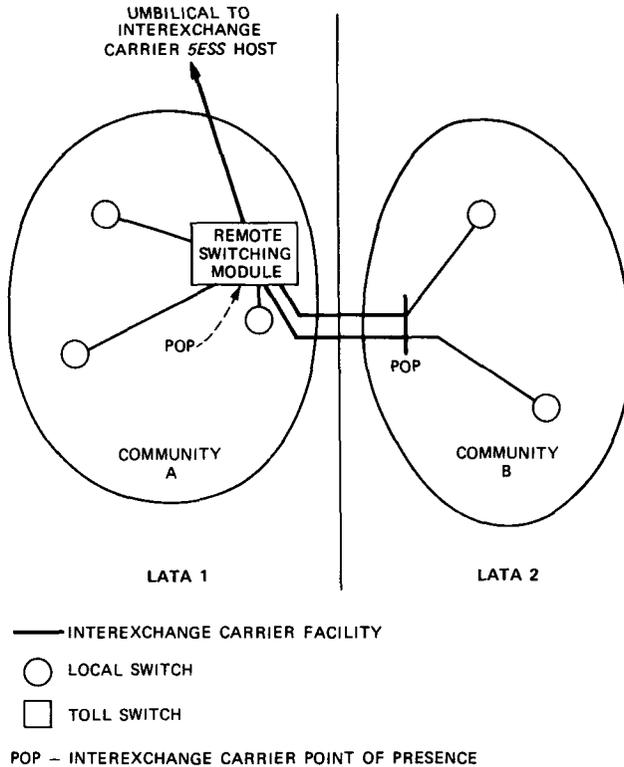
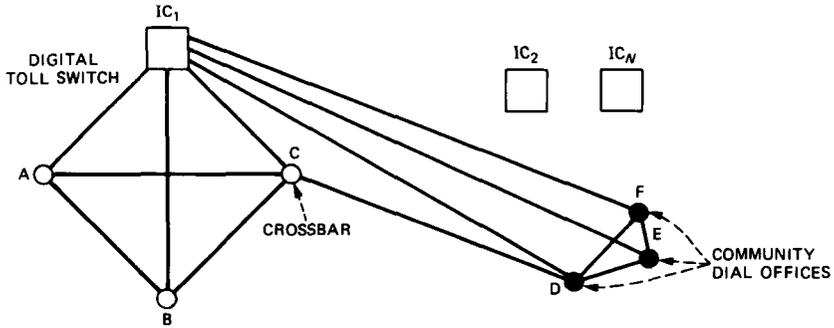


Fig. 13—Applying the 5ESS switch to an inter-LATA network.

international boundaries where nearby towns have strong communities of interest but lie in different toll areas.

4.2 Tandem networks

A primary need of telephone companies in the postdivestiture environment is for access tandem switches. These switches serve as an interface between the local switches and ICs. Access tandems concentrate the interexchange calls from local offices and route these calls to the proper IC. Consider the network shown in Fig. 14. Today the network consists of six local switches, each having toll trunks to a digital toll switch owned by IC_1 . IC_2 through IC_N also wish to provide service. The telephone company can put in trunks from each local switch to each IC or it can establish an access tandem network. Unless the traffic between each local switch and IC is initially large, direct trunk groups are difficult to justify economically. Indeed, if the traffic to the ICs—other than IC_1 —is small but growing, significant savings can be realized by sending this traffic to a tandem where all

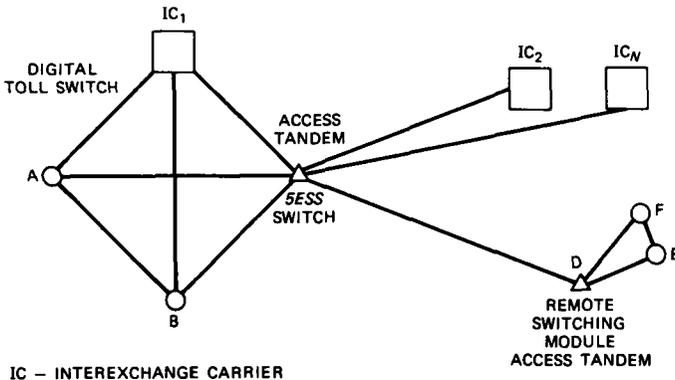


IC - INTEREXCHANGE CARRIER

Fig. 14—A sample access tandem network.

the traffic for ICs is consolidated and then trunked. In our example, we will replace office C with a 5ESS switch and establish it as an access tandem. In addition, we will replace the small CDO at office E with an RSM and it too can serve as an access tandem. The result is shown in Fig. 15.

Note that some of the larger local offices shown will continue to trunk traffic to IC₁ over direct groups, since the amount of traffic can justify direct trunking. All local switches, however, use the 5ESS switch (directly or via the RSM) to access IC₁ through IC_N. In fact, some of the smaller offices now use the access tandem to route traffic to the digital toll switch of IC₁. This solution saves significant facility costs, helps modernize the local switches, and provides for an efficient tandem switching structure that can flexibly accommodate uncertain, yet growing, IC traffic demands.



IC - INTEREXCHANGE CARRIER

Fig. 15—Applying the 5ESS switch to access tandem network.

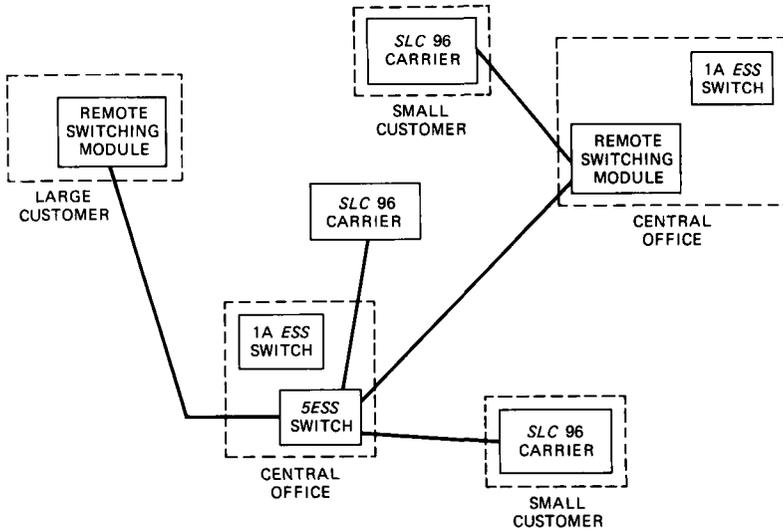


Fig. 16—Digital access networks.

V. MODERNIZING METROPOLITAN AREAS

Many metropolitan areas are dominated by the presence of the 1ESS™ and 1A ESS systems, which have replaced most of the large electromechanical offices in these areas. These are advanced stored program control switches with a rich set of business features. One might be led to conclude that the application of the 5ESS switch to these areas will consist of completing the replacement of the remaining electromechanical switches. However, the following are two additional types of application for which the 5ESS system is ideally suited:

1. Deployment of digital access networks
2. 1ESS system replacement.

5.1 Digital access networks

A digital access network is an overlay network consisting of the 5ESS system, digital loops, and digital remote switches. Figure 16 illustrates the concept. The objective is to locate new technology where it is needed, to provide ubiquitous access to digital networks for any customer in the area, and to provide a cost-effective and minimum-capital solution without requiring the replacement of Stored Program Control (SPC) technology.

This technique may become more popular in the future with the development of optical remote modules, where fiber lightguide interconnects the hosts and remotes and where fiber is extended into the loop plant with such systems as Fiber SLC 96 carrier. The trend in some metropolitan areas is towards fiber backbone routes and fiber

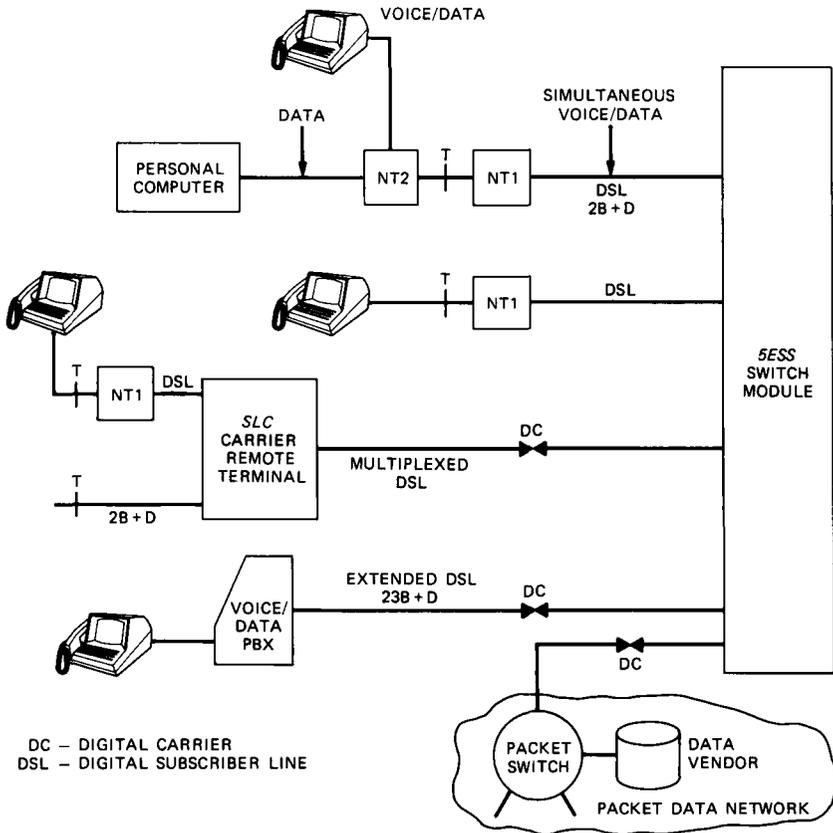


Fig. 17—ISDN access arrangements.

rings. This trend coupled with optical remote switches will accelerate the deployment of digital access networks.

The initial applications of the 5ESS switch will be replacements of those electromechanical systems that are colocated with other SPC switches. Rather than replacing them by consolidation with the SPC switch, the 5ESS switch technology can be placed in the existing SPC wire center. From here the digital access network will begin.

5.2 1ESS system replacement

Many 1ESS systems are relatively small, but are experiencing growth. They demand new features and capabilities available only on the 1A ESS system or new time-division digital systems like the 5ESS switch. In these instances, with high subscriber carrier penetration, and the ability to reuse the line and trunk link networks of the 1ESS system, the replacement of the 1ESS system can be economically justified.

5.3 Evolving the network towards ISDN

The 5ESS system, with its integrated digital interfaces to subscriber carrier systems and to digital carrier trunks, is helping to lead the way to an ISDN where there are no analog to digital conversions. When end-to-end digital services are added to this network, the ISDN can be realized. ISDN interface standards are being defined by the International Telegraph and Telephone Consultative Committee (CCITT) and by the Exchange Carrier Standards Association. Figure 17 shows the potential access arrangements for Digital Subscriber Lines (DSLs), extended DSLs to digital private automated branch exchanges, and multiplexed DSLs over integrated subscriber carrier systems. Current 5ESS switch plans call for development of ISDN capabilities that incorporate both circuit switching for voice traffic and packet switching for data traffic. These capabilities will lead the way to simultaneous voice and data applications across the network, accelerating the trend towards end-to-end digital networks and services.

VI. CONCLUSION

This paper demonstrates that the 5ESS switching system provides planners with the major building blocks needed to evolve today's network into a digital network offering end-to-end digital services. The modularity of the 5ESS system design, coupled with the ability to distribute control to remote switching modules, offers new low-cost solutions to long-standing network problems (e.g., small office modernization). It provides new ways to affect the evolution of the entire telecommunications network (e.g., local switching network, access tandem networks, interexchange carrier network, operator services). Low-cost interfaces between the 5ESS switch and digital loop systems and digital transmission facilities allow network planners to convert the network from analog to digital gracefully.

REFERENCES

1. D. L. Carney et al., "The 5ESS Switching System: Architectural Overview," AT&T Tech. J., this issue.
2. W. M. Ohnsorg, "Overview of Planning for the Application of New SPC Switching Technology in the Bell System," Nat. Telecommun. Conf., Washington, D.C., 1979.
3. B. Bulcha et al., "Feeder Planning Methods for Digital Loop Carrier," B.S.T.J., 61, No. 9 (November 1982) pp. 2129-41.
4. B. Bulcha et al., "An Area Planning Methodology for Wire Centers," Nat. Telecommun. Conf., Washington, D.C., 1980.
5. A. J. Ciesielka, D. H. Morgen, and G. P. O'Reilly, "Planning for the Integrated Local Digital Wire Center," Nat. Telecommun. Conf., Washington, D.C., 1979.
6. A. J. Ciesielka and D. C. Douglas, "Electronics in the Suburban and Light Urban Loop Networks, B.S.T.J., 59, No. 3 (March 1980), pp. 417-39.
7. H. E. Gray, G. P. O'Reilly, and M. J. Stefanik, "Planning Methodology for the Introduction of Local Time Division Digital Switching," Int. Switching Symp., Montreal, Canada, 1981.

8. B. H. Fetz et al., "Planning for Rural Modernization," Bell Lab. Rec., 58, No. 2 (February 1980) pp. 55-62.

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