

The 5ESS Switching System:

Introduction

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This special issue of the *AT&T Technical Journal* is devoted to the 5ESS™ switch. In this introductory paper the authors provide some historical background; outline the characteristics of this new, advanced system; and summarize its architecture, features, and status.

I. BACKGROUND

In March 1982, the first 5ESS switch was cut over in Seneca, Illinois. This new, multifunctional, time-division digital switching system is the product of development efforts at AT&T Bell Laboratories that can be traced back to the 1950s. Development of the 5ESS electronic switch was, and continues to be, driven by the worldwide evolution of both switching technologies and expanding telecommunications needs.

To introduce the more detailed articles that follow, this paper offers a brief history of AT&T Technologies electronic switches, discusses the characteristics of the new 5ESS switch, and introduces some of its technologically innovative features.¹

1.1 Local switching systems

The first general-purpose electronic switch, the 1ESS™ switch² (which was cut over in Succasunna, New Jersey, in May 1965), contained a *space-division* switching network and a digital electronic data processor under Stored Program Control (SPC).[†] It was primarily intended to serve urban areas with large numbers of lines (between

* Authors are employees of AT&T Bell Laboratories.

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

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10,000 and 65,000) and heavy traffic, including many business customers. The 2ESS switch, introduced in 1970, was designed to serve fewer lines (2000 to 10,000) and to meet the lighter traffic needs of suburban residential areas. In 1976 the smallest of AT&T Technologies space-division electronic switching systems, the 3ESS switch, began meeting the needs of rural Community Dial Offices (CDOs) with fewer than 4500 lines.

Also in 1976, new processors became available to modernize the 1ESS and 2ESS switches, doubling their call-carrying capacities. The 1A ESS switch incorporates the 1A processor, which has a readable and writable memory. The 2B ESS switch is equipped with the 3A central control, which combines integrated circuit design with semiconductor memory stores.

The first local electronic switches replaced earlier, wired-logic electromechanical systems such as the No. 1 and No. 5 crossbar and the still earlier step-by-step and panel progressive control systems. Stored program control led to greater flexibility in system design and reduced operations expenses in the telephone network. In early 1985, more than 3700 local electronic switching offices served more than 60 million lines worldwide.

Because of the high cost of processors and their associated memories, by the mid-1970s electronic switches still could not economically replace the smallest electromechanical switching systems. Yet these offices, serving 2000 or fewer lines, accounted for approximately 60 percent of the switching systems in the U.S. network. One response to this situation was remote switching. In 1979, the No. 10A Remote Switching System (RSS) (see Ref. 3) became available to connect these small offices to nearby host electronic switches by means of T- and N-carrier systems.

1.2 Toll switching systems

With the deployment in January 1976 of the first 4ESS switch⁴ in Chicago, fully digital electronic switching was introduced into the long distance network in the U.S.

The 4ESS switch, a high-capacity, toll and tandem switching system, brought many major technical advances to the switching art. The most important change was the use of a *time-division* digital network in place of the space-division network. Because of the rapid growth in the number of digital transmission systems, the switching network of the 4ESS switch was specifically designed to pass Pulse Code Modulation (PCM) signals without conversion. Transmission and switching functions were more closely integrated than in any previous switching system. Economic considerations, such as significant reductions in installation, operating, and maintenance costs, played an important

part in the introduction of the 4ESS switch. By the end of 1984, more than 100 systems were serving both North American and international applications. These systems have a total of 3.3 million trunk terminations and carry more than 5 billion calls per month.

1.3 Distributed systems

Following the successful introduction of time-division digital switching into the toll network, planning began for its application, with digital stored program control, in the local environment. Among the alternatives considered were adaptations of the 1A ESS switch and the 4ESS switch for local digital switching. Technology, however, was advancing rapidly in such areas as lower cost, more powerful microprocessors, and high-speed, fiber-optic communications systems. Such advances set the stage for a new generation of electronic switching with heavy emphasis on distributed network and distributed control. Thus, evolving technology and a strong market interest in digital systems led to the development of the 5ESS switch.

II. SYSTEM CHARACTERISTICS

The 5ESS switch complements the earlier systems, which so successfully replace the larger electromechanical local and toll offices. For example, it can bring electronic switching to even the smallest local office. In addition, the 5ESS switch provides digital services and capabilities for an extensive range of applications. To these ends, the new switch was designed with seven major characteristics in mind:⁵

1. The 5ESS switch is a *single system with multiple applications* (local, toll, operator services) that can cover the entire range of office sizes needed in telephone networks throughout the world. Table I shows a matrix of switching systems applied (as of 1983) across the metropolitan, suburban, and rural markets in the local, toll, and operator-services applications. The distributed control, modularity, and extensibility of the 5ESS switch allow it to serve all of these markets and applications. One consequence of this approach is the development of unified software to introduce new features throughout the family of 5ESS switches without regard to application or size. Well-defined internal interfaces allow a flexible, modular approach for both hardware and software so the system can be economically configured to meet the special needs of each market segment. For example, in the area of PCM transmission, two different international standards (North American and European) exist. From the start, the basic architectural and timing parameters of the 5ESS switch were designed to be compatible with both standards.

2. The 5ESS switch provides *integrated interfaces* between digital switching and transmission systems for both subscriber carrier systems

Table 1—Switching systems used in metropolitan, suburban, and rural markets in local, toll, and operator-services applications

Application	Market		
	Metropolitan	Suburban	Rural
Local	Crossbar tandem No. 1 crossbar No. 5 crossbar 1ESS 1A ESS	No. 1 step-by-step No. 5 crossbar 2B ESS	CDO No. 1 step-by-step 3ESS 10A RSS
Toll	No. 4 crossbar 1A ESS 4ESS	No. 5 crossbar local/toll 1A ESS	No. 1 step-by-step local/toll
Operator services	No. 5 crossbar Automatic Call Distributor/Traffic Service Position System	No. 5 crossbar Automatic Call Distributor/Traffic Service Position System 5ESS	Manual Traffic Service Position System/remote trunk arrangement

and interexchange circuits (24- and 30-channel systems). The 5ESS switch also has an efficient, easily maintained interface to analog interexchange circuits to simplify introducing the system into existing networks. Overall, the integration of functions will lead to a more rapid movement toward the integrated digital network and to the Integrated Services Digital Network (ISDN).

3. The 5ESS switch permits the *graceful incorporation of new technology* as it becomes available. This objective is not new, of course. For example, just as the 1ESS and 2ESS switch processors were upgraded in the mid-1970s with new technology, the ferreed network was also replaced by the smaller and more economical remreed at about the same time. Similarly, since the system's introduction in 1976, virtually all the major units of the 4ESS electronic switch have been redesigned to take advantage of technological innovations.⁶ These upgrades have pointed to the advantage of well-defined intermodule interfaces. Such interfaces become even more crucial as technology reduces the physical size of equipment and the replacement of units becomes important at the equipment bay level. The distributed nature and well-defined interfaces of the 5ESS switch also allow easy replacement and evolution of selected components as market trends warrant. For example, the switching module processor has already been upgraded to raise call-handling capability above initial capacity.

4. The *modular design* of the 5ESS switch allows increases in both network and processor capacity in reasonable, cost-effective increments. Earlier SPC switches had large growth modules. The resulting breakage penalty was as much as 5 to 10 percent of the switch price. To enable the system to be responsive to changes in forecasts and demographics, the design of the 5ESS switch allows for the addition or removal of equipment in operating exchanges and for conversion from one switching application to another (e.g., from remote switch to stand-alone exchange).

5. The 5ESS switch is *highly reliable*. Automatic fault detection, fault location, and reconfiguration capabilities ensure that faults can be identified, isolated, and repaired in a timely manner, thereby providing better service at lower maintenance cost.

6. The 5ESS switch is designed for both *local and centralized maintenance*. The provision of centralized maintenance has been one major factor in the economic attractiveness of stored program control for growth and replacement of electromechanical systems. When both approaches are provided, local maintenance can be used when the first systems are introduced. Then, as the number of systems increases, telephone administrations can introduce compatible centralized maintenance systems to obtain additional economic benefits.

7. The 5ESS switch allows *new features to be introduced by means*

of software. Techniques used in the 5ESS switch, such as a sophisticated operating system, a high-level language, and a modular design, make possible the rapid addition of features.⁷ In fact, the software environment is essentially the same among modules, enabling software to be ported among the various modules as architecture and feature needs evolve. Since maintenance routines constitute more than 50 percent of the system's software, these routines are also designed to facilitate changes.⁸ In addition, considerable effort has been expended on powerful off-line development systems and rigorous design methodologies⁹ that have already proven effective during the initial applications of the 5ESS switch's software. They are expected to be increasingly valuable as the demand for services and features continues to grow, particularly in light of important new concepts, such as the evolving ISDN.

III. 5ESS SWITCH TECHNOLOGY, ARCHITECTURE, AND FEATURES

3.1 *Technology*

The technological sophistication of the 5ESS switch is apparent at every level of its design, from devices to architecture. Examples of state-of-the-art technology in the 5ESS switch include:

1. Gated-Diode-Crosspoint (GDx) switch—a completely electronic (solid-state) line interface that reduces the space used by 60 percent over comparable interfaces and greatly improves reliability.

2. Digital signal processor¹⁰—a high-performance, high-density Very-Large-Scale Integration (VLSI) component that on one chip combines generation and detection of multiple tones with signal filtering, thereby reducing cost, space, and power requirements. This chip performs over 1 million operations per second.

3. Fiber optics—low-cost, high-capacity, internal communication links between modules that are resistant to electromagnetic interference.

4. Distributed control—microprocessor-controlled switch modules that provide call-processing intelligence, and allow for system growth in modular increments and full feature capabilities at remote locations. These modules are coupled by a packetized control network that ensures reliable and efficient communication among all the elements of the system.

3.2 *Architecture*

The 5ESS switch has a modular, distributed architecture consisting of an administrative module, a communications module, and a number of switching modules (see Fig. 1). The communications module contains a message switch, which handles the packetized system control messages, and a time-multiplexed switch, which interconnects switching modules with one another, as well as with the administrative module. Fiber-optic Network Control and Timing (NCT) links connect modules.

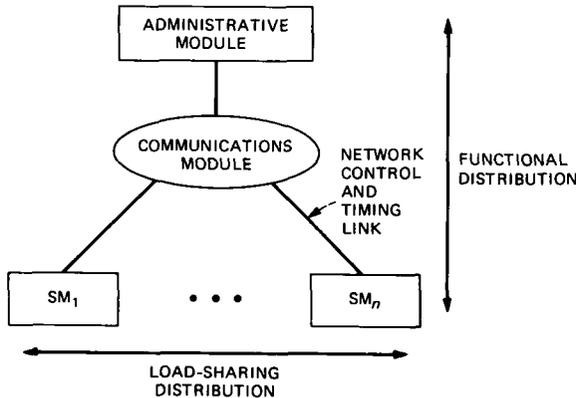


Fig. 1—Distributed architecture of the 5ESS switch.

In the architecture of the 5ESS switch, those functions that are best done globally—such as administration, resource allocation, and maintenance access—are provided in the administrative module. Those needs that are best handled close to the external interfaces—such as most of the individual call handling, provision of network capacity, and terminations for lines and trunks—are distributed in the switching modules. Thus, the switching modules provide the major processing power in the system, performing over 95 percent of the per-call work. In addition, they form the basic growth unit and, as such, can be physically located either locally or at geographically remote sites.

The design of the 5ESS switch will enable it to evolve to support Universal Information Services, a telecommunications industry goal that will enable network providers to offer their customers integrated transport, dynamic allocation of network resources, and adaptive, logically provided services.

3.3 Features

The flexible architecture of the 5ESS switch allows it to fulfill the needs of a spectrum of markets. For example, it provides basic and advanced subscriber services; toll and operator services; and extensive operations, administration, and maintenance features. Feature sets are being planned to take full advantage of the information-age capabilities of the ISDN. Table II shows the planned capacity levels through 1985 in terms of rated busy-hour calls, number of distributed switching modules, and line capacity.

IV. STATUS

The first multimodule 5ESS switch was put into service in August 1983 at Sugar Grove, Illinois. The first local/toll 5ESS switch was cut

Table II—5ESS switch capacities through 1985

Year	Rated Calls/Hour*	Maximum Number of Switching Modules	Nominal Line Capacity†
1983	130,000	30	50,000
1984	200,000	48‡	50,000
1985	300,000	192	100,000

* Sustained operation, including customer features, all effective attempts, all messages billed, with no degradation of maintenance and administrative responsiveness.

† Allows for typical mixture of lines and trunks.

‡ Includes remote switching modules.

over at Bradford, Pennsylvania, in October 1983. The remote switching module and integrated *SLC*® 96 carrier were cut over at Spotsylvania, Virginia, in April 1984. The first 5ESS switch with the international feature set was ready for service in Seoul, Republic of Korea, in February 1985.

The early thrust of the 5ESS switch has been small- to medium-size local and local/toll applications. In 1985, with the advent of the high-capacity enhancements and new features such as business and residence custom services, the application of the 5ESS switch will be expanded in both the North American and international markets. The early buildup of shipments of the 5ESS switch has been substantial. From just 183,000 lines shipped at the end of 1983, 5ESS switch line shipments grew by an additional 2.5 million in 1984, and more than 6 million lines will be shipped in 1985.

V. SUMMARY

This paper has presented a general introduction to the 5ESS switch. Its distributed architecture, use of sophisticated digital technologies, and modular hardware and software design put the 5ESS switch at the leading edge of SPC switching systems. The papers that follow discuss the system in more detail. The first discusses applications planning¹¹ for the 5ESS switch. This is followed by papers on the overall architecture,¹² the operational software,⁷ the maintenance software,⁸ the circuit-level hardware,¹³ the physical design of the hardware,¹⁴ and the software development system.⁹ The last set of papers addresses the first application and field experience,¹⁵ the operations plan,¹⁶ and factory testing.¹⁷

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