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The 5ESS *Switching System:*

Operations, Administration, and Maintenance Capabilities

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The *5ESS*™ switching system is a digital, time-division switching system that is being introduced into a multiplicity of operating environments—local, toll, private networks, and stand-alone applications. Many of these operating environments are currently dominated by analog, space-division switching systems. Furthermore, the *5ESS* switching system is being introduced into environments in which there have been increasing trends toward centralization and mechanization of operating procedures through the use of minicomputer-based support systems. The *5ESS* switching system has been designed to allow a smooth incorporation into these mechanized operating environments, while still retaining features needed for stand-alone operations in less mechanized environments. This paper describes the operational features, both administrative and maintenance, of the *5ESS* switching system. The emphasis is on the features that differ from those of earlier stored program control switching systems. These include features that represent enhancements over those of earlier systems, differences mandated by a digital, time-division technology, and features designed to more readily adapt to operations support systems.

I. INTRODUCTION

The *5ESS* switching system is the first time-division, digital switching system AT&T has designed to serve in both local and toll offices as well as in private network and stand-alone applications. As such, it is inherently a four-wire system, and includes integrated interfaces for

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digital-carrier-serving message trunks and Digital Loop Carrier (DLC)* systems. In addition, the *5ESS* switching system employs a modular hardware and software architecture. This architecture improves the economics of the switching system, allows more flexibility for growth, and simplifies the development process to introduce new technologies into the switching system and add new features. The operations of the *5ESS* switching system have been designed in concert with this modular architecture.

The *5ESS* switching system has been designed with careful attention to switching system operations. Over the past several years, there has been an increasing trend in the telecommunications industry toward centralized work centers and the use of computer-based Operations Support Systems (OSSs) to support those centers. The *5ESS* switching system has been designed for convenient integration into these centralized, mechanized operating environments, while retaining the features needed to operate in less mechanized or manual environments. In earlier vintage switching systems, these OSSs typically use the same Teletypewriter (TTY) interface that supports the work center in a nonmechanized environment. The *5ESS* switching system's interfaces to these OSSs are designed specifically for machine-to-machine communications and use higher transmission rates and the BX.25 protocol, a modified subset of the CCITT X.25 protocol.

Finally, the *5ESS* switching system also includes new features and improvements to existing features that address the operations of the switching system. These features are designed to take advantage of the new capabilities and economies that improved technology has made possible. These enhancements include improved craft interfaces and the integration of capabilities that had previously been performed by external equipment (e.g., line and trunk test capabilities) into the switching system.

This article is organized into three major functional areas of operations: planning and engineering, administration, and maintenance. Within each of the functional categories, the major operational differences and improvements over previous systems are discussed.

II. PLANNING AND ENGINEERING

2.1 Planning

Two aspects of the *5ESS* switching system have a major effect on planning for applications for the switching system: the digital switching network used by the system, and the modular architecture of the system, including a Remote Switching Module (RSM).

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

A digital switching system, such as the *5ESS* switching system, has economic advantages when interfacing with digital facilities. Thus, having a large proportion of digital facilities in an area stimulates the introduction of digital switching systems. Digital switching systems then in turn serve to increase the movement to digital facilities. This mutually stimulating effect is referred to as digital synergy. Digital synergy applies to both digital interoffice facilities and DLC systems. The *5ESS* switching system's architecture includes an integrated interface for T1-carrier message trunks and RSM umbilicals, the Digital Line Trunk Unit (DLTU), and an integrated interface for *SLC*® 96 carrier systems, the Digital Carrier Line Unit (DCLU). These integrated interfaces eliminate the need for terminal equipment in the central office and couple the planning of digital interoffice facilities and DLC systems with switching system planning.

The modular architecture of the *5ESS* switching system increases the range of applications for which the *5ESS* switching system is attractive. This architecture includes distributed processing so that as the termination capacity is increased, the call-processing capacity is also increased by adding Switching Modules (SMs). This enables the *5ESS* switching system to grow smoothly and economically from small-capacity configurations to large-capacity configurations. Having the same switching system in all applications simplifies operations in a telephone company. The *5ESS* switching system's design enables it to host a single-module or multimodule RSM. This RSM is an enhanced version of the standard SM that has been modified to provide stand-alone switching in the event it is cut off or isolated from the host. RSMs interface with their host using T1 carrier. The RSM is designed to make Stored Program Control (SPC) switching economical for more applications.

A "hot slide-in" procedure has been developed for the *5ESS* switching system. With this procedure, the *5ESS* switching system is installed and cut into service while housed in a temporary shelter. After the old switching equipment is removed, the in-service *5ESS* switching system is put in its place. This procedure reduces costs for offices that would otherwise require a building expansion.

2.2 Engineering

The *5ESS* switching system takes advantage of mechanized traffic data collection and processing systems (see Section III), which make it feasible to use a large amount of data to engineer an office. Most older SPC systems use Average Busy Season (ABS), Time-Consistent Busy Hour (TCBH) engineering methods. These methods require studies to determine the busy hour, and then base their engineering on data gathered during this hour. Because most traffic-sensitive equipment must provide good service when peak loads occur, regardless of the hour in which they occur, ABS TCBH methods based on 1 hour of data per day require conservative engineering. The *5ESS* switching system uses procedures in which data are collected 24 hours a day, and Once A Month (OAM) peak loads are calculated from these data. The *5ESS* switching system then may be engineered to render good service based on either TCBH loads (ABS or high day) or OAM loads.

The *5ESS* switching system's engineering (for both stand-alone *5ESS* switching system and RSM applications) is strongly influenced by the modular architecture of the system. In general, the switching system is engineered to determine the necessary quantities of the lowest-level units. The quantities of these units then determine the necessary quantities of the next higher level unit and so on. More specifically, the number and type of terminations appearing on the switching system in conjunction with their traffic characteristics are used to determine the number of SM subunits (e.g., line units and trunk units) that are required. The time-slot and call-capacity requirements of these subunits then determine the number of SMs required. Finally, the number of SMs determines the equipage of the Communications Module (CM), which is composed of a Time-Multiplexed Switch (TMS) and a Message Switch (MS). This process is mechanized in the *5ESS* Switch Digital Ordering and Planning System (5EDOPS).

The CM equipment used to interconnect SMs and handle messages between SMs and the Administrative Module (AM) is designed to provide full access. This design eliminates the need for CM traffic engineering.

III. ADMINISTRATION

Administration of the *5ESS* switching system is concerned with ensuring objective service levels at optimum cost. It involves provisioning and assignment, data administration, capacity and equipment management, and resolving traffic-related service problems.

3.1 Provisioning and assignment

The *5ESS* switching system incorporates several features intended to enhance the provisioning and assignment process. These features include the structure of the database, the switching system's craft interface for accessing the database, and the interface to the Remote Memory Administration System (RMAS). In addition, the integrated digital interfaces simplify the provisioning and assignment process for services provided off these facilities.

The *5ESS* switching system includes a database management system that supports a relational database structure. This provides the users

```
                         5ESS SWITCH
                        RECENT CHANGE
           TRUNKS — TRUNK GROUP & MEMBER VIEW — 32

#1. TGN              ___        12. CGASPN           _____
#2. MEMB NBR         ___        13. CLCI TRK ID      ___
 3. TEN              ____       14. HOLD BUSY        _
 4. DEN              _____      15. SATELLITE        _
 5. LTP              ___        16. OUT START DIAL   _
 6. CLEI             _______    17. TRF SAMPLE       _
 7. TRANS CLASS      __         18. CAMOPTLK TEN     ____
 8. SUPV             __         19. CAMOPTLK DEN     _____
 9. IDLE STATE       __         20. ACTN             _
10. IN START DIAL    _
11. STOPGO           __


Trunk group number. Enter from 1 to 999.
```

Fig. 1—A recent change view.

(the users may be either operating company personnel or other *5ESS* switching system software) with a logically structured database tailored to their needs, and enables the users to ignore the physical structure of the database. In the *5ESS* switching system, call-processing software accesses the database at a level, called the base relation level, in which the data are organized according to needs of this software. The craft interface is at the view level, which is created through logical operations on the base relations. Views have been designed to correspond to operating company work functions (e.g., add a new line) so that for each function, the necessary information can be obtained by accessing the appropriate views of the database.

The *5ESS* switching system includes its own craft interfaces to the switching system database and an interface to RMAS. Both of these interfaces are at the view level. The *5ESS* switching system's interface is similar in format and uses much of the same software as that used in the office data assembly process to initialize the database of a new office. The *5ESS* switching system has a menu selection routine from which views, the groupings of data at the view level, are accessed. The views of the database are presented in a screen format complete with navigational capabilities and help and error messages. Figure 1 is an example of a view. Database access using the view interface is available on site and remotely via Recent Change (RC) terminal(s). The database can also be accessed over the maintenance channel in a manner suitable for logging by the Switching Control Center (SCC) minicomputer. The *5ESS* switching system also has a 2400-baud, BX.25 link to RMAS. The RMAS interface is similar to that of the *5ESS* switching system. In addition, RMAS provides the *5ESS* switching system with enhanced data administration capabilities and provisioning features. These features include pending and history files to manage the entry of database changes into the switching system. Both the *5ESS* switching system and RMAS can print the switching system's data in tabular format so that paper versions of the office records may be maintained and updated.

Integrated digital interfaces simplify the provisioning process for T1-carrier message trunks and DLC systems. With integrated interfaces, there is no central office terminal equipment. Thus, there are no central office line assignments to be made, and the number of distributing frame cross-connects is greatly reduced. Combined with remote software provisioning, this gives the capability with the *5ESS* switching system to add and modify services on these integrated interfaces without requiring a central office visit.

Assignment for the RSM is accomplished via the host *5ESS* switching system. This enables the RSM to take advantage of the database management features incorporated into the host *5ESS* switching system and share the same craft interfaces. Only the distributing frame cross-connect work must be performed at the RSM site.

3.2 Data administration

Data administration ensures the availability, adequacy, and validity of the collected traffic data. Traditional traffic reports are available in human readable format over the Network Administration I/O channel. The *5ESS* switching system also provides an interface to the Engineering and Administrative Data Acquisition System (EADAS). EADAS provides an interface to the Total Network Data Systems (TNDS).

The administrative interface for the RSM is through the host *5ESS* switching system. Thus, all the administrative features of the *5ESS* switching system are also applicable to the RSM.

The EADAS interface uses the BX.25 protocol and is 2400 baud. EADAS polls the *5ESS* switching system for a half-hourly, hourly, and 24-hour data collection schedules. Data validation is performed by EADAS. For the *5ESS* switching system, EADAS creates C, E, H, and P schedules from the half-hourly data and passes them to the downstream TNDSs for additional processing. The C schedule includes trunking and customer usage data, the E schedule contains the extreme value data for usage-sensitive equipment, the H schedule includes hourly data and half-hourly data for special studies, and the P schedule has the processor capacity estimation data. The downstream TNDSs have been expanded to support the *5ESS* switching system as a new switching system type. These systems perform functions for network management, load balancing, forecasting switching system and facility growth, and indexing system performance. (See Refs. 1 through 3 for additional information.)

3.3 *Capacity and equipment management*

A primary function of switch administration is to ensure an efficient utilization of equipment. The goal is to maximize equipment utilization and minimize the quantity of equipment needed to provide the desired grade of service. Capacity management ensures that sufficient equipment is available and load balancing ensures that it is efficiently utilized.

The modular architecture and use of distributed processing in the *5ESS* switching system allows both call-processing and network capacity to be added. This is done by adding SMs to a system. Capacity estimation procedures using extreme value methods have been developed to determine and anticipate overload conditions. For the *5ESS* switching system, these procedures are expanded because of the distributed processing scheme, which requires multiple processors to be monitored. While adding SMs increases the call-processing and network capacity, SM subunits are added to provide additional terminations.

Since the design of the *5ESS* switch network is such that blockage can only occur in the line concentrator stage of the network, load balancing is only required to assure that individual concentrators are not overloaded. This is achieved by assigning lines based on their class of service. Trunks may be distributed to optimize reliability without regard to load balance. The *5ESS* switching system has no space-division junctors, hence junctor rearrangements are eliminated.

3.4 *Trouble resolution*

The switch administrator is responsible for the resolution of traffic-related service problems. The *5ESS* switching system includes an I/O channel—the NAC channel—for this purpose. This channel is a virtual channel over the BX.25 interface to the No. 2 Switching Control Center System (SCCS). This enables the administrator to take advantage of the SCCS minicomputer capabilities (e.g., logging, browsing, filtering, and alarming of messages). Over this channel the administrator has access to the switching system's database, to office status and control information, and traffic information. For dealing with traffic overload conditions, the *5ESS* switching system includes controls to reduce the load offered to the switching system and is designed to dynamically alter the allocations of system real time in response to changes in load. The essential service protection feature may be activated or inhibited to reduce the number of recognized requests for service via this channel. Network management controls are available to control the flow of traffic into and out of a *5ESS* switching system office over trunks. These controls may be activated "on-site" [at the Master Control Center (MCC) or SCC] or via EADAS/NM (network management).

IV. MAINTENANCE

The maintenance features designed into the *5ESS* switching system make it well suited for both highly mechanized environments and other less mechanized environments. Its inherent flexibility allows it to work in a variety of operational environments and configurations. The maintenance interface is a user-friendly one that, by the use of video displays and easy-to-use menus, guides the craft through the control operations used to maintain the system.

4.1 Maintenance objectives

The overall reliability and availability objectives of the *5ESS* switching system are detailed in Ref. 4. From a maintenance perspective, these objectives distill into the following points: First, the *5ESS* switching system should perform as much of the maintenance as it can without the need for craft intervention. Whenever a trouble condition occurs, the crafts people should be notified of it, along with the criticality of the event. When the crafts people must take corrective action, it should be easy to identify and isolate the trouble quickly and unambiguously, and the repair should be quickly effected. Lastly, except for pack replacement and other "hands-on" repair, all maintenance control and display capabilities should be available on-site and at the remote SCC.

4.2 Maintenance capabilities

4.2.1 General

The *5ESS* switching system has a full complement of audits, interrupts, purges, and diagnostics. Details of these may be found in Ref. 5.

4.2.2 Craft interface

The craft interface for system maintenance at the central office is the MCC. Figure 2 shows the most frequently used parts of the craft interface. Instead of having a custom, hard-wired key and lamp panel for each office, as other SPC systems have, the maintenance interface uses a video display and keyboard unit similar to the one discussed in Ref. 6. The displays are software controlled and are easily changed to track the particular *5ESS* switching system's configuration. The upper part of the screen always displays a summary of the critical indicators, including the alarm-level indications `CRITICAL`, `MAJOR`, and `MINOR`, and the "type" indicators such as `BLDG/PWR` and `MSGS/TMS`, which

LAB 1 3B20D 3.0.20 ttyl-cdL TTY 11 10/29/84 17:25:28 CDT

SYS EMER CRITICAL MAJOR MINOR BLDG/PWR BLD INH CKT LIM
TRAFFIC SYS INH CU CU PERPH OS LINKS

CMD<_ -102-COMMON PROCESSOR DISPLAY-

UNIT	(UCL) RST	RMV	DGN
CUx	30x	20x	50x
DFCx	31x	21x	51x
MHDx	32x	22x	52x
IOPx	33x	23x	53x
MTTYCx	34x	24x	54x
MCRTx	35x	25x	n/a
ROPx	36x	26x	n/a
SCCx	37x	27x	n/a
SW		OP	
CU	400	OOS	404
PORTSW	401	DGN	405
ROP	402		
MCRT	403		

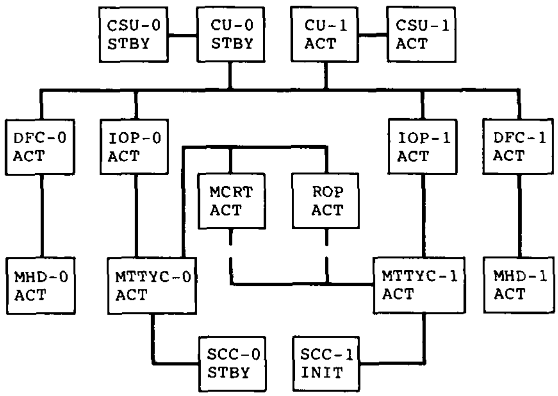

Fig. 2—Parts of a master control center.

indicate the trouble source. On monochromatic terminals, these indicators would be displayed in reverse video or blink to indicate the type and the severity of the trouble. For the optional color terminals, changing status would be shown by a change in color.

Below this area, the crafts people can select different "pages" to be displayed in order to perform the control and display functions similar to other SPC systems. The pages consist of an ordered list (a menu) of control and/or display functions that can be selected by entering a 3- or 4-digit number followed by an execute character. Usually accompanying this menu is a graphical representation of the status and interconnection of equipment. There are separate pages for different types of equipment and for different levels of detail.

As in other SPC systems, the *5ESS* switching system has a "beltline" function that allows craft at the switching frames to interact with the switching system. By means of a portable TTY, the crafts people can input messages and receive appropriate output and system status messages.

4.2.3 Diagnostics

Flexibility and power are the hallmarks of the *5ESS* switching system's diagnostics. An entire equipment unit, a particular subunit, or all the subunits in a particular community can be diagnosed. Complete tests, a range of test phases, or particular phases may be run. While most requests can be initiated automatically, all requests can be initiated manually. To aid in troubleshooting, interactive features such as stepping, looping, and pausing are provided. Manual requests can be entered from the maintenance terminal by either menu selection or message input.

Diagnostic results can be sent to the maintenance terminal and the printer. Unlike other SPC systems, which print trouble numbers that must be decoded by referencing a Trouble-Locating Manual (TLM), the *5ESS* switching system can be requested to print a list of suspected faulty circuit packs. This Trouble Location Procedure (TLP) option provides an ordered list of packs, including their locations, which simplifies the repair procedure. It is expected that 90 percent of all faults can be cleared by replacing one or more of the boards listed with nearly half of the faults cleared by the first pack on the list.

4.2.4 Emergency action interface

In the unlikely event that the *5ESS* switching system cannot recover from a catastrophic failure, the Emergency Action Interface (EAI) provides manual control and basic status information. The EAI circuit can access the *5ESS* switching system regardless of system configuration or software sanity. Firmware in the EAI controls a display that allows the crafts people to force system configurations, to inhibit error sources and sanity checks, and to initialize the system. In the event of a complete system outage, the EAI provides a gross diagnostic capability in the form of processor recovery messages. The EAI page is displayed on the same terminal as other maintenance displays, and is available at both the central office maintenance terminal and remotely at the SCC.

4.2.5 Initializations

Initializations in the *5ESS* switching system are very comprehensive. The *5ESS* switching system supports a variety of initialization levels from a single process purge to a full initialization and memory reload.[5] The distributed architecture of the *5ESS* switching system permits initializations of separate units of the switching system, often with little effect on the other units. For example, one SM may be initialized without interfering with call processing in other modules. Likewise, some levels of AM initialization have little effect on the periphery. If more drastic actions are required, the entire system may be initialized.

4.2.6 Switching Control Center System interface

The Switching Control Center System (SCCS) provides the hardware and software to control, administer, and maintain SPC systems from a remote centralized location. This is accomplished through a combination of audible and visual alarms, status panels, and video displays for status control. The SCCS also provides analysis and computational tools, office records, and interfaces to other operations systems and centers. (See Refs. 7 and 8 for more thorough discussions of the SCC.)

The *5ESS* switching system is fully compatible with the SCCS. All SCCS functions that can be performed on other SPC systems can be performed on the *5ESS* switching system. All maintenance control center functions are remoted to the SCC, including the emergency action interface page. The displays at the MCC and SCC are identical, which improves craft communications between the central office and the SCC. In addition, the *5ESS* switching system shares a common, standard interface design with other AT&T 3B computer processor-based systems.[9]

Communication between the *5ESS* switching system and the SCCS is via a duplicated data link using the BX.25 protocol. BX.25 is a packet-switching protocol for error-free data communications, which allows for the multiplexing of separate "virtual channels" on a single facility. Thus, savings are realized on facility and terminal costs while promoting a standardized interface to future packet-switched networks.

All alarms, control and display information, input and output messages, and other maintenance data are sent on separate, virtual channels over the same BX.25 link. This is in contrast to other SPC systems, where TTY and telemetry information are sent over separate, nonduplicated links. In the case of a link outage, BX.25 provides for an automatic switch to the standby link. Therefore, the interface to the SCCS is fully duplicated and full functionality is maintained during any single link failure.

4.3 RSM maintenance

The RSM in the *5ESS* switching system's architecture is an SM designed to be used in a variety of remote applications. As discussed in Section 2.1, to minimize the impact of host office troubles and facility failures, when the RSM cannot communicate with the host, its stand-alone mode will provide basic telephone service within the customer community. While in this mode, emergency lines will also be provided to assure access to emergency service.

While the maintenance of the RSM has been designed to be virtually identical to that of the host SM, the remoteness of the RSM implies some differences. Trouble will be sectionalized sufficiently to ensure that craft will be dispatched only when necessary, and that minimum spare parts will be taken to the remote site.

Most RSM maintenance will be controlled from the SCC, where testing will determine if and when a dispatch is necessary. Most tasks requiring craft at the RSM site will be accomplished by one crafts person, using a portable TTY. This TTY will have access to the SCCS via a secure dial-back arrangement, or to the host office as an extension of the belt line. Optionally, a remote MCC terminal may be provided at the RSM site. When necessary, assistance can be provided by a controller or analyzer at the SCC, or by another crafts person at the host office.

The crafts people at the RSM will have a simple status panel that will show RSM alarm information and an indicator that will show when the RSM is in the stand-alone mode.

4.4 Line and trunk testing

The *5ESS* switching system is designed to fit into the existing environment for line and trunk testing, and also to support improved interfaces for these functions. This includes providing testing capabilities within the *5ESS* switching system and supporting interfaces to remote test systems such as the Centralized Automatic Reporting on Trunks (CAROT) and Mechanized Loop Testing (MLT) systems. Thus, to support line and trunk testing, the *5ESS* switching system provides metallic access, built-in test capabilities, and craft interfaces (both local and remote).

The *5ESS* switching system includes a line and trunk testing craft interface called the Trunk Line Work Station (TLWS). This interface shares the same physical equipment as the MCC for switching systems maintenance and accepts two forms of input: menu mode and TTY messages. From this interface administrative actions such as changing the state of the line or trunk, actual line and trunk tests, and miscellaneous functions such as monitor-only connections may be performed. For large offices that require large volumes of testing, as many as six supplementary TLWSs may be equipped.

In addition to the manual tests that may be performed at the TLWS, the *5ESS* switching system performs automatic tests. For lines, these include standard per-call tests and Automatic Line Insulation Testing (ALIT), which includes tests of integrated *SLC* 96 system lines. The ALIT function is performed by equipment integrated into the *5ESS* switching system. Loop segregation tests are run on a periodic basis to differentiate between loaded and nonloaded loops. These tests ensure that the system provides the proper balance network for echo control during calls. For trunks, automatic outgoing transmission and operational test calls are provided.

For line- and trunk-testing OSSs, the *5ESS* switching system, in addition to providing metallic access for the conventional testing interface, is designed to support more sophisticated interfaces and eliminate the need for external test equipment. This permits external testing systems to share these capabilities. The *5ESS* switching system includes equipment called the Transmission Test Facility (TTF) and the Directly Connected Test Unit (DCTU) that, along with system software, perform test functions that external equipment such as the Remote Trunk Test Unit (RTTU) and Loop Testing System (LTS) provided for other switching systems. The TTF implements the loop segregation tests, the various transmission test lines, and the Remote Office Test Line (ROTL) functions. The DCTU provides dc and subaudio measurement capabilities. Thus, as well as providing for remote testing in the same manner as other switching systems, the *5ESS* switching system anticipates an environment where remote test systems (e.g., CAROT and MLT) request a test, and the switching system performs the test and delivers the results. In this environment, the test systems will communicate with the *5ESS* switching system in a manner similar to RMAS and EADAS, using BX.25 protocol.

Finally, in addition to performing tests for remote testing systems, the DCTU also eliminates the need for much of the portable test equipment at the central office. If the loops at the RSM are to be tested, they must also be equipped with their own DCTU.

V. SUMMARY

The *5ESS* switching system has been designed with an operational flexibility that allows it to work in a variety of operational configurations. In particular, the *5ESS* switching system has been designed with a set of enhanced interfaces that accommodate its integration into highly centralized and mechanized operating environments, as well as features that provide for operations in offices that are not as highly mechanized. Thus, the *5ESS* switching system includes a wide range of operational features and enhancements for a wide variety of operational environments.

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