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Networks, Signaling, and Switching for Post-Divestiture and the ISDN

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PREFACE

This report is submitted as partial completion of a series of studies being conducted for the National Communications System (NCS), Technology and Standards Branch, Office of the Manager, Washington, DC, under Reimbursable Order 5-40033.

Certain commercial names are identified in this report to specify and describe some of the necessary information. Such identification does not imply exclusive recommendation by the National Telecommunications and Information Administration or the National Communications System.

The views, opinions, and/or findings contained in this report are those of the author and should not be construed as an official NCS position or decision unless designated by other official documentation.

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LIST OF ACRONYMS

ACP	Action Point
AIS	Automatic Intercept System
AM	Administrative Module
ANI	Automatic Number Identification
ASM	Abstract Switching Machine
ASSL	Assembly Language
AT&T	American Telephone and Telegraph
BHCA	Busy Hour Call Attempts
BOC	Bell Operating Company
BSRF	Basic Synchronization Reference Frequency (formerly Bell System Reference Frequency)
CAMA	Centralized Automatic Message Accounting
CCIS	Common Channel Interoffice Signaling
CCITT	International Telegraph and Telephone Consultative Committee
CCNC	Common Channel Network Controller
CCS	Common Channel Signaling
CDO	Central Dial Office
CHILL	CCITT High Level Language
CM	Communication Module
CP	Coordination Processor
CPS	Central Processor Subsystem
DBMS	Data Base Management System
DLU	Digital Line Unit
DMERT	Duplex Multi-Environment Real-Time
DNHR	Dynamic Nonhierarchal Routing
DSE	Digital Switching Element
DSN	Digital Switching Network
DTMF	Dual-Tone Multifrequency
EAX	Electronic Automatic Exchange
ECSA	Exchange Carriers Standards Association
ENFIA	Exchange Network Facilities For Interstate Access
FCC	Federal Communications Commission
FG	Feature Group

LIST OF ACRONYMS (cont.)

GSS	Group Switching Subsystem
HU	High Usage
IDN	Integrated Digital Network
IOP	Input/Output Processor
ISDN	Integrated Services Digital Network
LADT	Local Area Data Transport
LATA	Local Access Transport Area
LCM	Line Concentrating Module
LGC	Line Group Concentrator
LM	Logical Machine
LP	Logical Port
LSM	Line Switch Module
MCC	Master Control Center
MF	Multifrequency
MFJ	Modified Final Judgment
MML	Man-Machine Language (CCITT)
MSGS	Message Switch
MTP	Message Transfer Part
NCP	Network Control Point
NCT	Network Control and Timing
NEC	Nippon Electric Corporation
NEMOS	Network Management Operations Support
NPA	Numbering Plan Area
NTI	Northern Telecom, Incorporated
OCC	Other Common Carrier
OSDS	Operating System for Distributed Switching
PABX	Private Automatic Branch Exchange
PBX	Private Branch Exchange
PCM	Pulse Code Modulation
PCU	Peripheral Control Units
PLC	Programming Language for Communications
POP	Point-of-Presence
POR	Plan of Reorganization

LIST OF ACRONYMS (cont.)

POT	Point of Termination
POTS	Plain Old Telephone Service
PROTEL	Procedure-Oriented Type Enforcing Language
PSS	Packet Switching System
PSTN	Public Switched Telephone Network
ROC	Regional Operating Company
RPS	Regional Processor Subsystem
RTR	Real-Time Reliable
SCC	Specialized Common Carrier
SDL	Specification and Description Language (CCITT)
SF	Single Frequency
SM	Switching Module
SN	Switching Network
SPC	Stored Program Controlled
SSS	Subscriber Switching Subsystem
STP	Signal Transfer Point
TAC	Terminal Access Circuit
TCE	Terminal Control Elements
TCM	Time Compression Multiplex
TCU	Telephony Control Units
TDMA	Time Division Multiple Access
TMS	Time Multiplex Switch
TSI	Time Slot Interchange
TSPS	Traffic Service Position System
TSS	Trunk and Signaling Subsystem
TSST	Time-Space-Space-Time
TST	Time-Space-Time
TUP	Telephone User Part
VFL	Voice Frequency Link
VLSI	Very Large Scale Integration
VSM	Virtual Switching Machine

NETWORKS, SIGNALING, AND SWITCHES FOR POST-DIVESTITURE AND THE ISDN

D.V. Glen*

There has been a significant international effort to develop standards for Integrated Services Digital Networks (ISDNs) at the same time that events leading to the divestiture of the American Telephone and Telegraph (AT&T) Company were occurring in the United States. The ISDN standards activity continues with end-to-end digital connectivity providing the basis for a myriad of new services for home and business as the objective. The divestiture has resulted in changed telephony markets and new network architectures for the Public Switched Telephone Network (PSTN). This report describes the PSTN operating structure as it existed prior to divestiture and as it now exists with new routing schemes, equal access principles, and Local Access Transport Areas (LATAs). Eight central office switches that are now, or have the potential to be, part of the new market and network structure in United States are also described. In essence, this report deals with the networks and switches that exist in the post-divestiture period and will become part of the anticipated ISDN era.

Key words: access tandem; CCITT Signaling System No. 7; central office switches; circuit switching; common channel interoffice signaling (CCIS); common channel signaling (CCS); Dynamic Nonhierarchal Routing (DNHR); end office; equal access; Integrated Services Digital Network (ISDN); Local Access Transport Area (LATA); local office; Public Switched Telephone Network (PSTN); stored program controlled (SPC); tandem switch

1. INTRODUCTION

1.1 Background

The VIIIth Plenary Assembly of the International Telegraph and Telephone Consultative Committee (CCITT), meeting in Malaga-Torremolinos, Spain, during October 1984, approved a series of Recommendations and Questions that promulgated the intensive work on ISDNs and other aspects of communications. The ISDN Recommendations, known as the I-Series, culminated a 4-year effort that set the stage for ISDN field trials and implementation. Some field trials have been conducted while implementation and other trials are planned. The ISDN Questions marked the start of another 4 years of intensive work leading to refined and new Recommendations in 1988.

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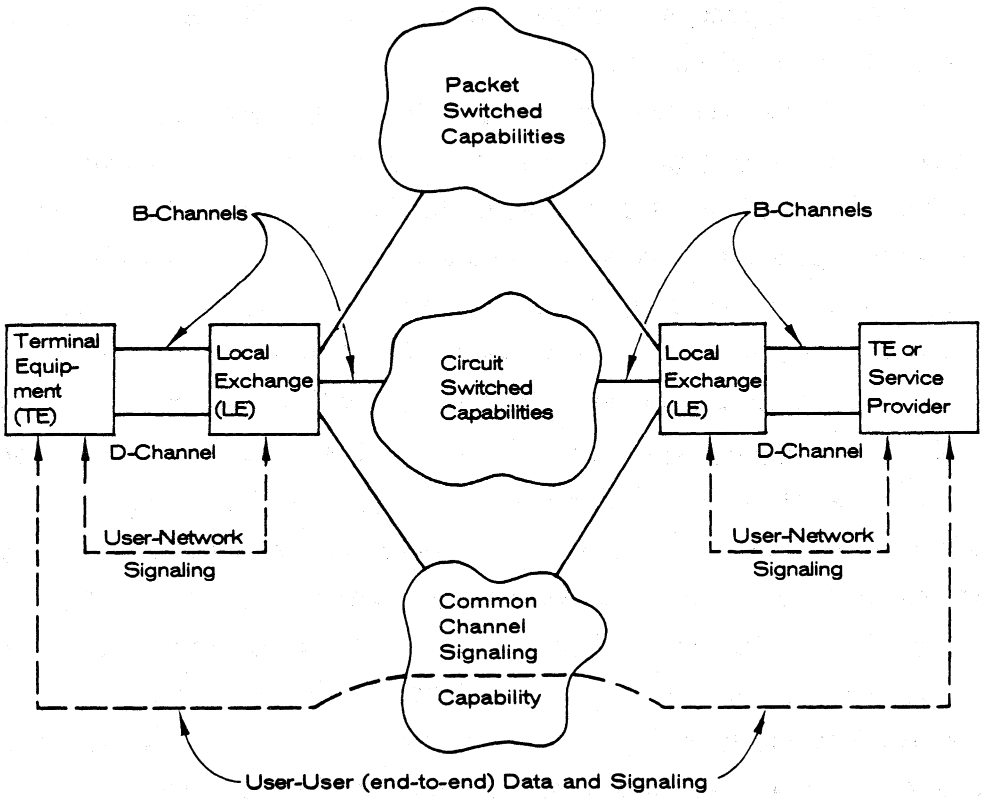


Figure 1-1. Basic concept of ISDN architecture.

The intent of the ISDN concept is to integrate and support a wide range of voice and nonvoice applications within the same network (Figure 1-1). Standard transmission rates with a minimum of standard interfaces are intended to provide a wide variety of services. These include telephony, circuit-switched, packet-switched, and leased-line data transfer; message handling such as telex, teletext, videotex, and image transfer such as facsimile and video conferencing.

Provisions for the ISDN also include service features and network management functions that could be supported through intelligence in the network or at the user terminal. For example, there could be a dynamic bandwidth allocation based on a user's needs. Access to an ISDN that provides the services is to be through a layered protocol structure.

The CCITT view is that the ISDN concept will evolve from existing Integrated Digital Networks (IDNs) and dedicated circuit- or packet-switched networks. As digital communication networks are just recently evolving from and replacing analog networks, the transition to an ISDN world could take a decade or longer. Depending on the country, an ISDN could interwork with a non-ISDN network(s) or other ISDNs.

With the ISDN moving toward a digital end-to-end (user-to-user) connectivity, conversion to digital equipment will continue. Concurrently, common channel signaling (CCS), specifically CCITT Signaling System No. 7 (CCITT No. 7), has been recognized as a key element of control signaling for the ISDN.

The importance of this activity has been recognized as indicated by the participation of companies and governments in ISDN standards committee activities. An equally important aspect is the current state of the Public Switched Telephone Network (PSTN), particularly since the divestiture of the American Telephone and Telegraph (AT&T) Company and the Bell Operating Companies (BOCs) that occurred on January 1, 1984. For many years, prior to divestiture, a particular hierarchal network structure was developed to serve the telephony needs of the United States. Due in part to divestiture, another kind of network structure has subsequently appeared. It is based on nonhierarchal routing between exchanges and local telephone areas where, in general, services are provided by the Regional Operating Companies (ROCs) and independent telephone companies. Other elements in the present communications structure in the United States are the ongoing changes that are being engendered by decisions of the Federal Communications Commission (FCC) and Federal courts.

1.2 Purpose and Scope

The main intent of this report is to give substance to what may appear as an abstraction at the standards activity level. The areas dealt with in this report are within the following areas of Figure 1-1:

- circuit switched capabilities
- common channel signaling capabilities
- local exchange

This report does not describe the ISDN; the above areas conveniently lend themselves to providing the reader with an overall view of material covered in this report and as a precursor to the ISDN. This is approached by describing past hierarchal networks, presently evolving nonhierarchal networks, and the central office switches. Some of these switches have applications for interexchange carriers and signaling purposes depending on switch implementation according to the requirements of a communications carrier.

1.3 Organization of this Report

Section 2 contains a description of what has been the traditional hierarchal network structure used for the PSTN in the United States. This includes the switching plan, operating subnetworks that are not apparent to the user, in-channel and common channel signaling, and the SPC network.

This is followed by what could be called new network architectures in Section 3. This section begins with a background look at the divestiture settlement between the United States Government and AT&T. This is followed by descriptions of the Dynamic Nonhierarchal Routing (DNHR) network, Local Access Transport Areas (LATAs), and equal access for interexchange carriers.

Section 4 provides descriptions of the hardware and software that exist in the local, local/tandem, and access tandem switches. These switches are the AT&T 5ESS, CIT-Alcatel E10-FIVE, Ericsson AXE System, GTE GTD-5 EAX, ITT Telecom System 12, NEC NEAX 61A, Northern Telecom DMS-100, and Siemens EWSD. The manufacturers of the switches have, or are participating in ISDN field trials in the United States and abroad. A summary of switch characteristics in terms of line/trunk capacities, control, software, access features and applications is included.

Section 5 provides a summary and conclusion for the report.

The appendix is a CCS signal transfer point (STP) application guide. The information in this appendix is intended for use with STPs from a specific manufacturer, but provides insight and information that can be applied by STP planners.

2. TRADITIONAL NETWORK ARCHITECTURE

There are two architectures to consider here for circuit-switched traffic. The first is the traditional hierarchal structure while a second, called DNHR, was started in August 1984.

2.1 Hierarchal Switching

A hierarchal structure of "switching centers" has been developed in the United States and Canada to efficiently handle the large volume of telephone and data messages each day. In 1980 this was on the order of 600,000,000 calls per day (AT&T, 1980). As part of a switching plan, each switching center was classified according to a hierarchy of five classes based on the highest switching function performed, interrelationship with other switching centers, and its transmission requirements. The switching centers are linked to each other by trunks. The hierarchy has used a tree topology to efficiently handle more than 150 million subscribers with two routing ladders (Figure 2-1).

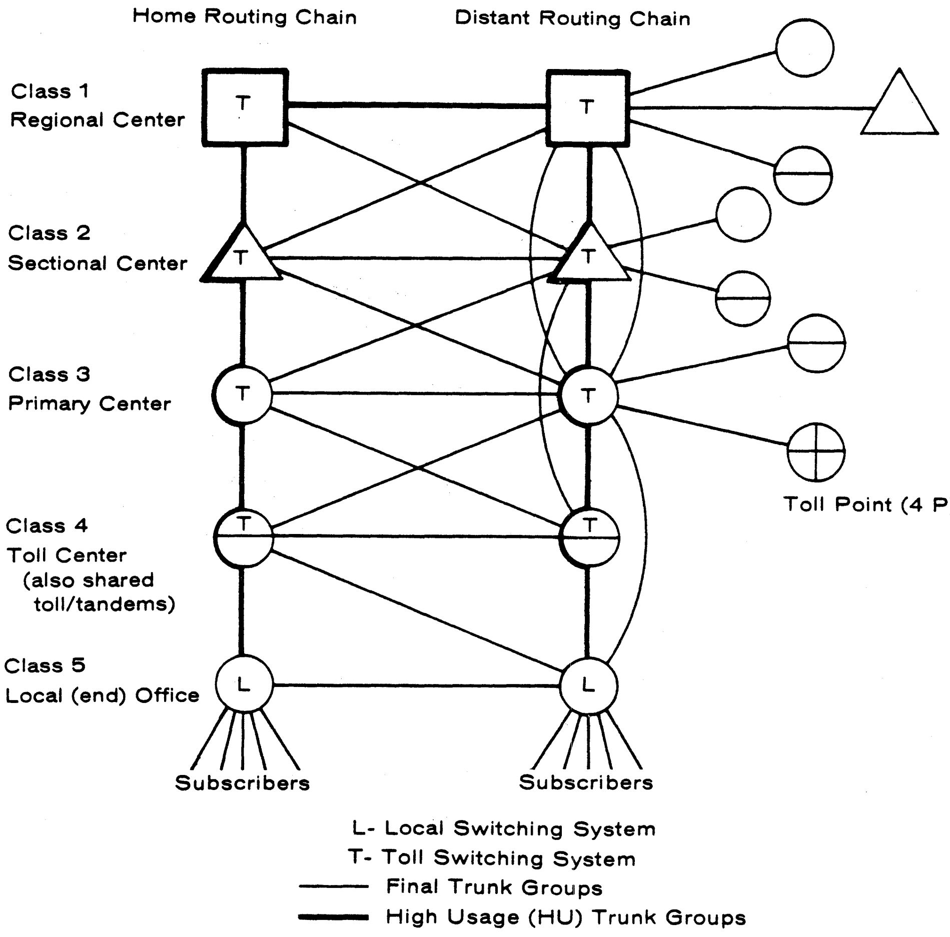


Figure 2-1. Network hierarchy and switching plan (after AT&T, 1980).

Subscribers to the PSTN are connected directly or through a Private Branch Exchange (PBX) via 2- or 4-wire local loops to the local (end) switching center designated as a class 5 office. Switching centers that provide the first level of concentration at end offices and the final level of distribution for traffic terminating at end offices are "toll centers" or "toll points" (class 4 offices). Within the hierarchy shown in Figure 2-1, the higher class switch can also perform lower switching functions. For example, the class 1 Regional Center can perform the functions of all the lower order switching centers (i.e., classes 2, 3, 4, and 5). Class 5 offices only handle class 5 switching.

The toll centers within the hierarchy can serve dual functions: toll or tandem on a shared basis. [This becomes an important distinction when the divestiture of AT&T was used to separate communications resources (Section 3.3).] Tandem switching refers to any intermediate switch used to establish a connection. Specifically, a tandem switch is used to interconnect class 5 end offices having insufficient interoffice traffic to justify direct trunks. Tandem switches are also used to handle overflow traffic on direct trunks between end offices. Toll switches, by that definition, can provide tandem functions.

Routing within the structure is always at the lowest level possible to minimize the cost of carrying the offered load. Where both subscribers are connected to the same end office, the connection is made through that office. Where each subscriber is connected to a different end office and the two class 5 offices connect to the same class 4 office, that toll center makes the connection. It is not necessary that class 5, 4, or 3 offices always home on the next higher level of switch. Any class 5 office can be served from any higher level switch (AT&T, 1980). The final route (basic) network architecture is shown in Figure 2-1 with the heavier lines. To prevent heavy traffic at higher levels and minimize signal degradation when numerous trunks and switches might be used, high-usage (HU) trunks are used between switching systems of any class where the trunks are economically feasible. Possible HU trunk groups are shown in Figure 2-1 with light lines. Various classes of switch systems could be directly connected to each of the offices via final trunk groups. For example, the class 1 office could have class 2, 3, and 4 switch systems trunked to it; the class 2 office could have class 3 and 4 switch systems trunked to it; the class 4 office would have only another class 4 switch system trunked to it.

While an HU trunk group may be established between any two offices where it is economically justified, another rule is also applied to avoid higher class switching for traffic to locations below it. The "one-level limit" rule is used to justify a HU trunk group where the switching functions performed at each of the trunk groups differ by no more than one level. (Note Figure 2-1 where HU trunk groups connect between the class 4 center in the home routing chain and the class 3, 4, and 5 centers and end office of the distant routing chain.) If traffic is low between the class 4 switching system of the home routing chain and the other offices, the one-level limit rule allows moving the trunk groups to one higher level. Traffic loads could justify trunk groups between the class 3 primary center in the home routing chain and the class 3 and 4 centers in the distant routing chain. Other interpretations of the one-level limit rule are explained in AT&T (1980).

Another principle is also involved in the hierarchal switching structure. It is called alternate routing. High usage trunk groups are large enough to handle only a portion of the offered traffic. The switching systems redirect traffic by automatic alternate routing to a different trunk group when all circuits of an HU group are busy. Overflow calls are shifted from the most direct route to a different trunk group while the switching system attempts to stay within a two-trunk, three-switch system route. This is done so that the circuit quality provided to the subscribers remains acceptable.

2.2 Hidden Subnetworks

The telecommunications network is a complex system, consisting of the revenue-producing network and many subsystems. A great amount of technology is involved in these building block subnetworks, and their functioning and interaction (Nesenbergs and McManamon, 1983). These subnetworks are the Centralized Automatic Message Accounting (CAMA) system, the Basic Synchronization Reference Frequency* (BSRF), the Automatic Intercept System (AIS), the Traffic Service Position System (TSPS), and the interoffice signaling network (Figure 2-2). While the following brief description of the systems is based on predivestiture operation, one form or another of these subnetworks is still needed in the post-divestiture era.

The output of a CAMA system is a prepared and mailed customer's bill. Information about a customer's call, such as the call duration is fed from a toll or tandem switch into an accounting register. Monthly statistics are compiled to determine a customer's bill.

The BSRF, distributed through its own subnetwork, is needed for transmission of a synchronized data stream and pulse code modulation (PCM) encoding of digitized voice. The BSRF standard with 3-fold redundancy, located underground in Hillsboro, Missouri, has an error rate of less than 1 in 10^{11}. The BSRF

*Note: formerly the Bell System Reference Frequency

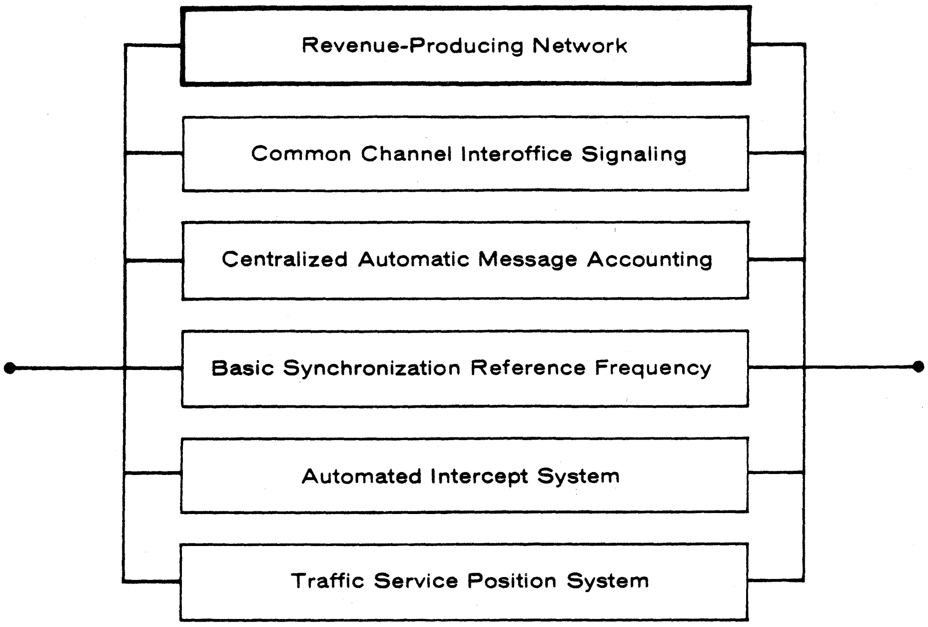


Figure 2-2. Hidden subsystems within the communications network (after Nesenbergs and McManamon, 1983).

standard is based on the Naval Observatory clock in Washington, DC, through a LORAN-C time standard link. The standard frequency extends through class 4 and 5 offices to Private Automatic Branch Exchanges (PABXs), remote switching units, and digital channel banks. A dividing line, based on divestiture, for distributing the BSRF would appear to exist between the class 4 and 5 offices. Based on divestiture, the AT&T Communications domain would extend through class 4 switches performing intra- and interstate switching, while the Bell Operating Companies (BOCs) would be responsible for distribution between class 4/5 offices and other facilities.

The AIS provides operator assistance to subscribers in the form of local (1+411) or within state long distance directory assistance (1+555+1212). Since divestiture, out-of-state long distance directory assistance is a function of a subscriber's long distance carrier (1+NPA+555+1212) where NPA is the Numbering Plan Area (area code). The AIS also provides occasional assistance to other operators such as resolving origination/destination conflicts by talking to subscribers and consulting data base information. Local directory assistance takes place at the class 5 end office while the remote directory assistance is with the class 3 Primary Center.

The TSPS provides service for credit card, collect, and bill-to-third-number calls. Previously operator-handled, the TSPS has become mostly automated through the Calling Card Service, which enables customers to make credit card calls by dialing-in the billing information without operator assistance. This new capability was made possible through modifications in TSPS and CCIS, which are key elements in the SPC network (Basinger et al., 1982; Confalone et al., 1982). The TSPS equipment is located at class 4 or higher ranking offices and gathers data from connecting trunks (i.e., between class 5 and 4 offices) through a Remote Trunk Arrangement or a local TSPS trunk circuit (AT&T, 1980). (Positioning of the TSPS within the SPC network is shown in Section 2.4)

2.3 Signaling

There are three types of signaling functions in telephony: supervisory, addressing, and call progress. These functions can be categorized as station or subscriber-line signaling and interoffice signaling. Transmission of these signals can be analog ac, analog dc, and digital. Further subdivision of signaling can be in-channel or common channel. In-channel signaling can be divided as inband or out-of-band. Inband methods transmit signaling information in the same band of frequencies used by the voice signals (e.g., single frequency, multifrequency). Out-of-band signals use the same facilities as the voice signal but a different part of the frequency band (e.g., direct current on customer loops to recognize on- or off-hook conditions).

Supervisory signaling involves the recognition of busy or idle states on subscriber lines and interoffice trunks, and then transmitting that information to the caller and switching system. Single-frequency (SF) tone signaling is used in conventional inband signaling to indicate the busy/idle state of trunk circuits between switches. Address signaling involves the transmission of digits of a called telephone number to a switching system or by one switching system to another. Dial pulse and dual-tone multifrequency (DTMF) signaling are used on subscriber lines while multifrequency (MF) signaling is the primary inband system for passing address information on interoffice trunks (Figure 2-3a). Call progress signals are transmitted to a caller to provide information to callers and operators relative to the establishment of a connection through a telephone network. Call progress signals are a variety of audible tone signals that indicate dialing, line busy, and ringing on the circuit (Keiser and Strange, 1985).

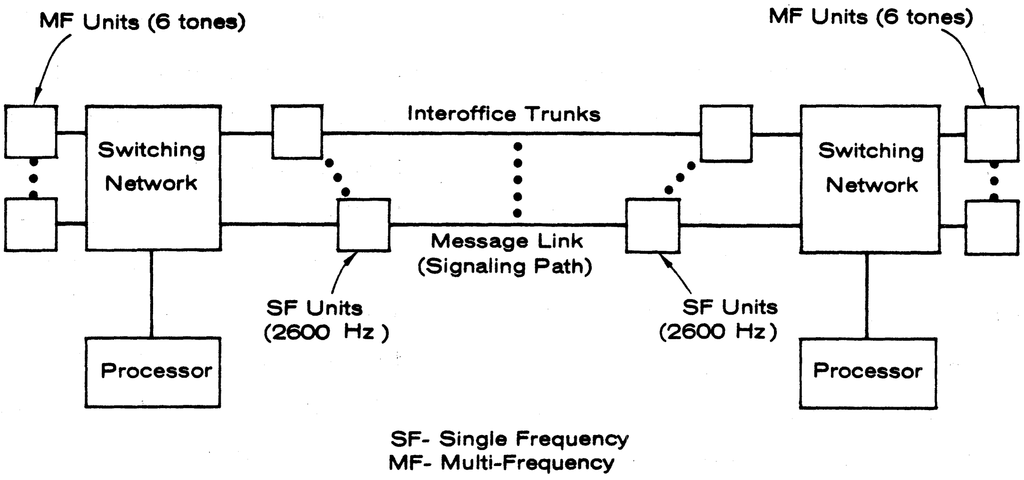
Common channel signaling (CCS) is a method that is employed in the public telephone network to exchange signaling data between processor-equipped switching systems over a network of signaling links (Figure 2-3b). The links are dedicated to control of signaling functions that are common to a number of channels. The AT&T version is called Common Channel Interoffice Signaling (CCIS) and uses a message format similar to CCITT Signaling System No. 6.

Common channel signaling can have three modes of operation: associated, quasi-associated, and disassociated. In the associated mode (Figure 2-4a) the CCS link closely tracks along its entire length the interswitch trunk groups that are served between end points. In the quasi-associated mode the CCS links may not be closely associated with the trunk groups that are served (Figure 2-4b). In the disassociated mode there is no close or simple association between the CCS links and the trunk groups being served. The disassociated mode permits nodes to communicate via signaling links when there are no functioning connecting trunks (Figure 2-4c). Network management and control functions can be performed with this arrangement (Linfield, 1979).

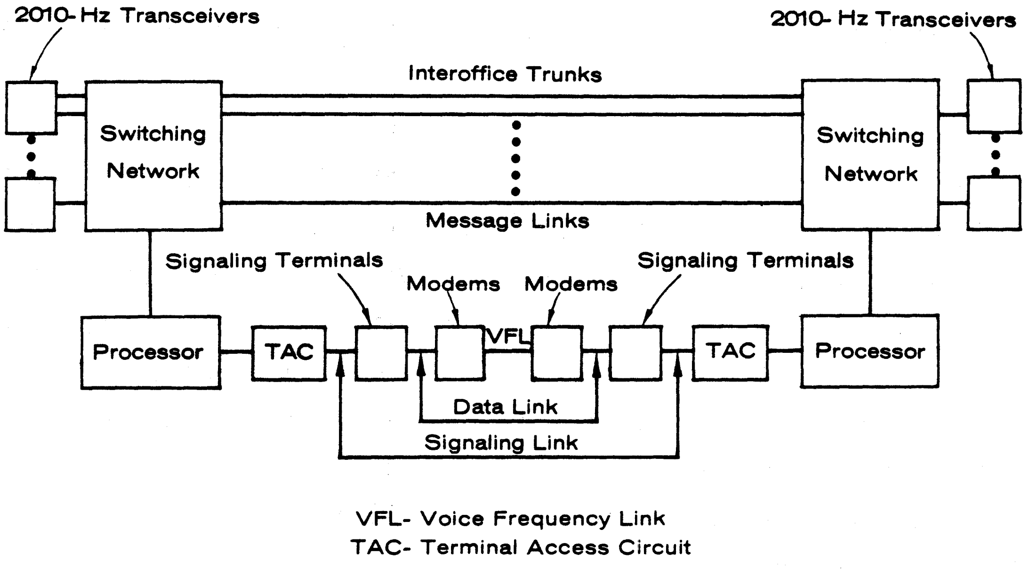
2.4 SPC Network

The SPC network consists of processor-controlled switching systems that are interconnected by CCIS to exchange supervisory, address, call progress, and other signals. In Figure 2-5, the switching system hierarchy is shown interconnected by the CCIS network. Signal transfer points (STPs) are used in the network to concentrate signaling information and to provide access to network control points (NCPs). Information that is relevant to customer services is stored at the NCPs (Lawser et al., 1982). Traffic Service Position Systems are shown within the hierarchy. At the end of 1983 there were 32 STPs, 34 NCPs, and 159 TSPSs in the SPC network (Andrews, 1984).

Access to the stored program control NCPs takes place when service calls are processed through switch offices [called action points (ACPs)]. The ACP recognizes the need for information on how to proceed with the call and sends a CCIS direct-signaling message to the NCP. The CCIS direct-signaling message consists of the dialed number, calling customer's line [referred to as automatic number identification (ANI)] and the identity of the ACP. The ACPs can be local and toll switches, or TSPSs. The NCPs retrieve customer calling

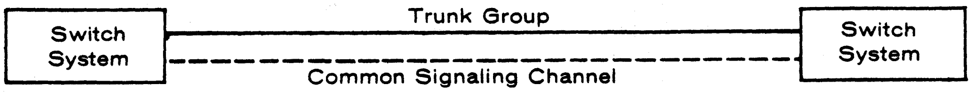


a) SF/MF inband signaling.

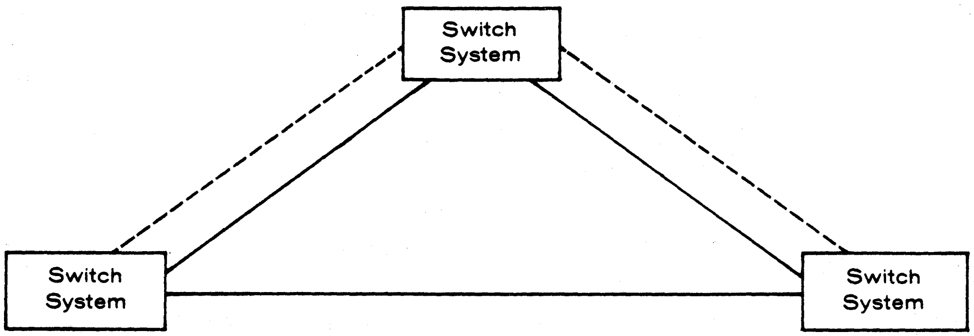


b) CCIS signaling system.

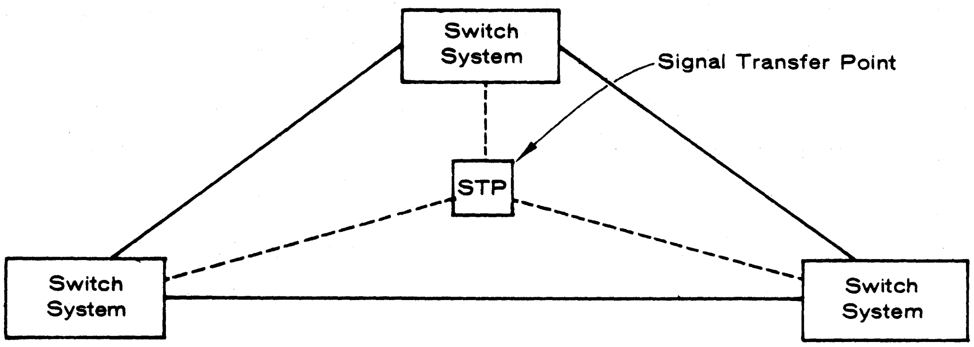
Figure 2-3. Inband and common channel signaling (AT&T, 1980).



a) Associated signaling.



b) Quasi-associated signaling.



c) Disassociated signaling.

Figure 2-4. Modes of common channel signaling operation.

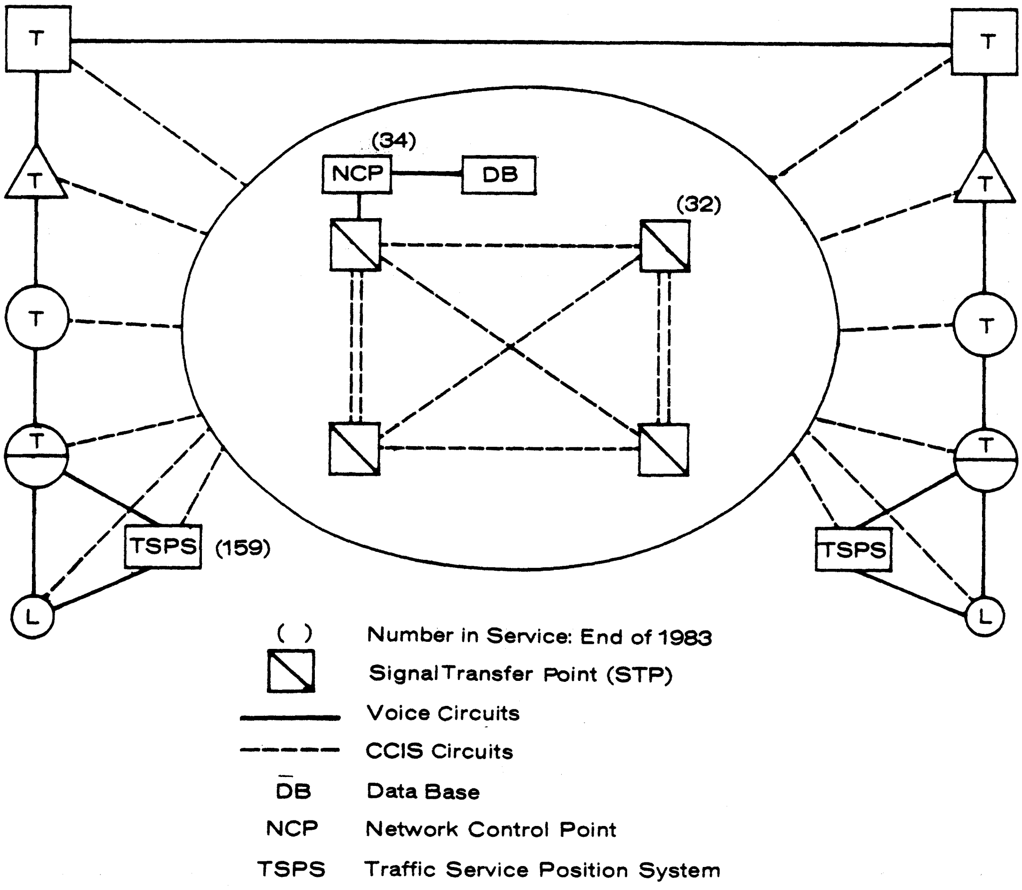


Figure 2-5. Stored program controlled hierarchal network (after Andrews, 1984).

instructions pertaining to the call, analyze the instructions, and then return call-handling instructions to the ACP (Lawser et al., 1982).

Redundancy is needed since the loss of a single NCP or its associated STP would block thousands of calls. Each NCP is paired with another NCP associated with a different STP located in another geographical location. If an NCP becomes inaccessible, its mate handles the traffic load.

Access links (A-links) from a switching office to paired STPs (called mate STPs) are provided in paired (mate) links, with one link to each STP (Figure 2-6). Bridge links (B-links) are provided between mate STPs in another region. Cross links (C-links) are used to complete a signal path through the mate STP when the direct A- or B-links fail (Frerking and McGrew, 1982).

The CCIS network uses 1) quasi-associated signaling to achieve economy of signaling traffic concentration through STPs and 2) packet-switched message handling that uses the BX.25 protocol. Initial signaling speed was 2400 b/s,

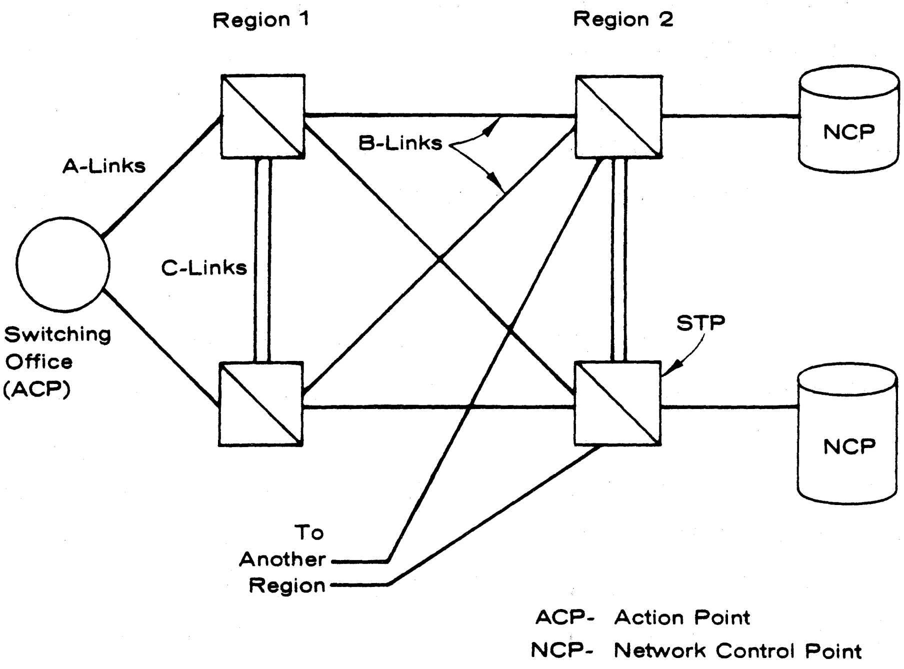


Figure 2-6. SPC network components (after Wolfe and Martellotto, 1984).

but this has been upgraded to 4800 b/s. As this CCS changes to CCITT No. 7 for ISDN, the signaling speed will be increased to 64 kb/s.

3. NEW NETWORK ARCHITECTURES

The description of network architectures and signaling so far is based on the hierarchal structure that was started during the 1930's, inplace in the 1950's, and continuously modified into the 1980's. The description that follows is based on current network architecture philosophy forced in large part by the divestiture of AT&T and Bell System companies.

3.1 Background

The antitrust suit of the United States versus AT&T et al., was settled on January 8, 1982. It is called the Modified Final Judgment (MFJ) because it replaced a 1956 Final Judgment in an earlier lawsuit filed against AT&T by the United States. A Plan of Reorganization (POR) was filed by AT&T on December 16, 1982. The MFJ was the basis for divestiture of the Bell companies from AT&T, while the POR provided the architecture of a new structure for the telephone industry. As a result, AT&T retained its long distance communication and telecommunication equipment manufacturing businesses (Andrews, 1984).

Other assets included retaining part of the Bell Laboratories. The 19 Bell System telephone companies were organized into seven Regional Operating Companies (ROCs). The MFJ and POR further divided the franchised areas of the ROC's into 161 LATAs. Eighteen other LATAs are served by other companies. This section will describe the developing inter- and intra-LATA network structures.

3.2 Dynamic Nonhierarchal Routing

The new network structure for inter-LATA traffic loads is evolving from the hierarchal to a nonhierarchal structure. The new structure is called DNHR. The switch systems will be classless and completely equivalent in their functions (Ash and Mummert, 1984; Mocenigo and Tow, 1984). Computer-controlled intelligence (i.e., SPC and CCIS) that has been built into the AT&T switching and trunking network is used for DNHR. Predetermined routing patterns can be changed up to 10 times per day based on measured and forecasted customer calling patterns. The changeover to DNHR started during August 1984 and is expected to be completed during 1987. Ninety-two existing 4ESS switches are affected by the changeover. Digital 5ESS switches could also become part of the changeover. Hundreds of millions of dollars are expected to be saved by AT&T in construction costs for new transmission facilities over the next 10 years by implementing DNHR.

3.2.1 Structure

There will be two parts, hierarchal and DNHR, to the new routing network structure. The conventional hierarchal structure (Figure 3-1) has primary center switch, T3, as a traffic concentration point. The DNHR part (Figure 3-1) appears as a large network of regional (class 1) switches to the hierarchal system below it. When the existing 92 4ESS switches are converted to DNHR, the apparently classless regional structure will exist in contrast to the current conventional hierarchal structure of regional centers across the country.

Three kinds of traffic are handled by the DNHR network (Figure 3-1).

1) Traffic that originates in different exchange access areas, but connects to DNHR switches: this traffic originates/terminates in exchange access networks 4 and 1.

2) Overflow traffic from the hierarchal network: this traffic is between exchange access areas 4 and 3.

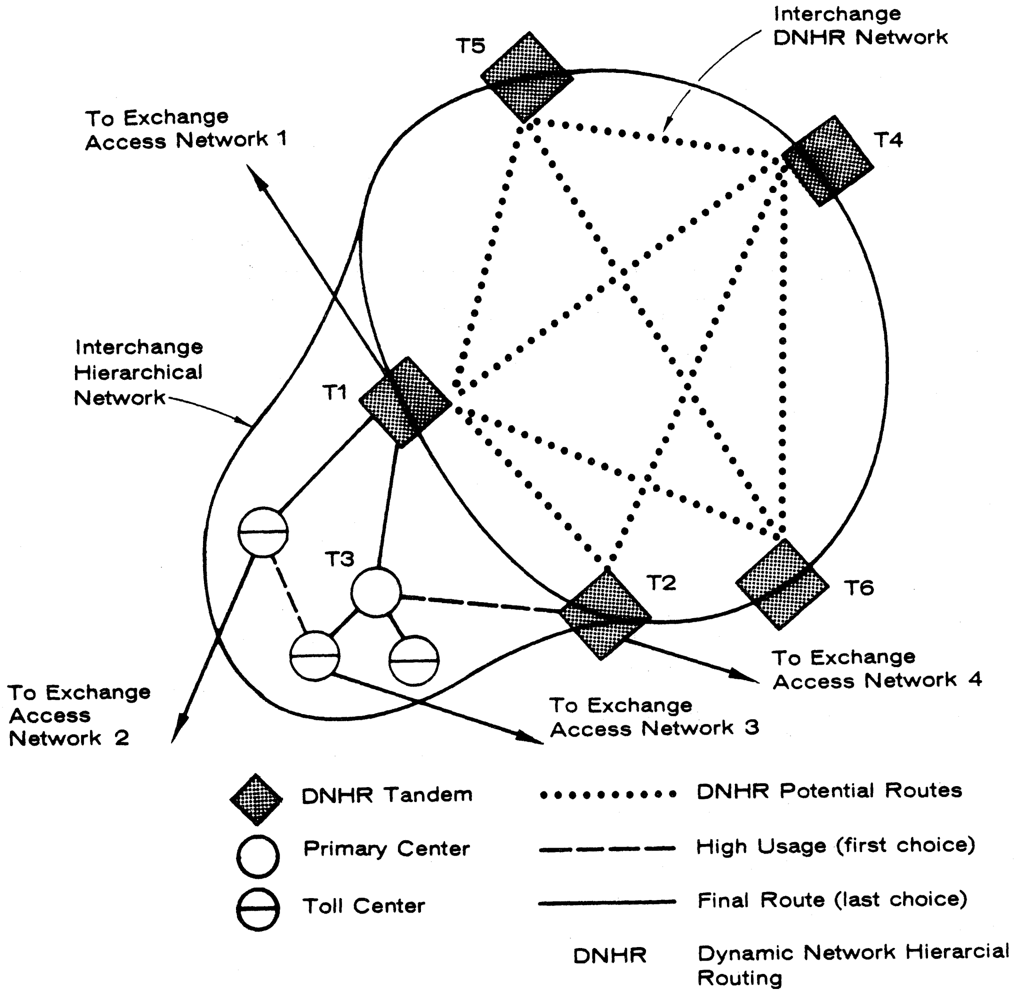


Figure 3-1. DNHR structure (Ash and Mummert, 1984).

3) Through-switched traffic loads from the hierarchal network: this traffic exists between exchange access networks 4 and 2.

These three kinds of traffic loads can be identified by a DNHR originating switch that can also determine the terminating switch. No more than two trunks will be used between originating and terminating DNHR switches for traffic that is identified as a DNHR call. Calls originating outside the DNHR network would appear to traverse at least three trunks to complete a call (e.g., one DNHR and two hierarchal trunks).

3.2.2 Routing

The principles of DNHR switching and routing are illustrated in Figure 3-2 (after Ash and Mummert, 1984). An originating switch in San Diego has control of a call until it is either completed or blocked in White Plains. The switching plan uses;

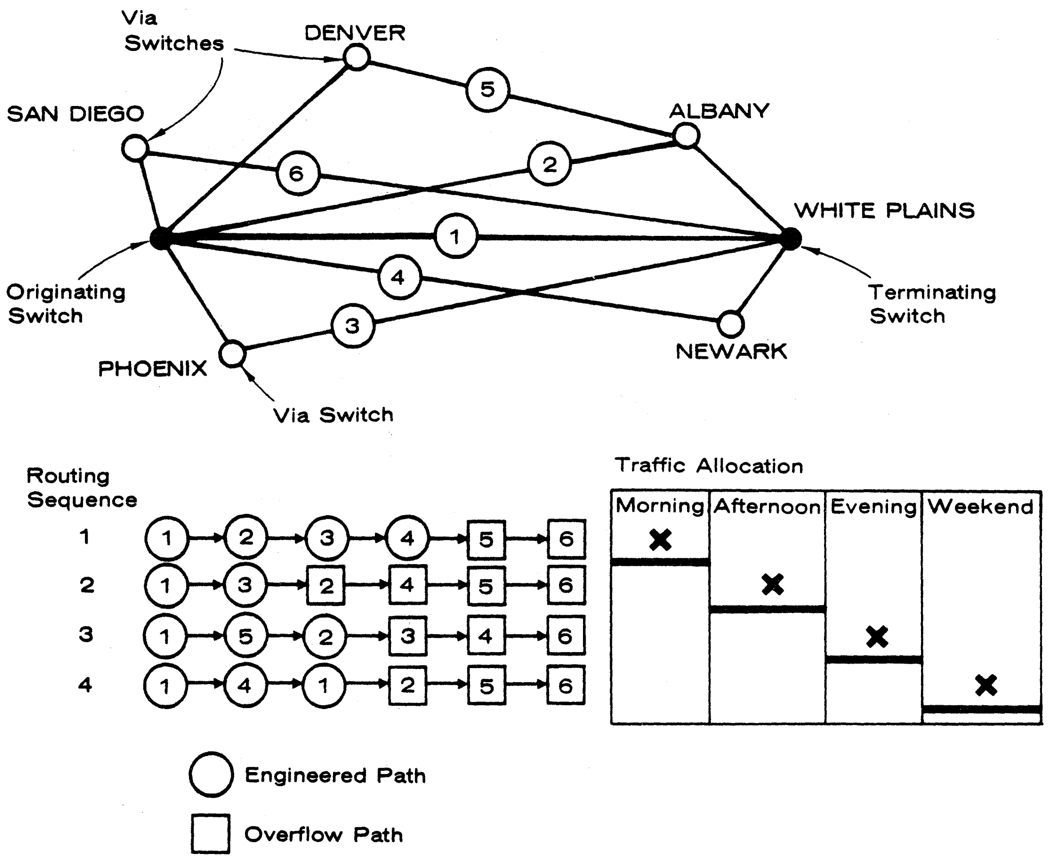


Figure 3-2. DNHR plan (after Ash and Mummert, 1984).

1) least-cost routing with no more than three switches or two trunks involved in a call (i.e., originating, terminating, and via, a third switch, between the other two),

2) predetermined optimal time varying routing that capitalizes on idle capacity in other parts of the network (i.e., path routing sequences that can vary ten times per day), and

3) using CCIS to inform the originating DNHR switch that blocking exists ("crankback") at a via switch and that another path may be attempted (i.e., real-time paths that handle overflow as a result of crankback). Attention should be given to the changes in the routing sequence, in particular for the engineered path, as the day progresses (Figure 3-2).

3.2.3 Management

Network management for the DNHR is different from that used for the hierarchal structure. The hierarchal structure depends on a decentralized, multisystem, multicenter structure. Any problem between two connecting regions is reflected only on those regions.

In contrast, the DNHR requires a centralized management approach because of the classless switches, no regional boundaries, and the use of different via switches as traffic load patterns vary throughout the day. A new Network Management Operations Support (NEMOS) center receives traffic data in one centralized data base. The NEMOS will automatically control the network, in realtime, based on traffic measurement samples. (Data that is collected and processed in the current management operation system is not enhanced to the extent that it will automatically control the network.) Based on measurement and forecastng, switch plan changes will be produced semiannually; trunking will be changed quarterly and also weekly if adjustments are necessary. Real-time changes will be possible in response to overflow conditions. The use of CCIS is integral to these switch plan, trunking, and routing changes.

The NEMOS has an automatic reroute algorithm capability that senses switch-to-switch overflow at certain levels. This information, collected every 5 minutes, is used by NEMOS to reroute traffic loads. The problem is approached by determining idle circuits between switch pairs. Traffic overflow from each switch pair is matched to idle circuits until all the overflows or all the idle circuits are paired. Reroute paths are removed when a switch pair falls below a particular threshold (Mocenigo and Tow, 1984).

The philosophy of the DNHR network is that the administration and management will be centralized, but the operation will depend on distributed intelligence at the switches. The SPC, with signaling instructions sent by CCIS from the NEMOS, will control the network switching.

3.3 LATAs and Equal Access

The LATAs are geographically defined areas of service responsibility where the divested operating companies and other communications carriers are authorized to route traffic. These carriers handle traffic that usually stays within state boundaries although exceptions exist. Traffic that crosses LATA boundaries must be handled by the inter-LATA carriers (Andrews, 1984).

3.3.1 Separation of Services

Under the hierarchal structure, local tandem and toll switching functions were often combined, for economic reasons, in a single switch within a class 4 office. According to the MFJ, all assets, including switches, were assigned to the dominant user. Generally, class 4/5 offices were assigned to a BOC, while tandems performing intra- and interstate switching were assigned to AT&T Communications. Disruption of service was avoided because sharing of assets is allowed on an 8-year leaseback plan. Under the consent decree it is also necessary to reroute traffic that had been carried on HU trunks across new LATA boundaries between end offices.

Two conclusions can be reached from these changes. First, the inter-LATA (i.e., interexchange) carriers prevail in the areas where HU trunks were used to carry traffic. Second, more switches in the class 4/5 category will be installed to carry traffic as the intra- and inter-LATA traffic is separated before the 8-year limitation on leaseback ends. These switches are described in Section 4.

3.3.2 Access

Prior to divestiture, the toll network (now the inter-LATA domain) as provided by AT&T and its competitors appeared as in Figure 3-3. A three-level hierarchy was used by terrestrial carriers when connecting to class 5 offices.

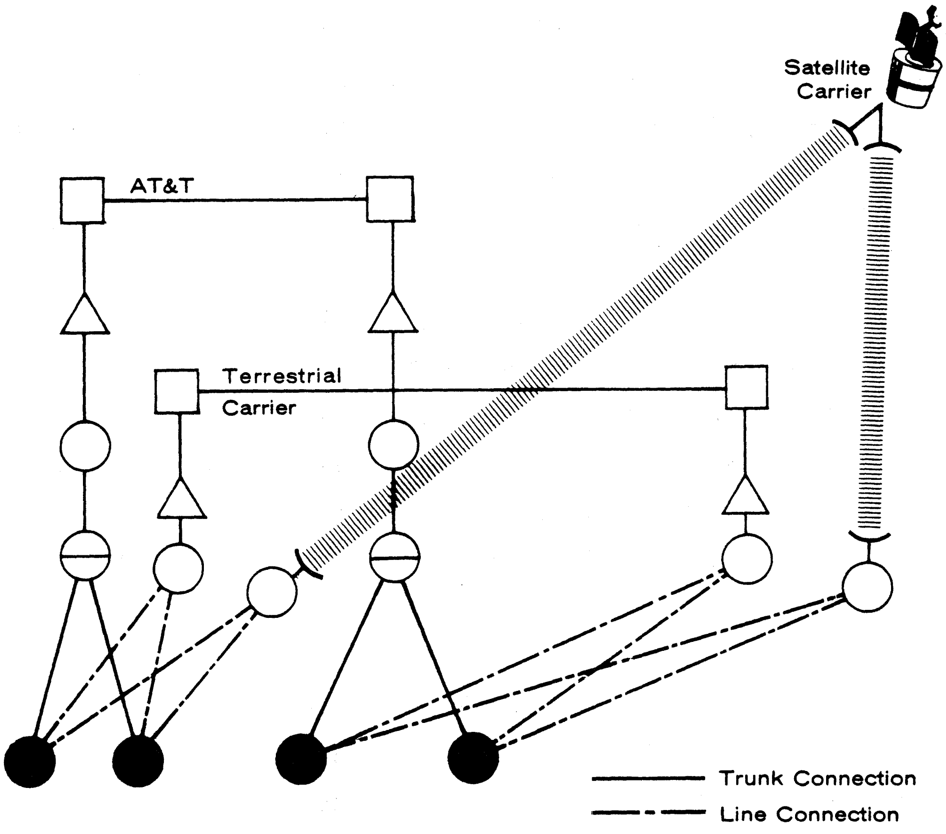


Figure 3-3. Toll networks for AT&T and other carriers (predivestiture) (Andrews, 1984).

Only one level using time division multiple access (TDMA) was and will likely continue to be used by satellite carriers.

For a subscriber to use a non-AT&T inter-LATA carrier it has been necessary to use touch-tone dialing to access a carrier. The dialing sequence would use a second dial tone and require approximately 24 digits, including the caller identification number, to establish the call.

This lengthy connect dialing sequence to a carrier other than AT&T is considered "unequal" access and inferior to an 11 digit call connection that includes the 1+. Switches with SPC are being modified to provide equal access for up to 999 inter-LATA carriers. Subscribers that are served by electromechanical switches will not have the same equal access to an inter-LATA carrier until the older switches are replaced. With full equal access implementation, a subscriber can have service from any inter-LATA carrier by dialing the normal 7- or 10-digit numbers. It will also be possible to override the regular carrier and select any inter-LATA carrier. This will require dialing an initial sequence of 10xxx where xxx is one of the 999 carrier selection numbers assigned to serve a LATA.

Equal access by subscribers to inter-LATA carriers is provided through direct trunks, tandem switching, or both. Tandem switches used in this way are called access tandems (Figure 3-4). About 250 access tandems are expected

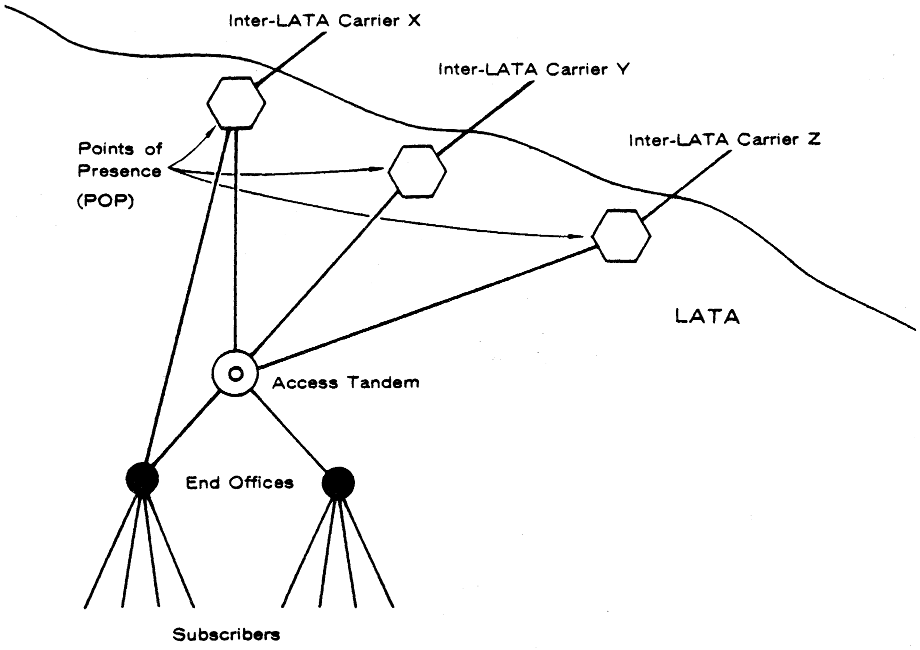


Figure 3-4. Equal access to inter-LATA carriers (after Andrews, 1984).

to be deployed by 1987 (Andrews, 1984). A switching system or facility where a LATA network is connected within the inter-LATA carrier structure is called the point-of-presence (POP) and more recently, point-of-termination (POT).

3.3.3 Signaling and New Services

Common channel signaling links to local offices were discontinued with divestiture. At the same time, STPs and NCPs heretofore owned by the Bell System were assigned to AT&T. Improvements in the inter-LATA signaling network are expected to include an increase in the signaling speed from 4.8 kb/s to 56 kb/s and higher capacity STPs that use CCITT No. 7. Other inter-LATA carriers, such as GTE Sprint and MCI others are also expected to implement CCS that will support their services and traffic.

The BOCs are expected to evolve their own CCS networks. Regional STPs and LATA action points for "800" service will use CCITT No. 7. Figure 3-5 shows the inter-LATA points-of-presence for CCS and voice circuits within the LATA domain. Intra-LATA STPs are also shown as being connected to POPs, access tandems, end offices, and data bases. From this it is clear that end offices that exist within the LATAs will have CCS and inter-LATA carriers will be part of the signaling between LATAs. Intra-LATA services that are expected include call-waiting, selective call-forwarding, call-screening, and calling-number display (Andrews, 1984). Data bases for services are expected to be located in inter- and intra-LATA networks depending on the service provider. [Note: As of September 1985, court motions have been filed by some BOCs to access the AT&T advanced 800 data base that permits a customer to use an interexchange carrier without changing the 800 number. Upon court denial, FCC filings have been made seeking to allow the 800 service, while other BOCs prepare their own versions (BOC Week, 1985)].

4. SWITCH DESCRIPTIONS

The eight switch systems that are described in this section have a number of functional attributes. They have circuit- and packet-switched applications, ISDN capability, including integrated voice and data, common channel trunk signaling using CCITT No. 7, and are marketed by U.S. and foreign companies for use in local, local/tandem, and access tandem offices. Based on the intra- and inter-LATA structures, these switches have been, and will be, installed by local and interexchange carriers. All are being manufactured or modified in

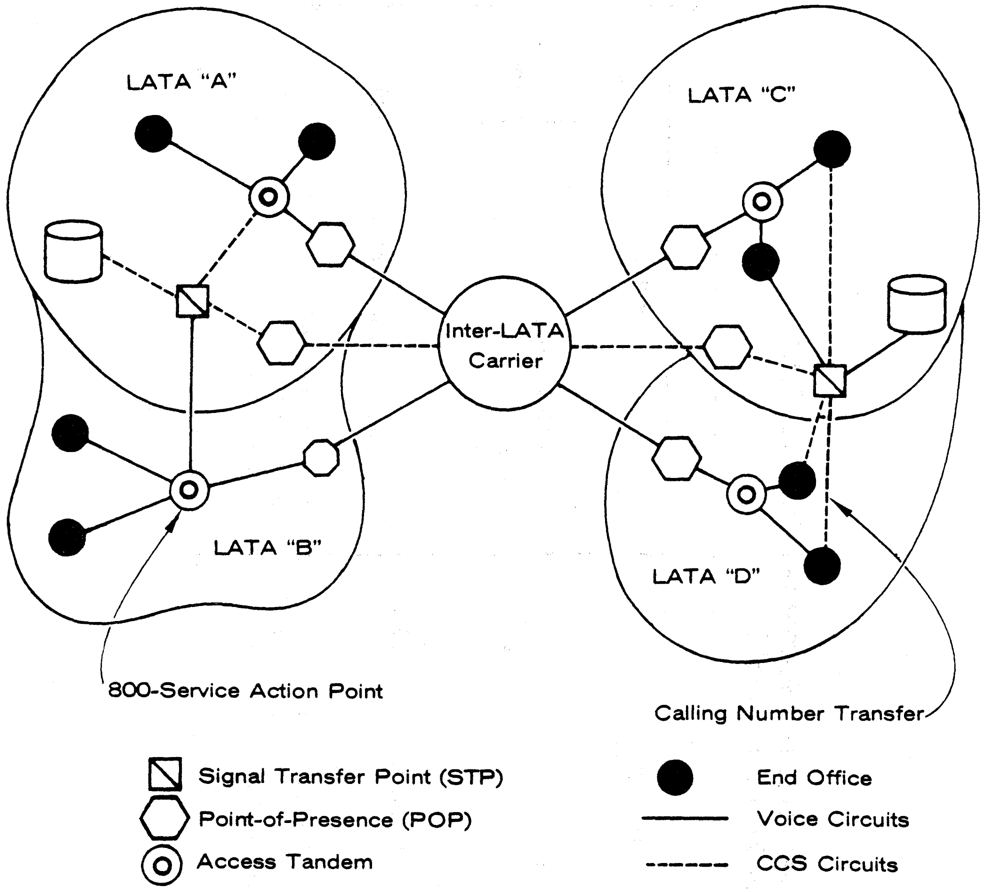


Figure 3-5. Inter- and intra-LATA signaling (after Andrews, 1984).

the United States to meet North American switch requirements. The information describing these switches has been obtained from the respective manufacturers, technical journals, or papers presented at conference proceedings. From the information available, the architectural approaches that are described will permit an adaptive approach to changing communications requirements and to the ISDN services that are emphasized by many of the switch manufacturers.

4.1 AT&T 5ESS

The AT&T 5ESS switch system has modular hardware and software that can be arranged to suit a customer's needs. It uses distributed processing to enable growth of capacity and capability. It has been designed to serve a range of applications and markets (Table 4-1). In some instances the 5ESS could replace older switches (i.e., step-by-step and 1ESS switches) or work in a coprocessing environment with another switch such as the 1A ESS.

Table 4-1. Market and Application Replacement Potential for the 5ESS (Marstersteck and Spencer, 1985)

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

The 5ESS hardware architecture has three major module components: an Administrative Module (AM), a Communication Module (CM), and one or more Switching Modules (SMs) including those for remote locations (Figure 4-1).

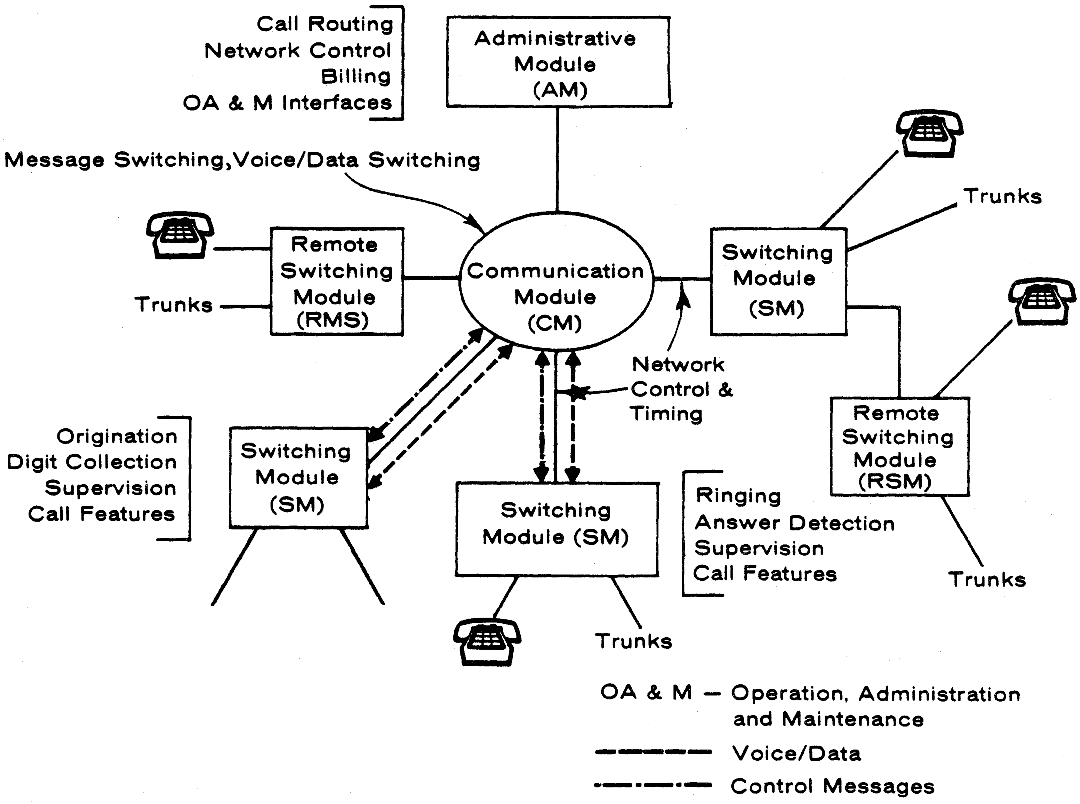


Figure 4-1. Hardware architecture for the 5ESS switch (Johnson et al., 1984).

4.1.1 Administrative Module

The AM provides interfaces required to administer, operate, and maintain the switch. The AM has dual 3B20D processors in an active/standby configuration for reliability. The active processor has control while simultaneously maintaining the standby unit. Should the active processor have a fault, the standby unit is switched into service without loss of data.

The AM performs call processing functions such as line and trunk group routing determination for the switch module, and the allocation of time-multiplexed-switch time slots. Call-processing support functions include systemwide craft maintenance, diagnostic control, software recovery and initialization, and certain limited fault recovery and error detection.

A disk memory and input/output processor (IOP) are subunits of the AM. The disk memory provides mass storage for programs and data while the IOP interfaces with support systems, video display units, printers, tape drives, and a Master Control Center (MCC). The MCC provides the interfaces for manual control of system operations and a system status display. Two craft interface languages are available for operation and maintenance functions on SPC systems such as the 5ESS. One is a language that is similar to that used in the 1A ESS. The second is the CCITT man-machine language (MML) (Carney et al., 1985; Gitten et al., 1984). The functions that are controlled by the MML are for 1) operational purposes such as routing, traffic, tariff, and system control administration, 2) maintenance of switching control and subscriber lines, 3) plant installation testing, and 4) testing of, for example, memory dumps (CCITT, 1980).

4.1.2 Communications Module

The CM contains a message switch that transfers call-processing and administrative data messages between the other two types of modules. Messages are transferred through the CM and then to the AM and SM modules by using the CCITT Recommendation X.25 level-2 (link layer) packet-switching protocol. The data packets are transferred to the modules through Network Control and Timing (NCT) links that use fiber light guides. There are two NCT links between each module. Each link carries a 32.768 Mb/s serial data stream containing 256 channels (time slots). This results in 512 channels between each module.

The 5ESS CM has a time-space-time (TST) architecture that is implemented by a time multiplex switch (i.e., to perform time-shared space-division switching) and a time-slot interchange unit (i.e., for time-division switching). The fiber-optic data links, that provide communication paths between SMs, are switched through by the centralized time multiplex switch (Carney et al., 1985; Gitten et al., 1984).

4.1.3 Switching Module

The SM is the expansion unit for the 5ESS switch. It consists of different types of interface equipment for line and trunk terminations, provides for call processing intelligence, and performs the first stage of switching. There are analog and digital interface units for lines and trunks. Although it may appear contradictory, one digital trunk line unit for interoffice trunks can terminate up to ten North American T1 lines at 1.544 Mb/s or up to sixteen 2.048 Mb/s digital lines (Carrey et al., 1985). A digital subscriber loop carrier system, the SLC^{TM}96, is a loop carrier pair-gain system that serves as a cable replacement or supplement that can carry up to 96 subscribers over a T1 line.

Equipment that is common to the SMs includes dual link interfaces (i.e., NCTs), duplicated module processors and slot-interchange units, and a digital services unit. The redundant processors control call processing, call distribution, and call maintenance. The slot interchange unit switches 256 time slots on each NCT link (512 total). It can connect these time slots to peripheral devices, or to the command module. The digital services unit provides time generation and decoding.

The 5ESS uses a computer and operating system that are an integral part of stored program controlled networks including central office switching and switch support systems. The 3B^{TM} Duplex Computer (3B20D) uses the Duplex Multi-Environment Real Time (DMERT) operating system. It is compatible with the UNIX operating system and also supports the C- programming language. [A name change has been made and the DMERT operating system is now called the UNIX^{TM} Real-Time Reliable (RTR) operating system.] Translation from the C-language to CHILL has also been considered.

The 3B20D computer system is used:

- in Network Control Points (see Section 2.4) to provide on-line, real-time bases for STPs in the CCIS network;
- in packet-switched data communications networks that use CCITT Recommendation X.25, including applications of the No. 1 Packet Switching System (1PSS) in Local Area Data Transport (LADT), ACCUNET Packet Switching Service and CCIS;
- for Traffic Service Position System traffic (see Section 2.2);
- as attached processors for the 4ESS^{TM} and 1A ESS^{TM} switching systems to provide file storage and off-load capability; and
- to serve the 5ESS switch as the central processor/administrative module in addition to several other functions (Becker, J.O. et al., 1984).

4.1.4 Software

The 5ESS software can be described in two ways: conceptual and operational. In conceptual terms, the 5ESS software architecture consists of a hierarchy of vested virtual machines where software is structured as a set of sequential abstract layers (Figure 4-2). These layers apply to all processors located within the hardware of the administrative, communications, and switching modules. The hierarchy is such that any machine, at any layer, uses the services of lower-layer machines and provides services for higher-layer machines.

The center circle in Figure 4-2 is the lowest layer of the hierarchy. It is the physical or "bare machine" and consists of the AM, SM, and the CM which contains the message switch and time multiplex switch (TMS).

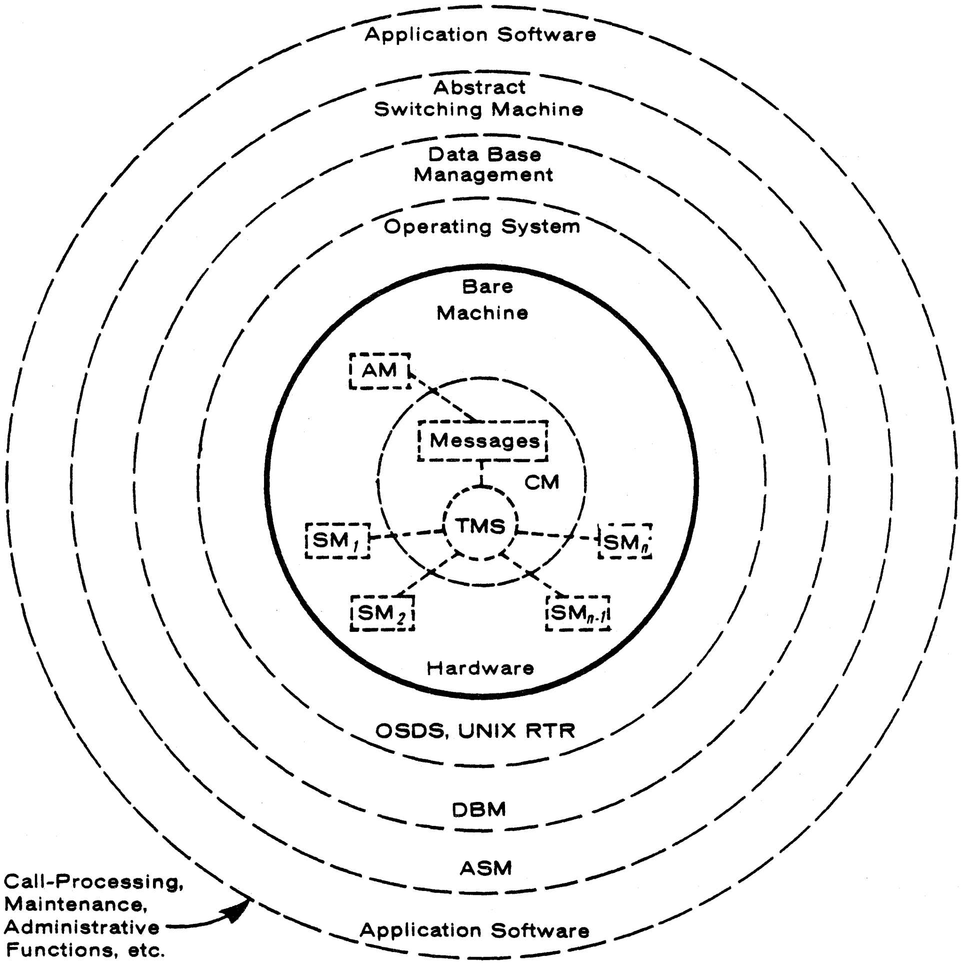
At the next layer, the Operating System for Distributed Switching (OSDS) runs on all processors. The OSDS in the switching modules is designed for switching applications in a distributed architecture. In the administrative module there is a general real-time operating system called the UNIX^{TM} RTR operating system along with OSDS running on the RTR in the form of several processes. The OSDS provides five major functions (Delatore et al., 1985):

- Processor isolation--hardware changes have a minimal effect on software design
- Concurrency control--the ability to handle a large number of activities as a sequence of separate tasks in a process
- Intra- and interprocessor message communication--message transmission within or between processors
- Resource scheduling--allocation of memory resources and processor time.
- Timing--1) a time of day clock for billing and time-stamping, and 2) timing requests required for process control.

At the next layer (the third) of the hierarchy, the virtual machine is for the Data Base Management System (DBMS). There is a collection of data bases that are located in some or all of the separate processes. The DBMS supports the various data bases and distributed management of the data so that the location of the data is transparent to programs.

The abstract switching machine (ASM) is at the fourth layer of the software model. The ASM is also known as a Virtual Switching Machine (VSM). Somewhat more detail will be presented for this layer because of the interesting concepts that are considered for call processing on facility maintenance.

An analogy of the virtual machine hierarchy can be made. A conventional operating system provides a virtual machine environment to application level



Notes: AM — Administration Module
CM — Command Module
OSDS — Operating System for Distributed Systems
RTR — Real-Time Reliable
SM — Switching Module
TMS — Time Multiplex Switch

Figure 4-2. Concept of 5ESS software architecture (Carney et al., 1985).

programs by implementing an abstraction of a bare machine. Similarly, the ASM/VSM provides high-level abstraction of the switching periphery to the switching application software (Hafer et al., 1984).

Within the VSM, there are basic resources available to the application software--the logical ports (LPs), network paths, and connectors. Also, a terminal process in the VSM is a concept where it controls the LPs, paths, and connectors it has acquired.

Customer access channels to the switch model (Figure 4-3) may be concentrated, or unconcentrated, and are used to transport customer information

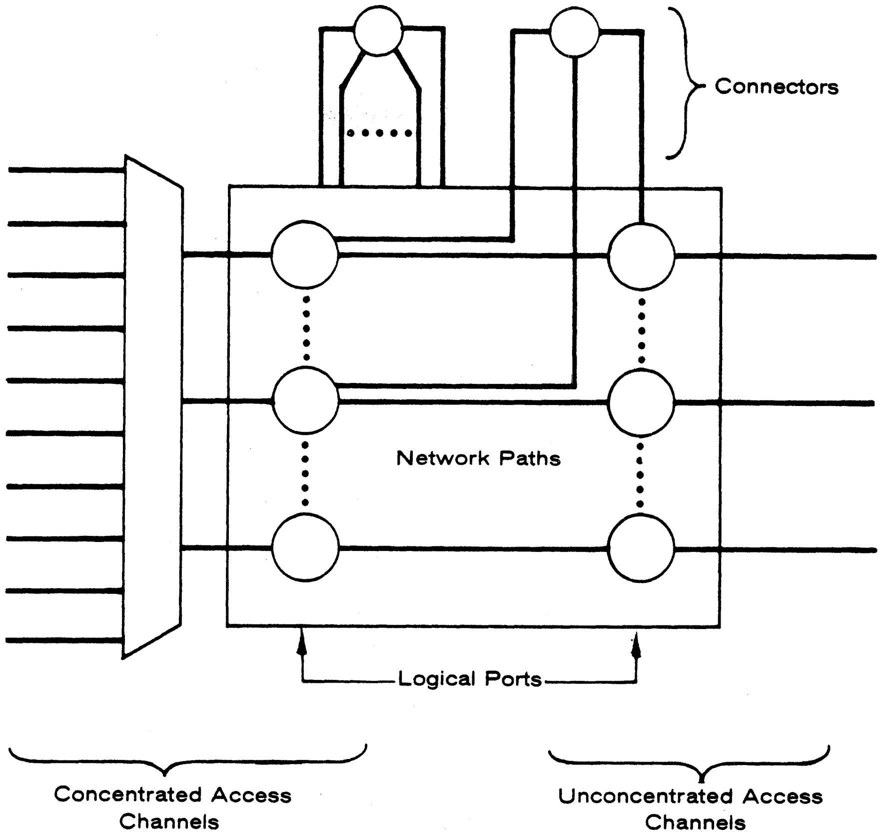


Figure 4-3. Simplified switch model (Hafer et al., 1984).

messages between distant terminals. The access channels are interconnected by network paths within the switch. A logical port represents an access channel to the switch. Connectors within the VSM represent an information mixer where the application of an algorithm to n input streams results in m output streams. Connectors provide the service concepts for message broadcast on a multiparty conference call. Different services may use different connectors. VSM paths in the switch model can represent 1) a communication channel in the switch, 2) different types of communication channels, and 3) interconnection of logical ports and connectors.

Terminal processes perform various types of operations on the logical ports representing customer access channels, on the network paths, and on connectors. Operations on LPs are open and close, establishment and release (i.e., between two LPs, two connectors, or an LP and a connector), and the joining of two paths. Operations on connectors are such that the terminal process inserts a connector for the purpose of establishing a connection between LPs.

In mapping the VSM into hardware, the LP associates with the physical connection of a terminal device such as a PBX, telephone, or video display terminal to the switch. LP hardware includes the port circuitry, concentration arrangement, and time slot interchange (TSI). Paths are implemented in the TSI and TMS. Connectors are implemented in conferencing circuits (Hafer et al., 1985).

The final layer of the virtual machine hierarchy is the application software. This software provides for call processing, maintenance, and administration.

So far this has been a conceptual description of the 5ESS software architecture. The operational software can be described as consisting of subsystem modules that communicate with each other while using specific message protocols and instructions across module interfaces. Subsystem components are shown in Figure 4-4. The switching periphery is the hardware nearest the lines and trunk ports. Routing and terminal administration is at the highest level and further removed from the hardware. As shown, all functions within the operating system (e.g., OSDS) span all processor modules.

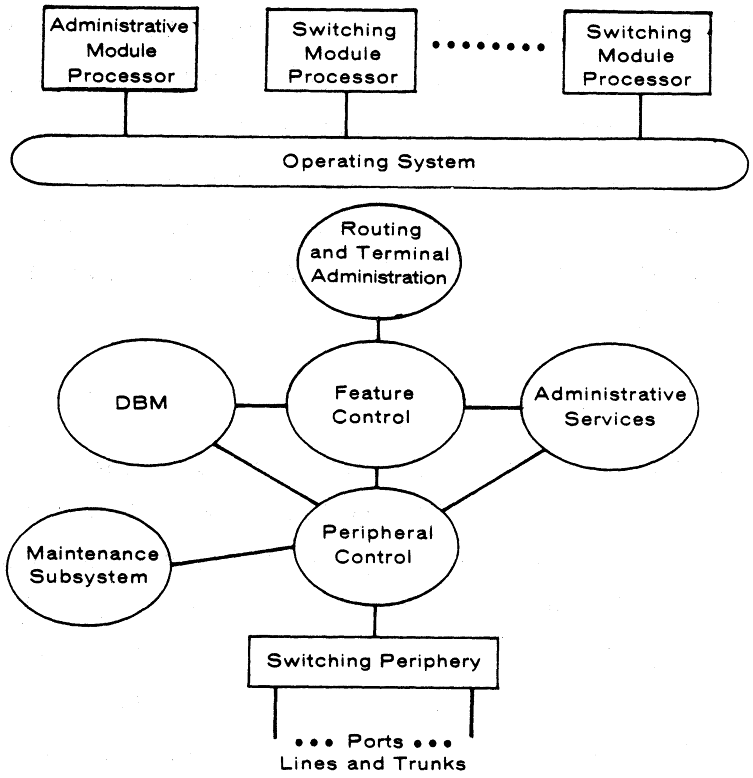


Figure 4-4. Operational software architecture for the 5ESS (Delatore et al., 1985).

Three major components of the call processing software are peripheral control, feature control, and routing and terminal allocation.

Routing and terminal allocation performs call routing and screening based on information from dialed digits and the originating line to route the call to the appropriate outgoing trunk or terminating line. The routing process provides the "link" between originating and terminating terminal process in feature control.

Feature control also consists of hardware-independent software. It is used for example, to implement Plain Old Telephone Service (POTS), coin service, hotel/motel service, and modular CENTREX features available on the 5ESS.

Peripheral control consists of hardware-independent software that provides a set of logical primitives that are used, for example, to ring a phone, out-pulse digits on a trunk, and make network connections. (Note: primitives are interactions between layers to convey a request, indication, response, or confirmation.)

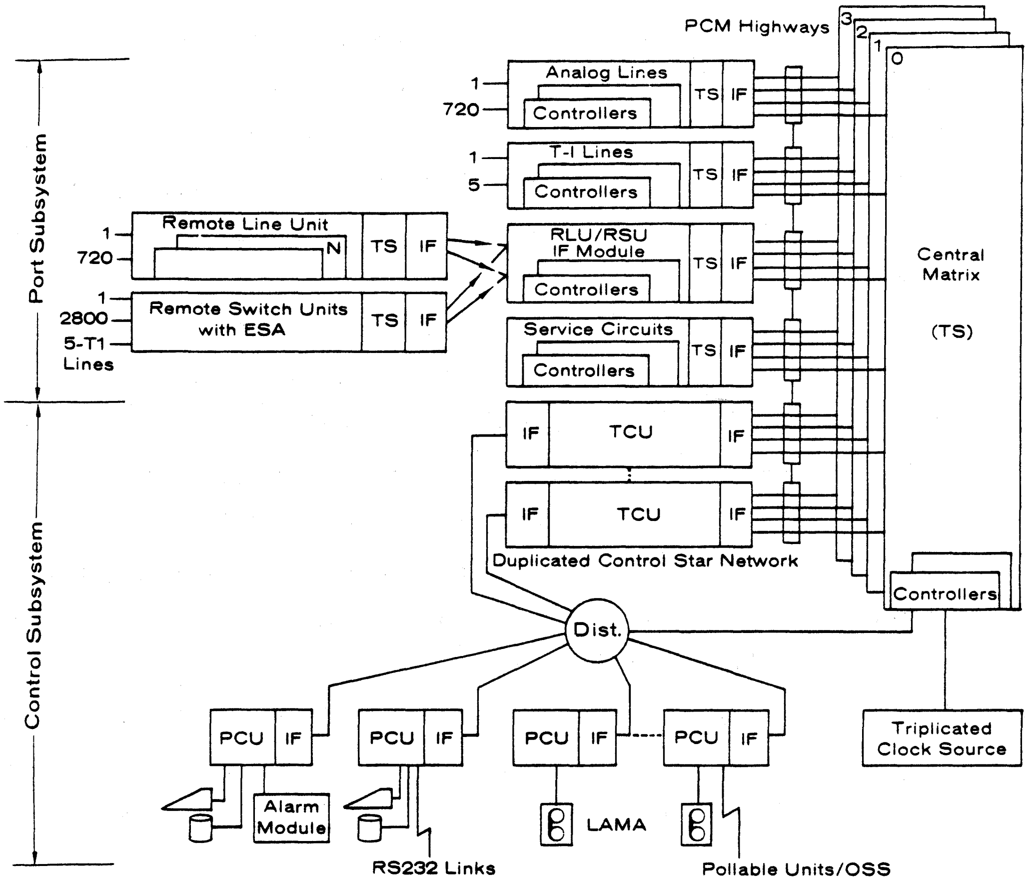
The overall architecture of the 5ESS call processing software was not changed because of divestiture. However, because of 5ESS end office and access tandem applications, two of the above components, routing and terminal allocation, and feature control did need modification. Enhancements were made to give each customer equal access to inter-LATA carriers on a per-call or presubscription basis. Software was added to feature control to provide new digit analysis, carrier selection and validation, and needed signaling functions. Routing and terminal allocation was changed to allow calls to be routed to carriers (Averweg, 1985).

4.2 CIT-Alcatel E10-FIVE

The E10-FIVE switch is intended for the North American market. The switch has a common source that is related to the CIT-Alcatel E10-S family consisting of switches for videotex, radiotelephone, and multiservice (i.e., terrestrial switching nodes for satellite data and voice networks). About 50% of the E10-FIVE hardware and software is common with the E10 products. All E10-S hardware, including specific developments for the E10-FIVE is developed in France. All E10-FIVE feature specifications, including the definition of hardware and software, are done in the United States. The E10-S common software is developed in France while E10-FIVE specific software is done in the United States (Katula et al., 1984). Applications of the E10-FIVE include services provided as class 5, class 4/5 offices, and access tandem facilities.

4.2.1 Hardware Architecture

The hardware for the E10-FIVE has three major subsystems; port, central matrix, and control (Figure 4-5).



Dist	- Control Highway Distribution
ESA	- Emergency Standalone
IF	- Interface
LAMA	- Local Automatic Message Accounting
OSS	- Operational Support System
PCU	- Peripheral Control Unit
TCU	- Terminal Control Unit
TS	- Time Switch

Figure 4-5. E10-FIVE architecture (after CIT-Alcatel, 1984b).

The basic functions of the port subsystem are to interface subscriber lines, digital trunks and service circuits, and to convert the analog and T1 circuits to the PCM transmission format (at 2.048 Mb/s) internal to the E10-FIVE. Each terminal unit in the port system that provides the interface also contains the first and third stages of the three-stage, time-division (TTT) switching matrix (i.e., time-slot interchange) through which the telephone, data, and other communications traffic is routed. Decentralizing the first and third switching stages is required so that each terminal unit has full access to any of 31 voice and 1 control channel and to any of the 4 PCM central matrix highways. (Note four PCM highways between the port system control units and the central matrix in Figure 4-5). There are two benefits to this design approach: the second stage (the central matrix) is nonblocking and a central matrix fault would cause only minor system degradation. Each port system control unit contains its own microprocessor to provide local control as well as communication with the other subsystems.

The central matrix is the second stage of the three-stage, time-division switching network. At the central matrix, voice or data communications transmitted on a time slot of an incoming PCM path (called "highways" by CIT-Alcatel) are transferred to another time slot on an outgoing highway. The central matrix provides the interconnection between units of the port subsystem. It also connects the control and port subsystems for the transmission of control information. The central matrix is made up of four independent planes, each of which is fully nonblocking.

Each central matrix unit has a capacity of 32 incoming and 32 outgoing highways. A plane that is fully equipped with four matrix units forms a 128 x 128 nonblocking matrix, with intermediate configurations at 64 x 64 and 96 x 96.

Each of the four independent planes contains one to four matrix units depending on required capacity. Each matrix unit on a plane has 32 input/output time slots, 31 for voice or data and 1 for control. This results in 992 (31 x 32) time slots entering and leaving a matrix unit. With full implementation of four planes and realizing that each message path requires two connections, one for each direction of transmission, 2000 simultaneous calls can be handled. Four fully equipped central matrix planes of 32 x 32 time slots can handle over 7900 simultaneous calls (CIT-Alcatel, 1984a).

Current E10-FIVE availability has a line capacity of 34,000 lines. Full architectural implementation can exceed 100,000 lines. Figure 4-6 illustrates the variety of line and trunk combinations that can be supported by various central matrix configurations from 32 X 32 to 256 X 256 time slots. For example, a 192 X 192 matrix arrangement can support approximately 78,000 lines and 5,500 trunks with an average of 3.7 ccs per line and 21.6 ccs per trunk (CIT-Alcatel, 1984c).

The control subsystem is comprised of two types of control units: telephony control units (TCUs) and peripheral control units (PCUs). The primary function of the TCU is call processing while the PCU provides interfacing with E10-FIVE peripheral equipment such as hard disk drives, tape drives, input/output terminals, and other peripheral devices.

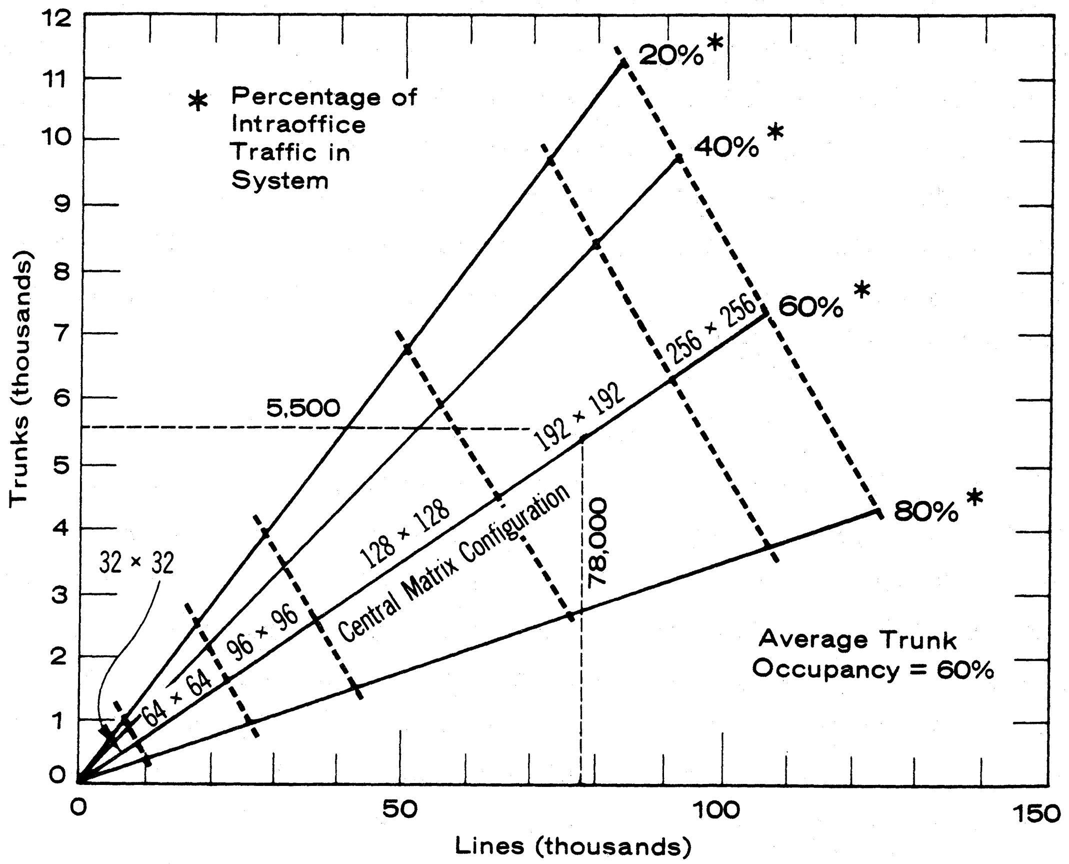


Figure 4-6. E10-FIVE class 5 capacity allocation for lines and trunks (CIT-Alcatel, 1984c).

There are three types of TCUs: service, call processing, and administrative. Service TCUs are highest priority and perform system management functions. Call processing TCUs have the next priority and establish calls through the system. Administration TCUs have the lowest priority. They perform routine administrative tasks and provide spares for the other TCUs.

Each E10-FIVE may be equipped with four PCUs. Two PCUs with a master/slave relationship have access to redundant 10- megabyte hard disk drives. These PCUs can also interface to X.25 data network and RS-232-C lines. The other two PCUs are intended for automatic message accounting, with one unit designated as active and the other as standby.

4.2.2 Software Architecture

Software architecture, like the hardware, in the E10-FIVE is distributed. The software is structured into modules called logical machines (LMs). Each LM is an independent entity that corresponds to a system function such as call processing, system management, or automatic message accounting. The logical machines were developed to permit software distribution and automatic transfer between particular units. A number of logical machines are loaded into the TCUs and PCUs where a memory space is occupied. Functions within an LM are divided into tasks that are addressed by a task number. The LMs communicate with each other based on the address number without regard to task location in the same or another PCU or TCU.

4.3 Ericsson AXE System

The Ericsson AXE network switching system from Sweden is intended to compete in the same market areas in the United States as the other switches in this report. Ericsson business areas include Public Telecommunications, Information Systems, Cable, Components, and Radio Communications. Public Telecommunications covers sales of telephone exchanges and transmission equipment. Sales in the United States have mainly consisted of transmission equipment. Due to the restructuring of AT&T and resulting market opportunities, Ericsson has opened a research, development, and support center in Dallas, Texas. Its purpose is to adapt the AXE system to U.S. technical requirements (Ericsson, 1985a) and to respond to signaling requirements that will be determined by current standards work in the United States.

4.3.1 System Structure

The AXE, or AXE 10, system structure is organized in a five level hierarchy of functional modules: two system levels, subsystem, function block, and unit (Figure 4-7). Each module at the upper levels is comprised of a combination of hardware and software, as required, to fulfill functional requirements. Software and hardware are explicitly separated at the function unit level.

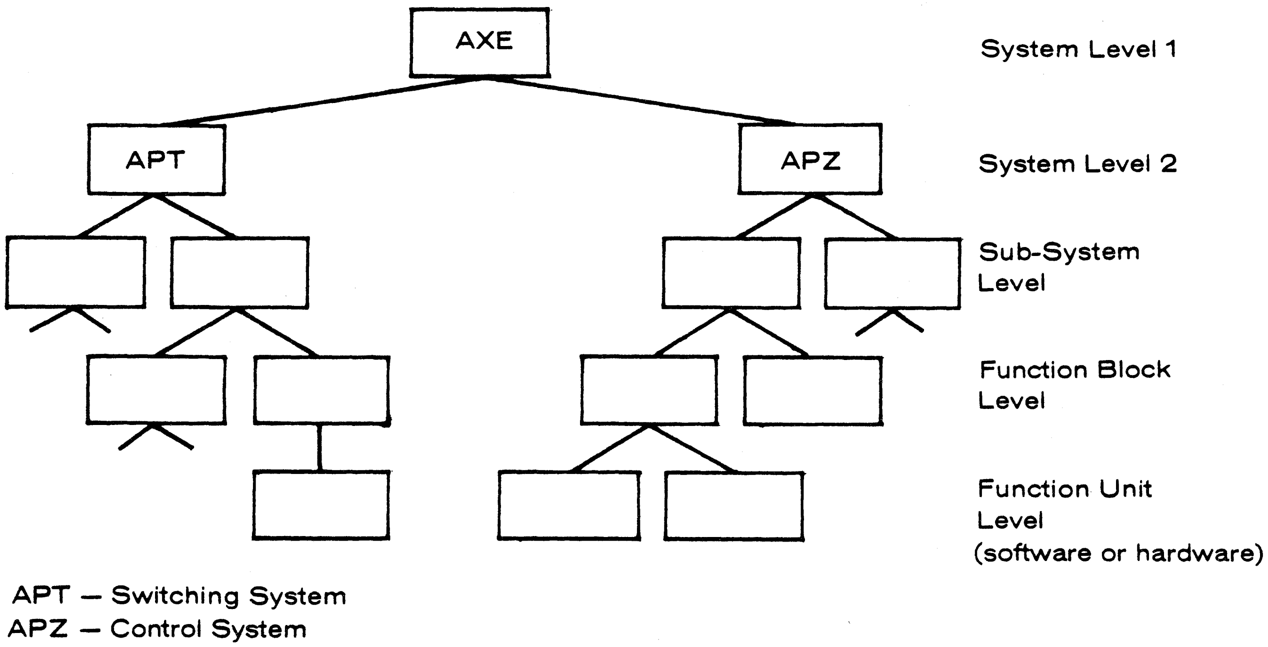


Figure 4-7. AXE 10 system functional levels (Ericsson, 1985b).

The AXE 10 is divided into two major systems: the APT switching system for traffic handling, operation and maintenance, and the APZ control system for call processing (Figure 4-8). There are four main subsystems within the APT switching system:

- the Subscriber Switching Subsystem (SSS)
- the Group Switching Subsystem (GSS)
- the Trunk and Signaling Subsystem (TSS)
- the Common Channel Signaling Subsystem (CCS).

The APZ control system consists of two subsystems with central and distributed logic. They are:

- the Central Processor Subsystem (CPS)
- the Regional Processor Subsystem (RPS).

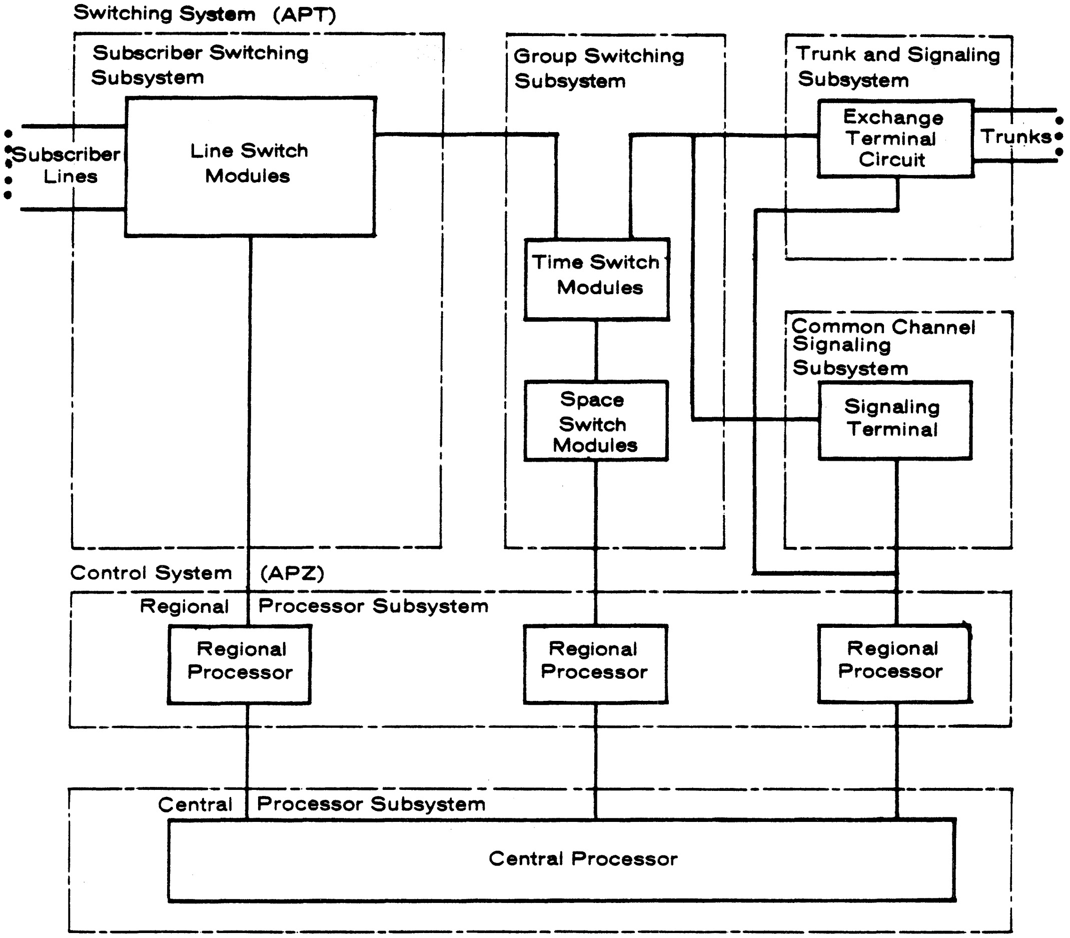


Figure 4-8. AXE 10 hardware structure (Ericsson, 1985b).

Strict boundaries have been defined for subsystems and block structures for the purpose of tailoring function blocks to market requirements. The modularity simplifies engineering extension and changes. The following description will consider the APT and then the APZ subsystems.

4.3.2 Switching Subsystems

The APT switching system consists of both hardware and software within the main subsystems that handle subscriber switching, group switching, trunking and signaling, and common channel signaling (Figure 4-8).

The Subscriber Switching Subsystem supervises the state of connected subscriber lines, sets up and releases connections in the subscriber switching network, and sends and receives signals between subscribers. This subsystem contains the digital subscriber switch that is built up of a series of line switch modules (LSMs). The line switch modules contain interface circuits, regional processors, terminal circuits, and a nonblocking time switch that accesses the AXE 10 digital group switch.

The Group Switching Subsystem is controlled by a software system that sets up a path through the group switching network between the subscriber switching and trunk and signaling modules (Figure 4-8). This subsystem contains the digital group switch that is composed of time switch and space switch modules forming a TST structure. Time switching is performed by buffer memories and space switching by electronic crosspoint matrices. This digital group switch is essentially nonblocking so that any trunk can be connected to any vacant port of the switch without the traffic influence of any other trunk. This makes it unnecessary to balance loads or rearrange network terminations as new trunks are added.

The Trunk and Signaling Subsystem includes circuits for connecting trunks and signaling devices to the group switch.

The Common Channel Signaling Subsystem includes signaling terminals for CCITT common channel signaling systems No. 6 and No. 7. The CCS implements the message transfer parts and has been designed to permit incorporating changes in the user parts of CCITT No. 7.

Other APT subsystems consist entirely of, or almost all, software. These subsystems are devoted to:

- traffic control by setup and release of speech connections
- automatic message accounting
- operation and maintenance such as line supervision and fault locating
- subscriber services for speed calling, call transfer, forwarding, and tracing.

4.3.3 Control Subsystems

The APZ control system divides switch functions based on 1) simple dedicated functions such as repetitive scanning operations requiring minimum processing in realtime, and 2) higher-level processing such as fetching and decoding instructions, and data processing of arithmetic logic operations for switch interrupt functions. The regional processors handle the routine tasks while the central processor handles the sophisticated tasks. Both are microprogrammed using machine instruction. In addition to the regional and central processor subsystems there are other subsystems to provide:

- maintenance functions for fault detection and repair
- operator-machine communication that uses the CCITT Man-Machine Language (MML) for operation and maintenance

Depending on switching office traffic requirements, there are three processor models [sized in terms of Busy Hour Call Attempts (BHCA)], consisting of hardware and software, available for the AXE central processing system. They are the APZ 213 (small offices; 11,000 BHCA), the APZ 211 (small-medium offices; 150,000 BHCA), and the APZ 212 (large offices; 800,000 BHCA). According to Ericsson (1985b), the structure of the APZ 212 allows changes that extends the capacity to 2,000,000 BHCA. Each of these processors has a similar logical and physical structure and each is duplicated for reliable operation in the AXE switch system.

The differences are in processor capacity and partially unique implementation.

The implementation varies as follows (Sandberg et al., 1984):

APZ 213 - address translation, physical communications, and handshaking are controlled by central processor firmware that is microprogrammed

APZ 211 - a regional processor handler performs signaling and other functions between the central and regional processors

APZ 212 - a signal processor performs signaling between the central and regional processors, and between the redundant central processors.

Software is compatible among the processors.

No switching hardware is directly controlled from the central processor.

The APZ 213 can control up to 32 regional processors, the APZ 211 can control 512, and the APZ 212 can control 1024 (Ericsson, 1985b).

4.4 GTE GTD-5 EAX

The GTD-5 Electronic Automatic Exchange (EAX) from GTE has major applications in the following areas:

- consolidation of community dial offices
- new installations and replacement of analog dial offices, suburban offices, and metropolitan class 5 offices

- new installations and replacement of class 4/5 offices.

The main switching system of the GTD-5 EAX is called a base unit. A smaller remote switch, a remote line unit, and a multiplexer are also available. This discussion will dwell on the base unit.

4.4.1 System Overview

There are three major hardware groups that are organized according to control function requirements in the GTD-5 EAX: peripheral, network, and central control (Figure 4-9).

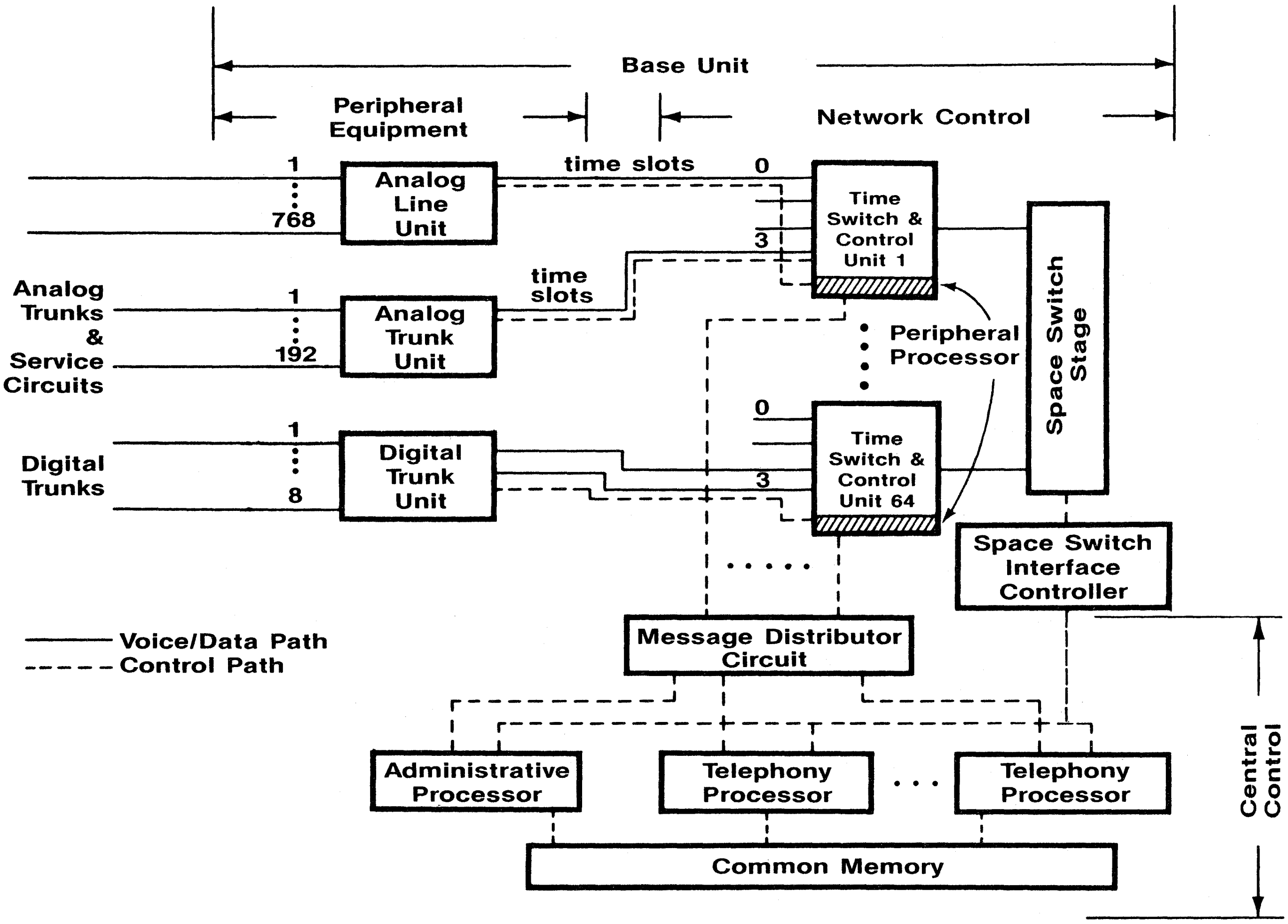


Figure 4-9. GTD-5 EAX base unit structure (after Karsas and Pietralunga, 1984; GTE, 1985).

Peripheral equipment provides interfaces between the switch system in the network control group and the trunks and subscriber lines. The network control equipment provides the necessary network switching and maintains control of the interface units. Central control equipment provides the resources required for call processing, system administration, and maintenance.

Software for the GTD-5 EAX is similarly organized on a functional basis within the three major groups. The software design uses a modular approach that is implemented with multiprocessors. This allows for distributed processing and load sharing. There are four software systems, including the operating system. The three processor systems and the respective software are located as follows:

- peripheral processing is located in the network control
- an administrative and multiple telephony processors are located in the central control group.

The system software language is PASCAL.

4.4.2 Hardware

The peripheral equipment consists of Facility Interface Units (FIUs) for analog lines, analog trunks, and digital trunks. Conversion of the signals is made to a duplicated 193-channel interface connected to the duplicated network control equipment (Bassett and Donnell, 1981). The analog line and trunk units contain the necessary circuitry for analog-to-digital, digital-to-analog, and two-wire/four-wire conversion. CODECs are used in the line and trunk units. Digital trunk units can interface up to 128 T1 lines, distributed on 16 interface units, to the switches in the network control unit. These digital trunk units have provision for external clock synchronization to a CCIS data link module (GTE, 1985).

The network equipment in the base unit consists of elements that form a Time-Space-Time (TST) switch. The units that make up network control are time switch and control units, space switches, and a network clock. Units of peripheral processors, originating and terminating time switches, and the space switch form the TST switch structure (Figure 4-9). The peripheral processors operating in an active/standby mode control the peripheral interface units and the associated time switch (Bassett and Donnell, 1981). The originating time switches multiplex the line channels into the switch network. The space switch stage switches data between the originating and terminating time switches. A fully-wired space switch will provide a 32 X 32 matrix for 75,000 lines.

Expansion can be made to a 64 X 64 space switch by adding three more 32 X 32 matrices.

Peripheral processors are informed by central control processors of required time switch connections to the space switch stage. The space switch is also under control by administrative and telephony processors of the central control unit (Krikor et al., 1981).

The central control unit components perform all the logical functions required to process telephone calls. A duplicated message distributor circuit interfaces the central control to the time switch and control units; a separate space switch interface controller connects to the space switch stage (Figure 4-9). The main elements of the central control unit consist of one administrative processor and up to seven telephony processors. All network connections within the office are controlled by these processors. The administrative processor handles maintenance and administrative functions. Telephony feature-dependent functions are handled by more than one telephony processor. A call function can be performed by one processor that finishes its task and then another processor handles the next function (Bassett and Donnell, 1981; GTE, 1985).

Peripheral processors communicate with the central processor via the message distribution circuit that provides a dedicated connecting network among the processors (Karsas and Pietralunga, 1984).

4.4.3 Software

As noted earlier, peripheral processors are located in the network equipment, while the administrative and telephony processors are located in the central control equipment.

The software, with the associated hardware, performs the functions that are summarized in Figure 4-10. Originating peripheral processor software detects and analyzes stimuli detected by scanning functions. Analysis is based on analyzing device states such as off-hook, on-hook, dialing, and signaling. This information is translated as a logical device report message that is sent to the telephony processors via the message distributor circuit. The telephony processors perform feature-dependent functions necessary to process calls. The functions include device report analysis based on the state of the call and the class of service. The analyses result in control of

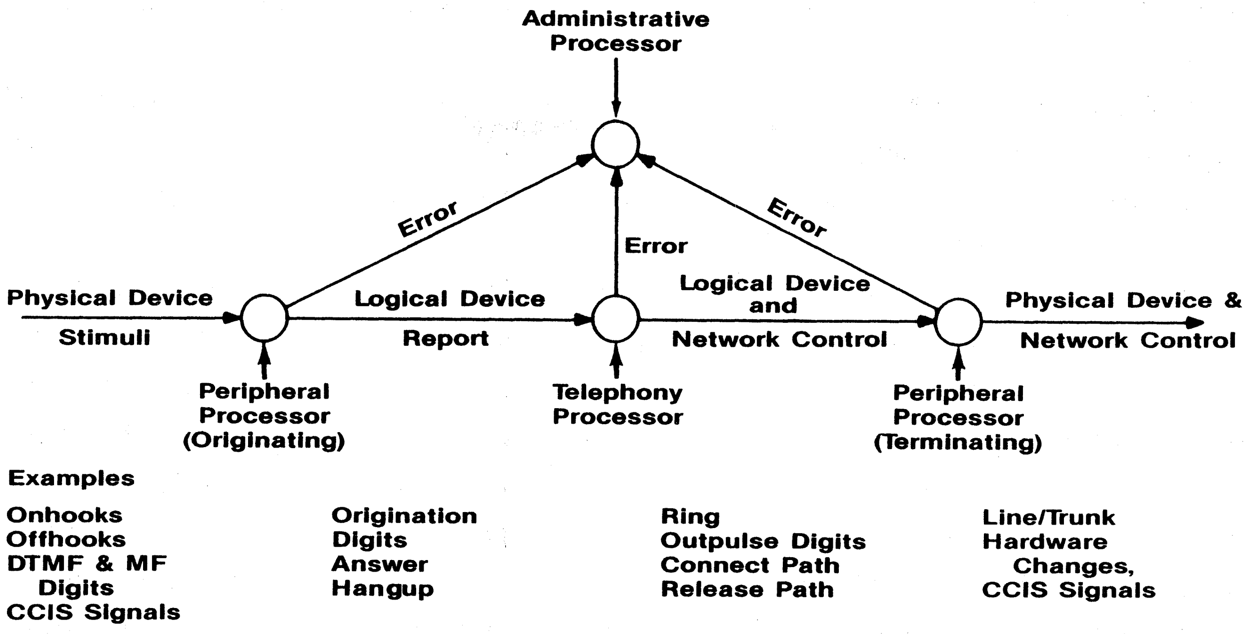


Figure 4-10. GTD-5 EAX call processing (Jackson and Patfield, 1981).

devices attached to the network, selection and release of the network path, digit analysis, trunk group selection, and traffic data collection--actions necessary to progress the call. Messages are then sent to the terminating peripheral processors through the message distributor circuit with instructions to take appropriate action that includes timing and interfacing of line and trunk hardware. The administrative processor software has the responsibility of call processing resource administration and maintenance data. This includes malfunction (error) analysis, traffic data accumulation, automatic message accounting for billing purposes, and network and switch management to block or reroute traffic (GTE, 1985; Jackson and Patfield, 1981).

The system software language is PASCAL. GTE performed a detailed analysis of the advantages and disadvantages of CCITT CHILL, ADA, C, other programming languages, and considered designing a new language. PASCAL was determined to have a number of advantages that were suitable for the GTD-5 EAX (Anderson et al., 1984). These include:

- simple and concise
- confusing defaults not accommodated

- strong data type declaration and abstraction capability
- an already-defined language.

Enhancements were added to the standard PASCAL. The language was then implemented in the GTD-5 EAX.

4.5 ITT SYSTEM 12

The ITT System 12 (formerly the 1240) switch is intended for metropolitan, suburban, and rural market areas that include LATAs, signaling, remote networking, business, and special services. LATA services encompass local, local/tandem, and remote network applications. Signaling services are STP applications that use the North American version of CCITT No. 7. Remote networking applications include switching and access nodes, and digital loop carrier systems. Business services are based on an incremental implementation of switch features by adding data transmission capability on existing wire pairs for Centrex, ISDN subscriber access, and administrative, operational and management modules. Special services provide automated performance monitoring and maintenance of special-service circuits for hubbing and digital test access.

4.5.1 Hardware Architecture

The System 12 has a modular, fully-distributed, control architecture. Overall, the architecture consists of a Digital Switching Network (DSN) that is connected through standard interfaces to a series of modules (Figure 4-11). The modules have two levels composed of terminal hardware and terminal control elements (TCEs) (Figure 4-12). The control elements establish digital paths for in-channel data streams through the DSN to interconnect the terminal hardware. In this sense, the switching network is end-controlled by the control elements. This allows paths to be established between terminal modules without a central control or path search mechanism (Van Malderen, 1985).

4.5.2 Modules

The types of system modules include interfaces for analog, digital, and ISDN subscriber line modules and also analog, digital, and ISDN trunk modules (Figure 4-11). In addition, there are other modules for common channel

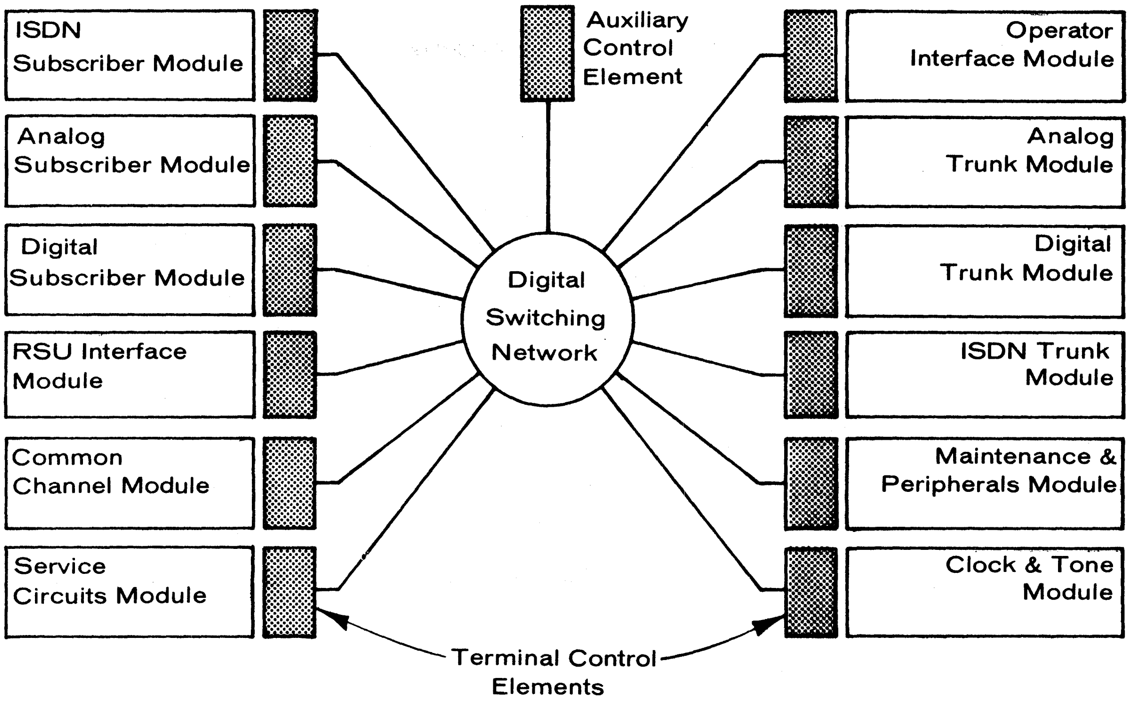


Figure 4-11. System 12 hardware architecture (Cohen, 1985).

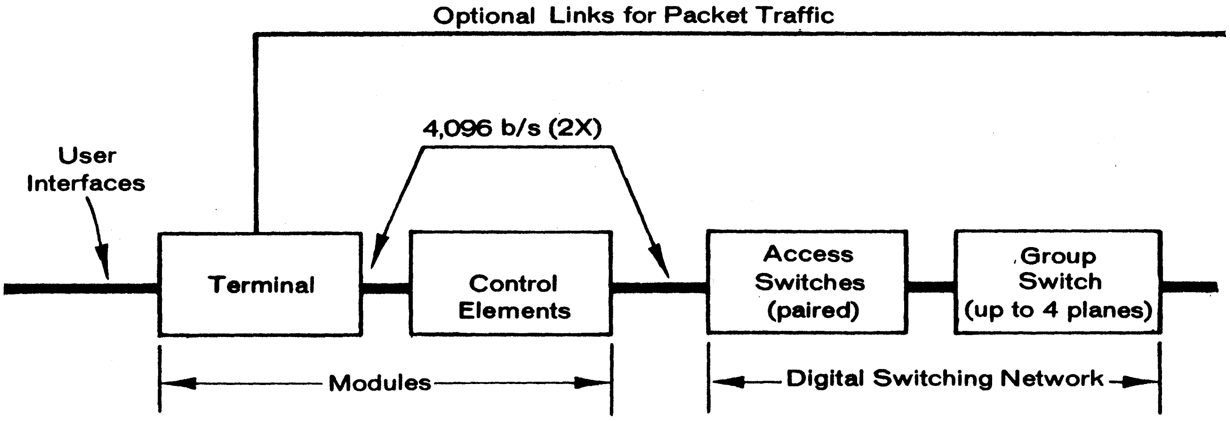


Figure 4-12. Hardware elements.

signaling (i.e., CCITT No. 6 and No. 7). Interface modules are a function of user requirements.

4.5.3 Control Elements

There are two types of control elements in the System 12 switch: those directly connected to the terminals (i.e., TCEs) and auxiliary control elements for added processing and data base storage.

Each control element contains three basic units: a microprocessor, its memory, and a terminal interface. The microprocessor runs on programs stored in the memory. The terminal interface connects each line or trunk module to the DSN access switch through two duplex PCM links. Each PCM link has 32 channels, 16 bits per channel, with an 8000 Hz repetition rate. This results in a PCM bit rate of 4,096 bits per second.

Each microprocessor can establish a simplex path from one terminal through the DSN to a second terminal and microprocessor within another TCE. The second microprocessor can then establish a return simplex path to the first microprocessor. These two paths are then used to transmit messages between the TCEs. Duplex traffic requires establishing two simplex paths through the DSN. Path selection in each direction is independent due to the random digital switching element (DSE) path selection process.

4.5.4 Digital Switching Network

The basic building block of the DSN is the DSE, which has 16 input and 16 output ports. Each port is a PCM link with 32 channels (i.e., 16 bits/channel, 4,096 b/s) similar to that between the TCEs and access switches. The combination of 16 input and 16 output ports with 32 channels results in a total of 512 input and 512 output ports for each DSE board. In-channel commands from the control elements allow a path to be established from any input to any output channel.

An entire DSN is builtup by interconnecting DSE printed circuit boards containing a standard VLSI known as a switch port.

Full-size DSN configurations consist of four planes, each with three switching stages (Figure 4-12). A three-stage group switch allows up to 512 switch pairs to be connected. The DSN access switch constitutes a fourth stage of switching. The access switches are paired and are also constructed from DSEs. For reliability, each control element is connected to each access switch in a pair, and then each access switch is connected to the four planes.

It is possible to start a System 12 from less than 100 lines and progress to over 100,000 lines. In its simplest form, it is possible to start with one switch element per plane. By adding additional stages, a capacity of 30,000 erlangs is possible based on 100,000 lines in a local exchange, or 60,000 trunks in a toll exchange (Van Malderen, 1985).

4.5.5. Software Architecture

System 12 software is located in the terminal and auxiliary control elements. The modular software is primarily based on the virtual machine concept. It is possible to structure functions of a system so that programs on a higher level are not aware of how functions are implemented at a lower level. There are four software levels in the System 12 virtual machine concept (Figure 4-13).

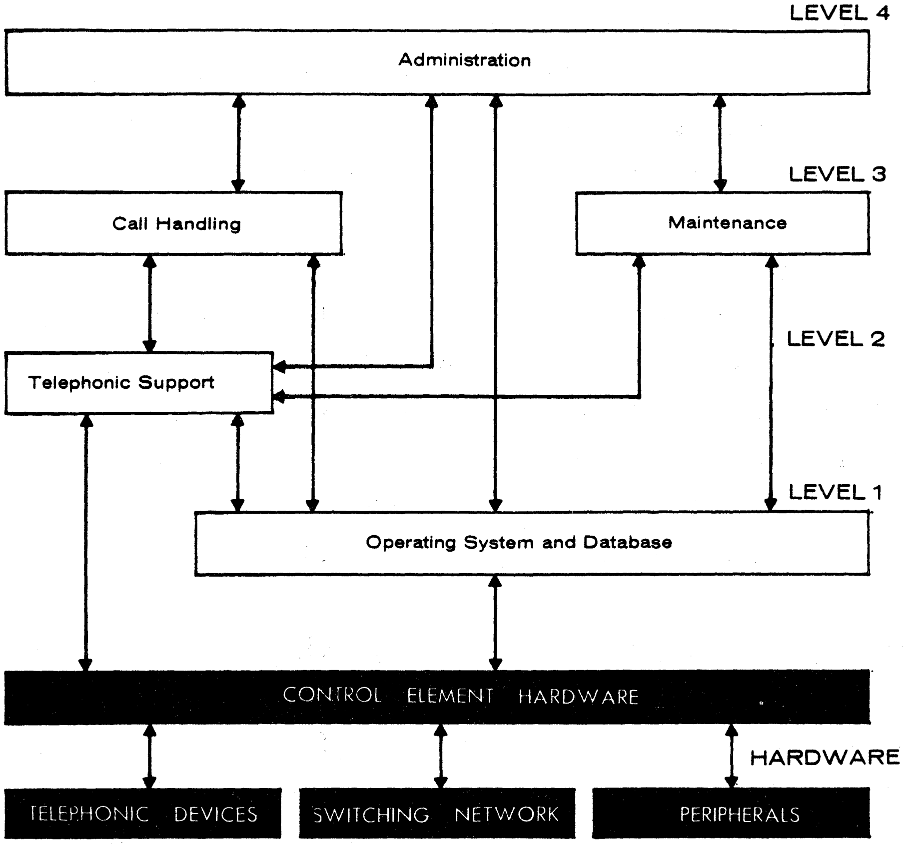


Figure 4-13. System 12 virtual machine concept for software functions (Becker, G. et al., 1985).

Level 1 is closest to the hardware and contains the operating system, device handlers, and database.

Level 2 supports primitive telephone functions, including conversion of signals into telephone messages, trunk resource management, and call-charging functions.

Level 3 supports application functions such as maintenance and call handling that generate data for administration. A virtual machine executes telephonic functions directly.

Level 4 consists of administration programs operating on the call-handling data.

These levels of problem definition are converted into CHILL programs. The software packages are distributed according to allocation required in a particular exchange (Becker, G. et al., 1985).

4.6 NEC NEAX 61A

In 1963, Nippon Electric Corporation (NEC) of Japan established NEC America to represent the company in United States telecommunications and electronics industries. A Dallas complex located in Irving, Texas, since 1978 serves as switching group headquarters and a manufacturing facility for the NEAX 61A.

The NEC NEAX 61A switch is a digital, stored program controlled system designed for end offices, tandem offices, and particularly for interexchange carriers. One of the customers for this product is GTE Sprint Communications Corporation. The NEAX 61A was developed for SCC use and is based on the NEAX 61 family that has a broad range of line capacities and applications (Jaluria et al., 1984).

As part of a network, the NEAX 61A supports a range of common carrier applications, such as Exchange Network Facilities for Interstate Access (ENFIA) A, B, and C connections. [Note: As of January 1, 1984 the ENFIA was designated a Feature Group (FG) when it became part of the Exchange Carriers Standards Association (ECSA) switched access service arrangement tariffs. ENFIA-A became FG A and ENFIA-B and C were combined into FG B. ENFIA-A facilities provided connections between switching systems of other common carriers (OCCs) and line terminations at BOC end office switching systems. ENFIA-B provided trunk rather than line connections at end offices. ENFIA-C was similar to ENFIA-B except that OCC trunk connections were to a local tandem switch system.]

4.6.1 Hardware

There are four hardware subsystems in the NEAX 61A (Figure 4-14):

- application subsystem
- switching subsystem
- processor subsystem
- operation and maintenance subsystem

The application subsystem consists of service modules for lines, trunks, and service circuits (Figure 4-14). These modules provide the interface between outside facilities and the switching and processor subsystems. All modules include a duplicated primary multiplexer/demultiplexer and microprocessor controller. The service interface modules are intended to be modified or replaced as requirements change.

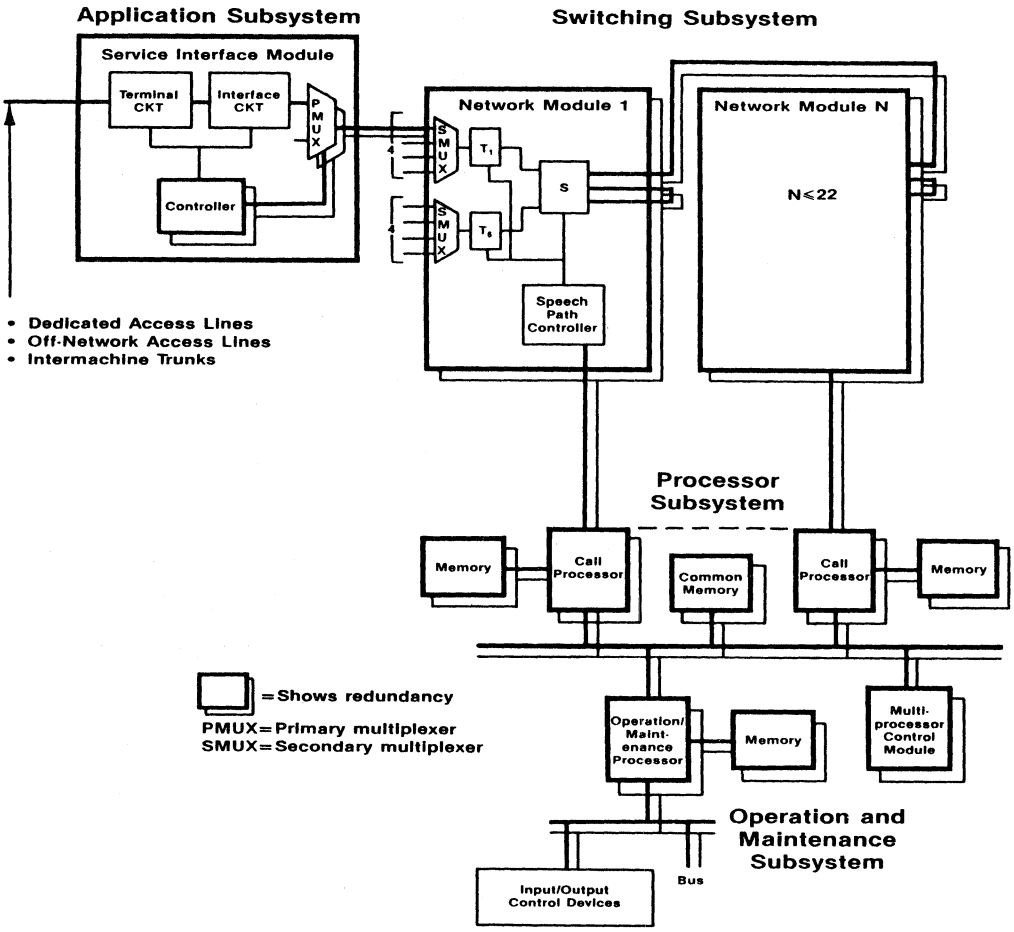


Figure 4-14. NEAX 61A system structure (after Jaluria et al., 1984).

Lines and trunks are the two basic interfaces for connection to the NEAX 61A switching system. These include dedicated access lines, off-network access lines, and intermachine (interexchange) trunks. Dedicated access lines connect directly to the NEAX 61A and can serve single-line telephones, key systems, and private branch exchange (PBX) trunk terminations. These customer facilities may, or may not be in the same city as the NEAX 61A switch. Off-network access lines are for connections between the NEAX 61A and the local operating company class 5 offices. The class 5 office provides a first dial tone; the NEAX 61A provides the second. Intermachine trunks connect to another NEAX 61A system or to a common carrier switch (i.e., different networks are connected through high usage and final trunk groups). Transmission interfaces are provided for analog channel banks (two T1 interfaces) and for 24 or 120 channel digital transmultiplexer connections to radio or frequency-division-multiplex equipment.

The switching subsystem is a modular, four-stage, time-space-space-time (TSST) division multiplex network. Currently, 12 network modules are being interconnected in the switching subsystem, although switch capacity allows up to 22 network modules. There are 2,520 user channels plus 360 service circuit channels per network module. Each network module is controlled by an independent call processor. Each network module also has a speech path controller that sends information between the interface modules and an associated call processor. The call processor also controls the speech path controller that establishes signal paths through the controller.

The processor subsystem consists of up to 22 call processors with the specific task of communication system control. Each call processor controls a network module and the associated service interface module (Figure 4-14). The call processor passes information on a high-speed bus to setup speech path connections between network modules.

The operation and maintenance subsystem consists of several input/output (I/O) controllers connected to the operation and maintenance processor. Network control and supervision are performed through the I/O devices that provide a operator/machine interface for network control, testing, charges/traffic recording, and data base maintenance (Jaluria et al., 1984; NEC, 1984).

4.6.2 Software

The switching control software is divided into two parts for the NEAX 61A (Figure 4-15):

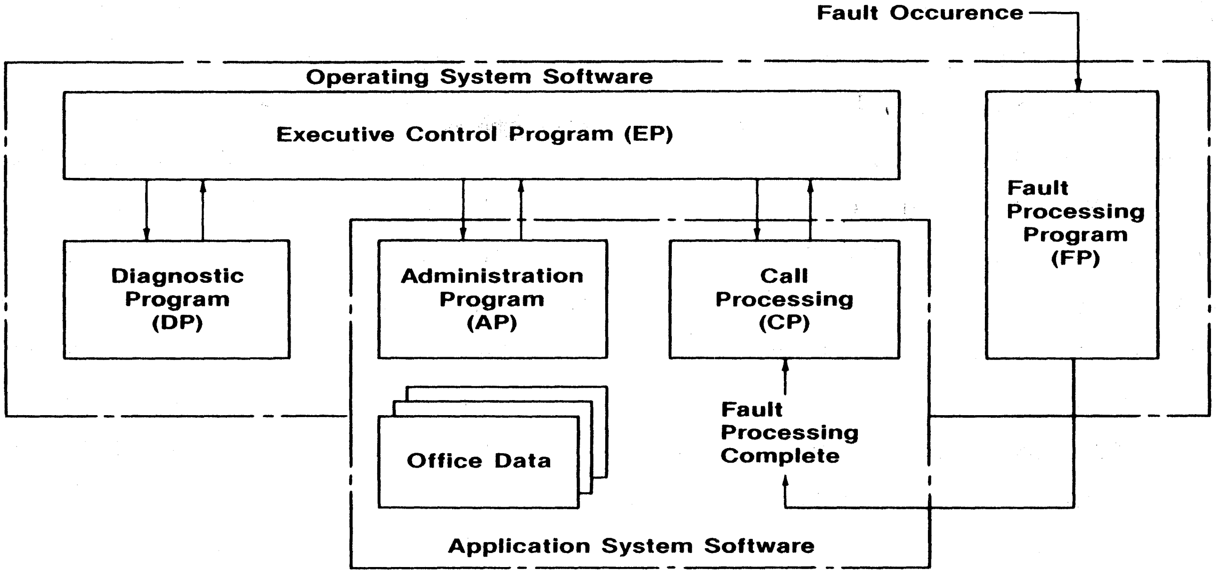


Figure 4-15. NEAX 61A switching software structure (Jaluria et al., 1984).

- operating system--consisting of executive control, fault processing, and diagnostic programs
- application system--consisting of call processing and administration programs, and an office data base

The operating system programs provide instructions to perform the following functions.

> The executive control program regulates the normal program execution of the call processing, administration, and diagnostic programs. Other functions are the allocation of system software resources such as memory area control of I/O devices, and data communications between program modules and between processors.
>
> The fault processing program has the highest operating priority. It performs the required procedures to isolate system problems by interrupting normal program execution. This program identifies the fault, places the defective equipment off-line, and the back-up system on-line. This equipment reconfiguration takes place as maintenance personnel are notified through audible alarms and visual displays. After placing faulty equipment off-line, the diagnostic program initiates testing of that equipment. Maintenance personnel are notified of the fault location through a diagnostic dictionary.

The application system software performs the following functions.

> The call processing program performs the principal functions of the NEAX 61A switch, that of call input/output and internal system processing. Input processing determines the need for call processing through signal detection by monitoring input terminals for on-hook, off-hook, digit receiving/sending ringing, or talking conditions for the direct access lines, off-network lines, and intermachine trunk connections, as necessary. The output processing includes control of the speech path subsystem and communications between subsystems. Internal processing controls task execution (NEC, 1984).
>
> The administration program monitors the call processing activity and collects data for administration and billing. Data includes charges, usage rates, and traffic statistics.
>
> Office data is related to site information that is unique to each location (i.e., line classes, routing tables). Office data is modified as required.

As stated earlier, the NEAX 61A is particularly suitable for interexchange carriers. Another model, the NEAX 61E is intended specifically for class 5 offices. Its characteristics (see Section 4.9) are as follows:

Architectural Capacity

Lines	80,000	maximum line <u>or</u> trunk capacity
Trunks	43,200	
Traffic (E)	15,972	
Call Handling (BHCA)	350,000	
Configuration	TSST	
Word Length (bits)	32	
Signaling	CCITT No. 7	
ISDN	Basic, Primary	

4.7 NORTHERN TELECOM DMS-100

The Northern Telecom, Incorporated (NTI) DMS-100 family of switches is intended to provide a range of telecommunication services. The DMS-100 is a switch for use in a class 5 office. With appropriate adaptations it can provide cellular mobile services and be used as an equal access end office. A DMS-200 switch is designed for class 4 through class 1 toll centers and access tandem switch applications serving between a few hundred to 60,000 trunks. A DMS 100/200 switch is designed for local/toll operation with a combination of up to 100,000 lines or 60,000 trunks. It can serve equal access end office and access tandem switch applications. A DMS-250 is a toll switch for specialized common carriers requiring tandem switch operation. The DMS-300 is intended to meet requirements for international gateway operations (NTI, 1984).

Since the introduction of the DMS-100 in 1978, a series of module changes have been made without requiring a complete redesign of the DMS-100 switch. This section is specifically concerned with the DMS-100 switch and the new modules.

4.7.1 Structure

The NTI DMS-100 switch family has four functional areas (Figure 4-16) encompassing a series of devices assigned to accomplish particular tasks. The functional areas and some of the modules are:

central control complex
- message and device controller
- central processor unit
- program store memory
- data store memory

network
- network module
- network message controller

peripheral modules
- trunk module (analog interface)
- digital trunk controller
- line group controller
- line control module
- others

maintenance and administration
- input/output module.

4.7.2 Hardware

The central control complex is the SPC main call-processing component for the DMS-100 (Figure 4-17). A program controls call processing, maintenance and administrative routines, and directs activity in other parts of the switch as a result of these routines. All units within the complex are duplicated. The message and device controller is a collector/distributor unit for signal buffering and routing between the central processor and peripheral equipment. The controller also contains a system clock that is synchronized to the basic reference frequency. The source clock provides timing for the switch system, peripherals, and network. The central processor unit has access to the control

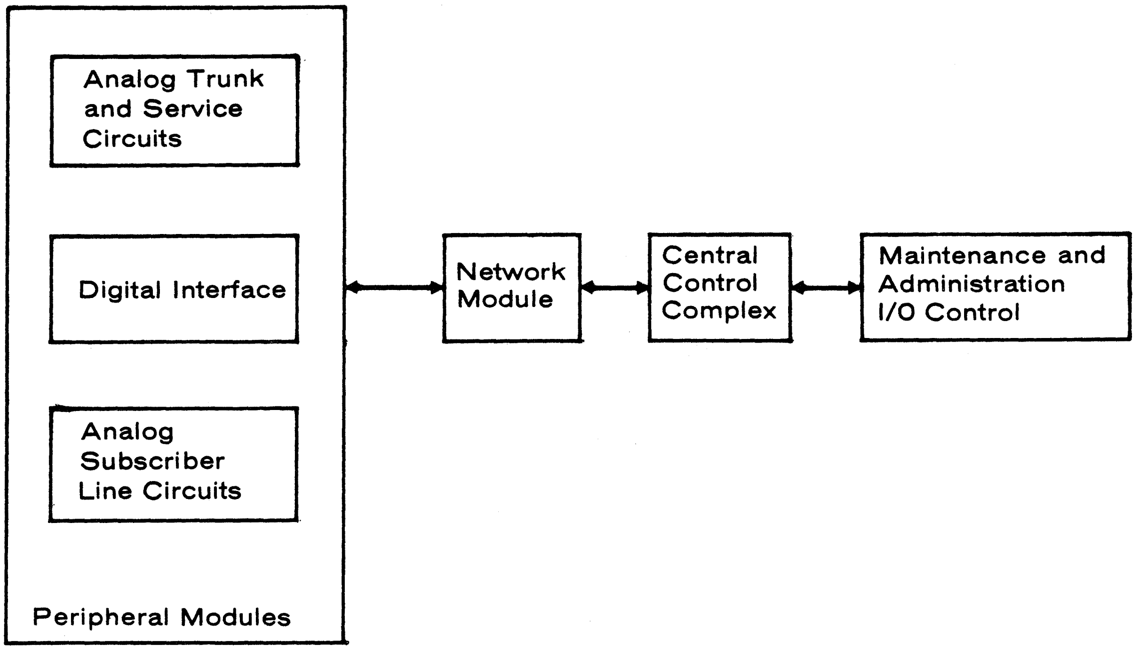


Figure 4-16. Four functional areas of the DMS-100 family (NTI, 1984).

complex data and program store memories. It uses information within those memories to respond to network conditions by issuing commands to parts of the network. The program store memory is the repository for program instructions required by the central processor. The data store memory contains the transient or per-call type of information and customer data.

Within the network function area, the network module is the basic building block of the network units of the DMS-100. It is a four-stage time (TTTT) switch that is used to provide a voice path between an originating and terminating peripheral module. The central processor controls the voice path via messages to the network module and distributes control messages concerning the peripheral modules. There are two planes (plane 0 and plane 1) in the four-stage time switch. Both perform the same operations, but only the active side does signal processing while the other side assumes control should a fault occur.

Since being introduced in 1978 and prior to 1984, the DMS-100 family of switches has relied on four types of microprocessor-based peripheral modules: trunk modules that serve as interfaces to analog trunks, digital carrier modules for digital trunks, line modules that interface analog subscriber lines, and a remote line module that is located away from the host and performs the same duties as the line module. The peripheral module functions are call supervision, dial pulse timing, digit transmission and reception, and analog-to-digital conversion.

A series of new peripheral modules was introduced in 1984. They are backward-compatible modules that replace the interfaces for digital trunks and line modules. The analog trunk interface is not being replaced.

As shown in Figure 4-17, DS-30 serial ports (or DMS-X for operation to 160 Km) interconnect the hierarchal levels by conveying control messages between the central control complex, the input/output modules, and the network switching. The DS-30 port system is a Northern Telecom interface that permits module replacement without affecting other modules. The DS-30 message protocol allows the central control to communicate sequentially with a series of input/output and network modules. The switching network, in turn, can communicate with the peripheral modules (Wood, 1984).

Within the peripheral module area, the line group controller (LGC) is called a first-tier module that controls second-tier modules, known as line concentrating modules (LCMs). Other second-tier modules that are controlled by the line group controller are line concentrators and remote switching centers. The LGC performs high-level call processing such as digit analysis and tone control. The LCM performs lower-level functions such as line supervision and digit collection. The LGC carries up to 640 PCM speech and signaling channels. Of the 640 channels, only 480 actually carry speech. The remaining channels are used for control messages, status indications, and tone distribution. A time switch within the LGC is used to direct messages and tones onto PCM channels.

The basic second-tier module, the LCM, operates under control of the LGC. The LCM provides time switching and concentration between subscriber line circuits and serial ports to the LGC.

The digital trunk controller is a variant of the LGC just discussed. It can be configured as a digital trunk controller to handle up to twenty DS-1 trunks by placing trunk call processing software in the unit microprocessor and providing DS-1 transmission interfaces. Another variant of the LGC acts as the system interface to all common channel signaling links, including CCIS and CCITT No. 6. CCITT No. 7 is being added.

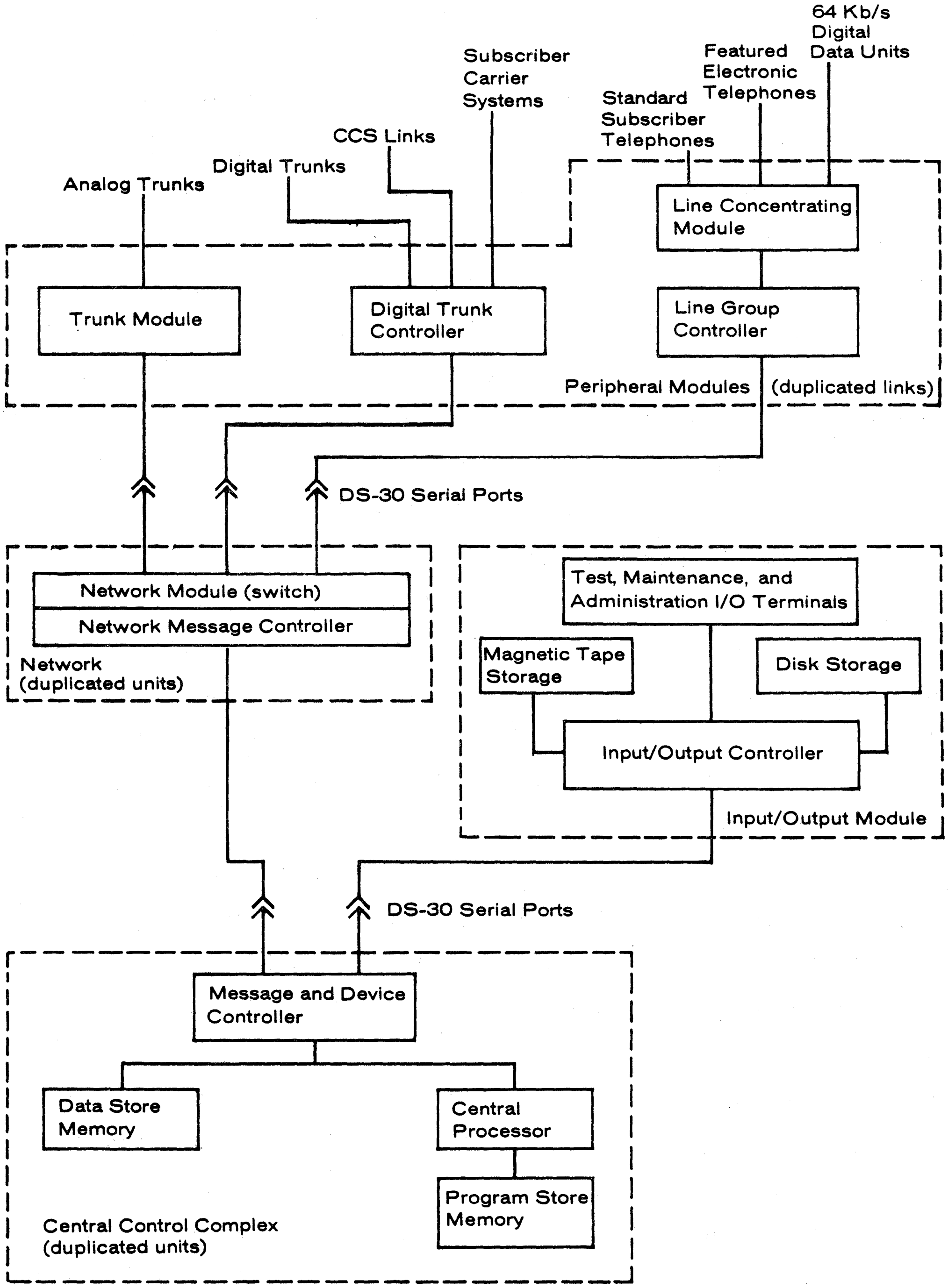


Figure 4-17. Structure of DMS-100 (after NTI, 1984; Wood, 1983, 1984).

Each trunk module (also a first-tier peripheral module) encodes and multiplexes incoming speech from a maximum of 30 analog trunks into a digital format. Decoding and demultiplexing is performed in the other direction of transmission. The PCM bit streams containing trunk supervisory and control signals, are combined with internal control signals, and transmitted at 2.56 Mb/s to the switch network module (NTI, 1984; Wood, 1984).

The input/output module contains controllers and serves as an interface to local or remote devices that are used to perform system maintenance, testing, or administrative functions.

4.7.3 Firmware/Software

The DMS-100 family contains firmware/software that is classified into two main categories, central control and peripheral. The central control firmware/software performs functions necessary for switch operation such as high-level control of calls and system maintenance. Most of these programs are written in the Procedure-Oriented Type Enforcing Language (PROTEL). At the same time, some time-critical or maintenance operations are programmed directly in firmware. The peripheral firmware/software is microprocessor-oriented for distributed processing. It performs repetitive, time consuming tasks such as scanning, control, and maintenance of telephony interfaces. The software in peripheral modules is written in assembly language. PASCAL is used for programming the line group and digital trunk controllers.

As with other switches in this section the software has a highly modular structure that is designed around operating functions. The different software modules accommodate the type of office (local, toll), the features required (CENTREX, CCS), and the hardware supported (trunk types, digital carriers, etc.).

4.8 SIEMENS EWSD

The Siemens EWSD digital electronics switching system is based on an architecture that results in a family of switch sizes corresponding to size and capacity requirements. A common architecture uses similar hardware and software subsystems to implement the different-sized switches (Table 4-2).

Table 4-2. EWSD Size and Capacity Range

Capacities \ Model	DE3	DE4	DE5
Lines	< 1,000 - 7,500	< 3,000 - 30,000	< 7,500 - 100,000
Trunks	750	3,000	10,000
Traffic (E)	> 1,600	> 1,600	> 27,000
Call Handling (BHCA)	27,000	110,000	900,000

Application of the EWSD switch family include local offices, tandems, international gateways, rural offices, and remote switching units. Capabilities for these switches include applications for centralized operation and maintenance, CCITT No. 7, and ISDN.

Modifications are being made to the EWSD to meet North American requirements with switch availability scheduled for late 1986.

4.8.1 Hardware

Common subsystems within the EWSD (Figure 4-18) are the:

- digital line unit
- line trunk group
- switching network
- common channel network controller
- coordination processor.

The digital line units (DLUs) provide interfaces for direct connection to subscriber loops, remote line units, remote switching units, integrated EWSD pair gain, and integrated SLC^{TM}96 pair gain. The line units also establish a uniform interface to the remainder of the EWSD switch. For example, a basic function of the digital line units handling subscriber loops is to convert analog signals into digital form and concentrate the traffic. Appropriate conversions are also performed at the other line unit interfaces so that the

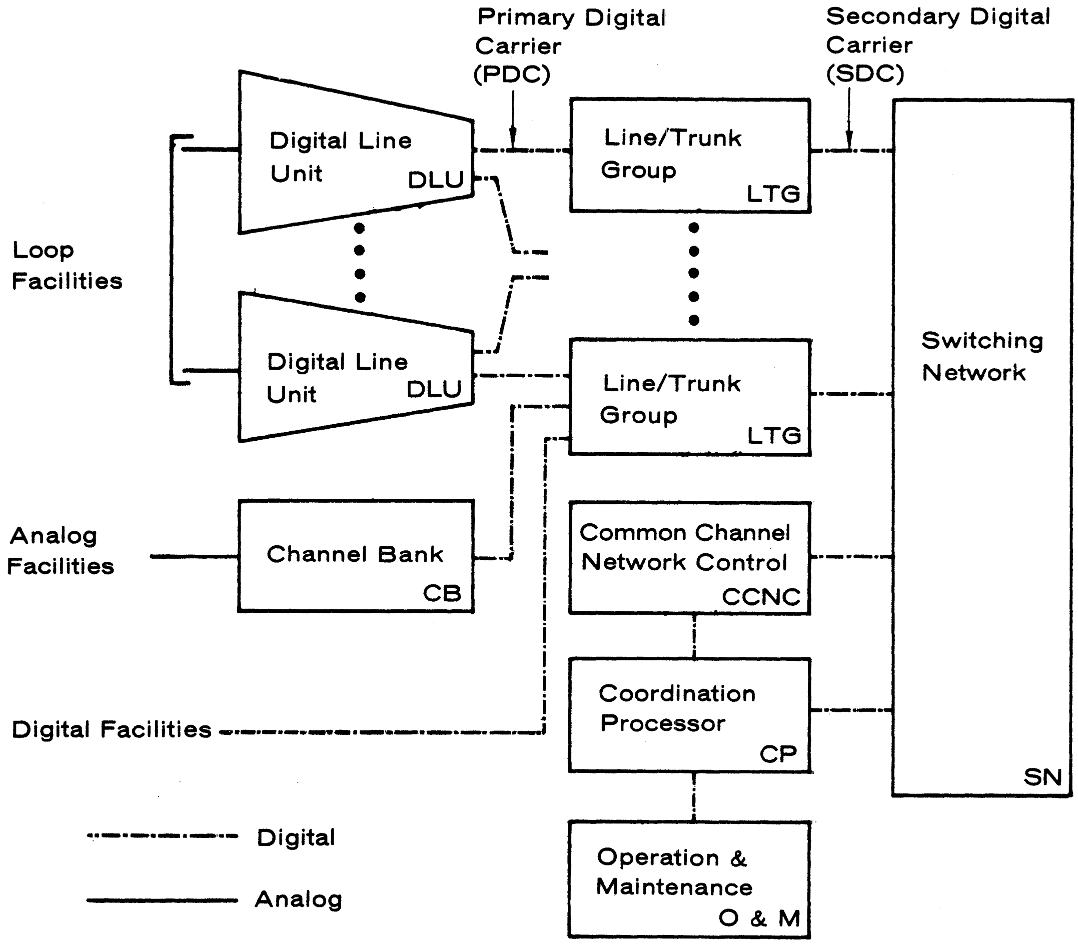


Figure 4-18. EWSD switching family common architecture (Siemens, 1985).

traffic at the primary digital carrier is at 2,048 b/s (i.e., 32 PCM channels X 64 kb/s) to the line trunk groups on 24 trunks per T1 carrier, as required.

The line/trunk groups form the interface

- between the switching network and digital line units
- through channel banks for analog trunks
- directly to digital trunks for PCM transmission lines.

The line trunk group (LTG) is a self-contained functional unit that is controlled by an associated microprocessor. A major share of the signaling and call processing functions are performed in the LTGs. The secondary digital carrier transmission rate to the switching network is 8,192 b/s (i.e., 128 channels at 64 Kb/s).

The main task of the switching network (SN) is to provide interconnection between the line-trunk groups and the common channel network controller (CCNC). Another task is to provide switch message channels between the coordination processor, the group processors of the LTGs, and the CCNC. An added function is to distribute clocking pulses to the LTGs from the coordination processor. The switching network structure is determined by the application range of the unit. The DE3 and DE4 have TST structures while the DE5 is a TSSST configuration. All connections between two switch network ports pass through all stages of the network. In the time stages, PCM words change highways (channels) and time slots according to their destination. In the space stage(s), PCM words also change channels according to their destinations without changing time slots. Five module types in the switching network provide:

- control functions
- time switching for inputs and outputs
- space switching in the central stage(s)
- link interfaces between time switching modules and the link/ trunk group
- linkage between control functions and the central processor.

The coordination processor (CP) is the highest level processor in the EWSD distributed processing structure. The CP coordinates all major processes within the switch, call processing, operation and maintenance, and fault isolation and recovery procedures. Redundancy of units within the CP is used to provide reliability. Duplicated modules within the coordination processor include:

- message buffering between the CP and peripheral control devices
- system clock pulses from a duplicated central clock
- switching processors for call processing
- input/output processor arrays.

The common channel network controller performs signaling functions between switching processors at 64 kb/s. Only CCITT No. 7 common channel signaling is used for interexchange signaling, specifically layers 1, 2, and 3 of the message transfer part (MTP). In-channel signaling is not used by the EWSD. Layer 4 procedures [telephone user parts (TUPs)] are performed in the respective line/trunk groups. Digital common channel signaling links at 64 kb/s are routed between the line/trunk groups and the controller through the switch network. Another option for signaling control with CCITT No. 7 between exchanges is to use modems with a transmission rate of 4.8 kb/s. The common channel network controller has three main tasks:

- to direct incoming TUPs to the relevant line/trunk groups
- to direct outgoing TUPs to a common channel signaling line
- to forward incoming signaling messages to their destination if they are intended for another signal point.

4.8.2 Software

The EWSD software features modular structuring for portability that permits use on different commercial support computers. CHILL is the primary programming language that is used except where assembly language is used in the group processors of the line trunk group (Botsch et al., 1984). Software for the EWSD is organized in three major categories (Figure 4-19):

- exchange software
- support software
- operation and maintenance communication software.

The exchange software provides the programs and data required for the operation of the switching system. It is distributed in all the processors of the EWSD hardware that is described in Section 4.8.1. The categories of exchange software that coincide with the hardware are shown in Figure 4-20. Support software provides the programs necessary to develop, produce, and maintain the exchange software. The operations and maintenance software permits communications between processors at different exchanges and also for operation and maintenance centers through file access, conversion, and transport functions (Siemens, 1985).

The highest level of software exists in the coordination processor. This software is structured using a hierarchy of virtual machines. This hierarchy of various layers was created so that changes in hardware or firmware affect only part of the software. Higher layers of software remain unaffected and see lower layers as the same virtual machine. The virtual machine concept permits the software operating system and application programs independence

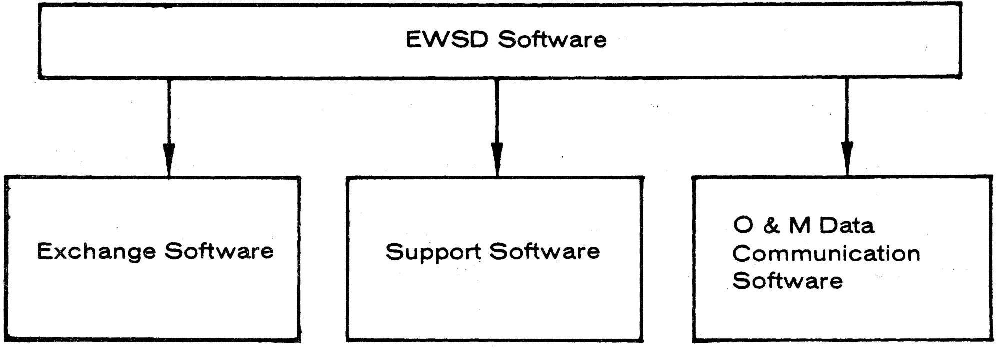


Figure 4-19. EWSD software organization (Siemens, 1985).

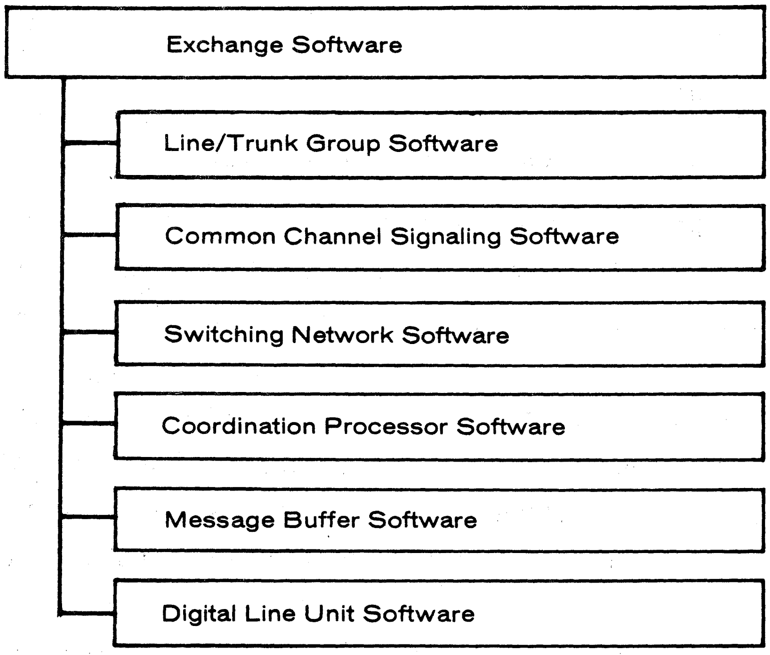


Figure 4-20. EWSD organization of exchange software (Siemens, 1985).

from processor-dependent parts of the system. An added feature, called "pluggable software," to the virtual machine model allows software subsystems within the layers to be omitted, modified, or replaced without disturbing other parts of the layer. The layers are broken outside the operating system nucleus into a wing structure (Figure 4-21). Independent software function blocks for call processing, administration, maintenance, and system functions (e.g., input/output, recovery) surround the nucleus. Use of the layer and wing structure permits the distribution of functions and the addition of features without disturbing other subsystems (Botsch et al., 1984).

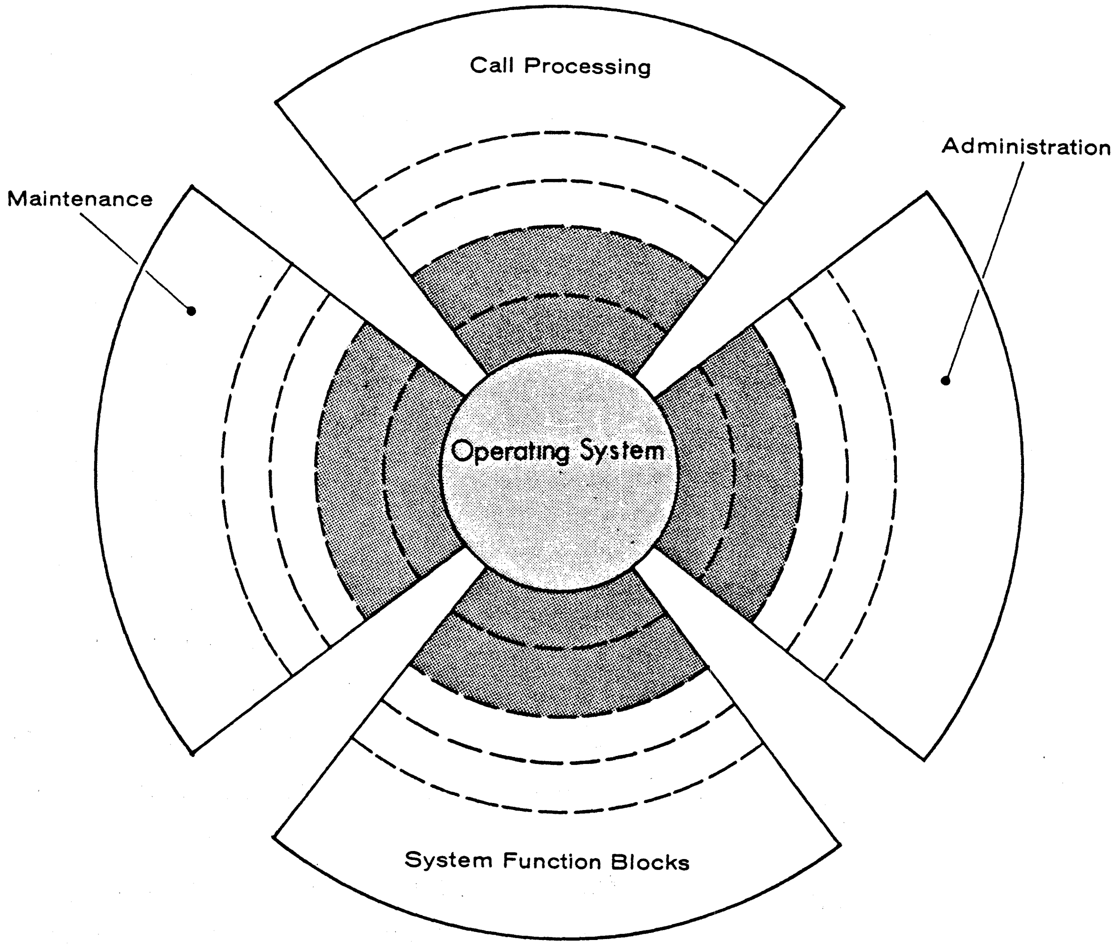


Figure 4-21. Simplified layer and wing software structure (Botsch et al., 1984).

4.9 Summary of Switch Characteristics

This section has provided a description of eight central office switches. The source material for these descriptions has been from the respective manufacturers, conference proceedings, and technical journals. This has resulted in a different emphasis for describing a particular switch, whether in terms of hardware or software. For example, some descriptions of switch software are based on approaches such as the use of virtual machines, while other descriptions dwell on the functions performed under software control.

Table 4-3 is a compilation of switch characteristics. This information is based on available data and has been verified whenever possible with company representatives. Technical modifications continue so that this information should be considered as being subject to change at anytime.

The switch models are characterized in terms of capacity, signaling, architecture, software, transmission, and features. All have applications in local offices, in LATAs, and as local tandem or access tandem switches.

Switch capacity is stated in two ways: current and architectural. The current capacity is the switch size that can be delivered to a customer depending on traffic requirements. The architectural capacity is the ultimate or theoretical size that is possible for that model of switch according to current design effort. Modifications in a processing unit, for example, could change the stated values.

There are two kinds of entries for current and architectural capacity. One, the number of trunks may be in the range of 10 to 15 percent of the number of lines. This configuration ratio is based on a "reasonable design mix," although particular systems can vary significantly. An example of this entry in Table 4-3 is the AT&T 5ESS that shows 50,000 lines and 7,500 trunks. Two other entries (e.g., ITT System 12 and Siemens EWSD) have a capacity of 100,000 lines or 60,000 trunks. These capacities can be modified as line, trunk, features, and service requirements are considered in determining the configuration to be deployed at an office.

Signaling (Table 4-3) is shown for lines and trunks. The manufacturers meet subscriber line signaling requirements as necessary. Manufacturers will also comply with signaling requirements that are agreed upon by standards committees such as CCITT Study Group XI with the participation of accredited standards committees, such as ANSI T1, in the United States. Standards in this category include CCITT Recommendations Q.920, Q.921, Q.930 and Q.931.

Model / Characteristic	Northern Telecom DMS 100/200	Siemens EWSD
CAPACITY		
CURRENT (1985) (1)		
LINES	INFORMATION	LATE 1986
TRUNKS	UNAVAILABLE	DELIVERY IN
TRAFFIC ABSBH (E)		UNITED STATES
ATTEMPTS (BHCA)		
ARCHITECTURAL (2)	(4)	(4)
LINES	1,000-100,000	1,000-100,000
TRUNKS	60,000	60,000
TRAFFIC (E)	38,000	25,000
ATTEMPTS (BHCA)	350,000	1,000,000
SIGNALING		
LINES (6)	---	---
TRUNK (7)	CCIS, NO. 7	NO. 7
ARCHITECTURE		
CONFIGURATION	TTTT	TST, TSSST (8)
TECHNOLOGY	SPC	SPC
CONTROL	DISTRIBUTED	DISTRIBUTED
WORD LENGTH	16	32
PROCESSING	LTIPLE, CENTRAL	MULTIPLE, CENTRAL
SOFTWARE		
OPERATING SYSTEM	(10)	(10)
LANGUAGE(S)	ROTEL, PASCAL	SDL, MML, CHILL
TRANSMISSION		
SUBSCRIBER LOOP	TCM	ECHO CANCELLATION
FEATURES		
ISDN ACCESS	ASIC, PRIMARY	BASIC, PRIMARY
PACKET ACCESS		X.25, X.75
ADPCM		---
AT&T SLC-96^{TM}	YES	YES
CENTREX (type)	YES	YES
FIBER INTERFACE		YES
CELLULAR	YES	
LAN	YES	

Notes For Table 4-3.

(1) Switch capacity that is delivered according to customer order during 1985.

(2) Switch capacity according to architectural or theoretical limits.

(3) Trunk capacity is calculated at 10 to 15 percent of line capacity based on a reasonable mix rationale.

(4) Capacity is stated in terms of lines or trunks. This may also be used to achieve an equivalent combination.

(5) Capacity is stated in terms of ports.

(6) Subscriber line signaling requirements are met as required.

(7) Some U.S. market entries do not plan on implementing CCIS.

(8) Configuration is determined by switch size.

(9) Will use 32 bit words upon conversion from 8086 to 8286 microprocessors.

(10) Manufacturer's operating system.

(11) Proprietary version of CHILL; incompatible with CCITT version.

(12) Modified Programming Language for Communications (PLC).

(13) Proprietary versions of Programming Language for Communications (PLC) and Assembly Language (ASSL) are used.

(14) Available with NEC NEAX 61E class 5 switch.

Trunk signaling has CCIS and CCITT No. 7 as entries for some switches while only one signaling protocol (CCITT No. 7) is shown for others. Signaling implementation for the companies that are established in the U.S. market includes CCIS and CCITT No. 7. The companies that are establishing a presence in the United States plan to implement CCITT No. 7 in anticipation of its acceptance rather than to invest resources in the older signaling system.

Different switch configurations, SPC, control (usually distributed), and word length (16 or 32 bits) and central processor are shown under architecture. Call processing functions, such as signal processing, call control, switching network control, and resource management are handled by multiple central processing units in six of the switches. Notable exceptions are Ericsson and ITT. The Ericsson AXE 10 has a single proprietary central processing unit. The ITT System 12 has microprocessors that are located in terminal elements to establish end-to-end paths through the switch (i.e., the digital switching network is end-controlled).

The respective software has operating systems that are unique to each switch. MML and CHILL (or variants thereof) are the most common maintenance and programming languages.

Time compression multiplex (TCM) and echo cancellation are transmission schemes that are under consideration for the ISDN. As shown in Table 4-3, switch manufacturers have expressed a preference for one approach or the other. Approximately 2 to 3 years ago, TCM appeared to be the preferred technology. More recently, technological advances have also made echo cancellation an attractive prospect. Whichever method is selected by the CCITT and U.S. standards committees will be implemented by the manufacturers.

Features for these switches include basic and primary ISDN access, X.25 packet switching and X.75 gateway interfaces, CENTREX or similar type services, and interfaces for fiber-optic cables. Manufacturers have, are planning, or are in the processing of deciding implementation of 32 kb/s voice (adaptive differential pulse code modulation, ADPCM) and SLC-96 interfaces, as appropriate, for each particular switch.

5. SUMMARY AND CONCLUSION

Changes are occurring in approaches to telecommunications philosophy and implementation for many reasons. Two of the most important events are:

- the divestiture of AT&T on January 1, 1984
- the continuing and accelerated development of standards, including those for the ISDN and signaling.

The traditional hierarchal structure of the PSTN has changed. It is now based on a nonhierarchal structure with dynamic routing. Intra- and inter-LATAs, and equal access for exchange carriers have become a reality. Common channel interoffice signaling, based on CCITT signaling system No. 6, will be replaced by CCITT No. 7 as the evolution continues toward the ISDN(s).

As the routing and signaling structures are changing, the market opportunities for switch manufacturers are also changing as a result of divestiture. Central office switches were previously provided by a limited number of manufacturers. Since the divestiture, and the opening of the U.S. marketplace to increased competition, a number of companies are planning and already succeeding in penetrating the U.S. market. Central office switches from eight manufacturers are described in this report. They are the AT&T 5ESS, CIT-Alcatel E10-FIVE, Ericsson AXE 10 system, GTE GTD-5EAX, ITT System 12, NEC NEAX 61A, Northern Telecom DMS 100/200, and Siemens EWSD. Each of these switches appears to be a candidate for post-divestiture networking and for application within the ISDN. These switches are described in this report in terms of hardware, software, and a table that is used to summarize their respective characteristics. Architectural structures and software languages are different for each of these switches, but a common requirement is that signal format compatibility exists between central offices. One of the major problems in using these switches in an ISDN environment is the lack of software compatibility. A diversity of switches within a common carrier requires that the software for routing, features, or applications be rewritten as required by each switch. This, of course, adds to system operating costs. A generic software release is preferable and possible when a standard switch is selected by a carrier. This would appear to be a major consideration toward ISDN structuring. The switches in this report were designed with the modular concept, for both hardware and software. Therefore, ability to grow is an inherent design of the switches, but software operating compatibility systems and languages are a basic problem in the realization of an ISDN.

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APPENDIX: COMMON CHANNEL SIGNALING STP APPLICATION GUIDE

The CCS STP application guide in this appendix is from ITT Telecom. It is intended for use by network planners and engineers that are involved in dimensioning STPs that will use CCITT No. 7 with ITT System 12 STP products. Although the information in this appendix is related to ITT System 12, the planning and design rationale should prove informative to interested readers.

The System 12 STP products for CCS include a Main STP, Satellite STP, and Mini STP. The recommended signaling network uses a distributed hierarchy (Figure A-1), although a conventional star network can be used. The former is recommended for revenue producing and other economic considerations. Table A-1 provides a summary of STP CCS system features followed by the pages of the ITT Telecom applications guide.

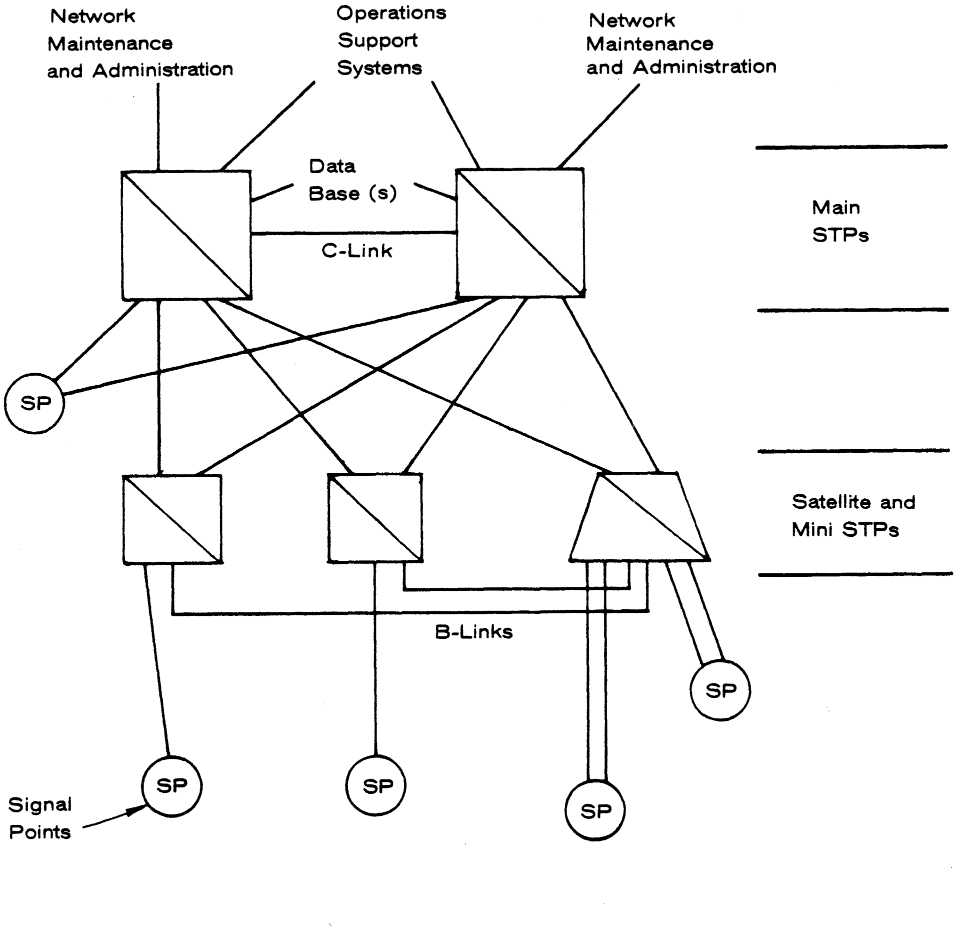

Figure A-1. Distributed network hierarchy for CCS (ITT, 1985).

Table A-1. STP CCS Features

CHARACTERISTIC	STP	SATELLITE STP	MINI-STP
Function	Tandem	Routing	Concentration
Port Capacity	210	56	14
- CCS7 Modules	15	4	1
- Ports/Module	14	14	14
Operating Speed (Kb/s)	56	56	56
Traffic/CCS7 Port			
- Normal E (kb/s)	.4 (22.4)	.4 (22.4)	.4 (22.4)
- Failure E (kb/s)	.8 (44.8)	.8 (44.8)	.8 (44.8)
Interfaces/Protocols			
- Signaling Link (1)	DS-0	DS-0	DS-0
- Packet I/O (2)	BX.25	BX.25	BX.25
- Physical (For BX.25) (3)	RS-232-C	RS-232-C	RS-232-C

NOTES: (1) 64 kb/s for direct connection to D4 channel banks or T1 data multiplexers.

(2) Enhanced version of CCITT X.25. System also accomodates X.25.

(3) Accomodates up to 9600 b/s.

Reference

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COMMON CHANNEL SIGNALING
STP APPLICATION GUIDE

COMMON CHANNEL SIGNALING STP APPLICATION GUIDE

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FIGURES PAGE

TABLES PAGE

WORKSHEETS PAGE

1.00 INTRODUCTION

1.01 Purpose. The Common Channel Signaling STP Application Guide provides guidance and direction to network planners and equipment engineers involved in planning and implementing Common Channel Signaling No. 7 (CCS7) networks using ITT System 12 common channel signaling products.

Network planning considerations are described in this guide to aid network planners involved in network design. These considerations will also serve as valuable background information to implementation planners and engineers responsible for implementing the network. For these individuals, this document covers system dimensioning for the Signal Transfer Point (STP). As an aid to this process, a series of worksheets are also provided.

In conjunction with an STP equipment catalog and price list, the worksheets allow the engineer to determine equipment quantities, configuration, and pricing.

1.02 Scope. This is the second issue of this document. This issue's scope is limited in the equipment engineering section to ITT's initial offering of a full STP. Subsequent issues will incorporate information in support of the Satellite STP and Mini STP, as well as enhanced STP interfaces (BX.25) and functioning such as Operational Support System (OSS) connectivity.

2.00 APPLICABLE DOCUMENTS

2.01 Related CCS7 Documentation.

- STP Material Price List
- 738-00458 Common Channel Signaling No. 7 STP Technical Specification
- PUB 54020 AT&T Communications - Telecom Canada Specification of CCITT Signaling System No. 7
- PUB 60110 Digital Synchronization Network Plan, December 1983
- TSY-000082 Technical Advisory Signaling Transfer Point Requirements, October 1984
- PUB 51001 New Equipment - Building System (NEBS) General Equipment Requirements, March 1981
- 577-100-100 ITT System 12 System Application Guide
- 738-00216 ITT System 12 LATA Services Switch Application Guide
- 738-00594 ITT System 12 Common Channel Signaling STP Application Description
- 738-00596 ITT System 12 Common Channel Signaling STP Feature List

3.00 NETWORK APPLICATIONS

3.01 Network Planning Considerations. This section describes CCS7 network planning considerations for deployment of a distributed network of ITT System 12 STP products. It provides network planners with guidance for designing CCS7 networks and summarizes the results of ITT Telecom's generalized studies.

The ITT System 12 product line includes three CCITT No. 7 signaling products: a full STP, a Satellite STP, and a Mini STP. These products can be implemented in a variety of ways consistent with the Telco's criteria of redundancy, robustness, and operational procedures.

The STP can be used in a star architecture where all signaling points are linked directly to the STP. The operating company, however, can use the Satellite STPs and Mini STPs in a distributed network. The network then handles messages at the lowest level possible. Figure 1 depicts these two architectures. The distributed architecture includes two levels, with the STP at one level and the Mini STP and Satellite STP at a lower level.

The distributed architecture makes more efficient use of inter-office and inter-exchange transmission facilities. This can be quantified in terms of expense, revenue, or investment. The expense of leasing facilities from an inter-exchange carrier can be estimated. The revenue potential of leasing facilities to paying customers versus tying them up as overhead signaling expense is another way to view the opportunity cost. The difference in the timing and sizing of facility relief projects can be determined as an estimate of investment impact.

A key point in economic analysis is that the number of ports required at the STP is greatly reduced when Mini STPs and Satellite STPs are deployed. The STP in a distributed architecture represents a much lower investment than in a star architecture. The additional investment in Mini STPs and Satellite STPs can be offset by facility savings.

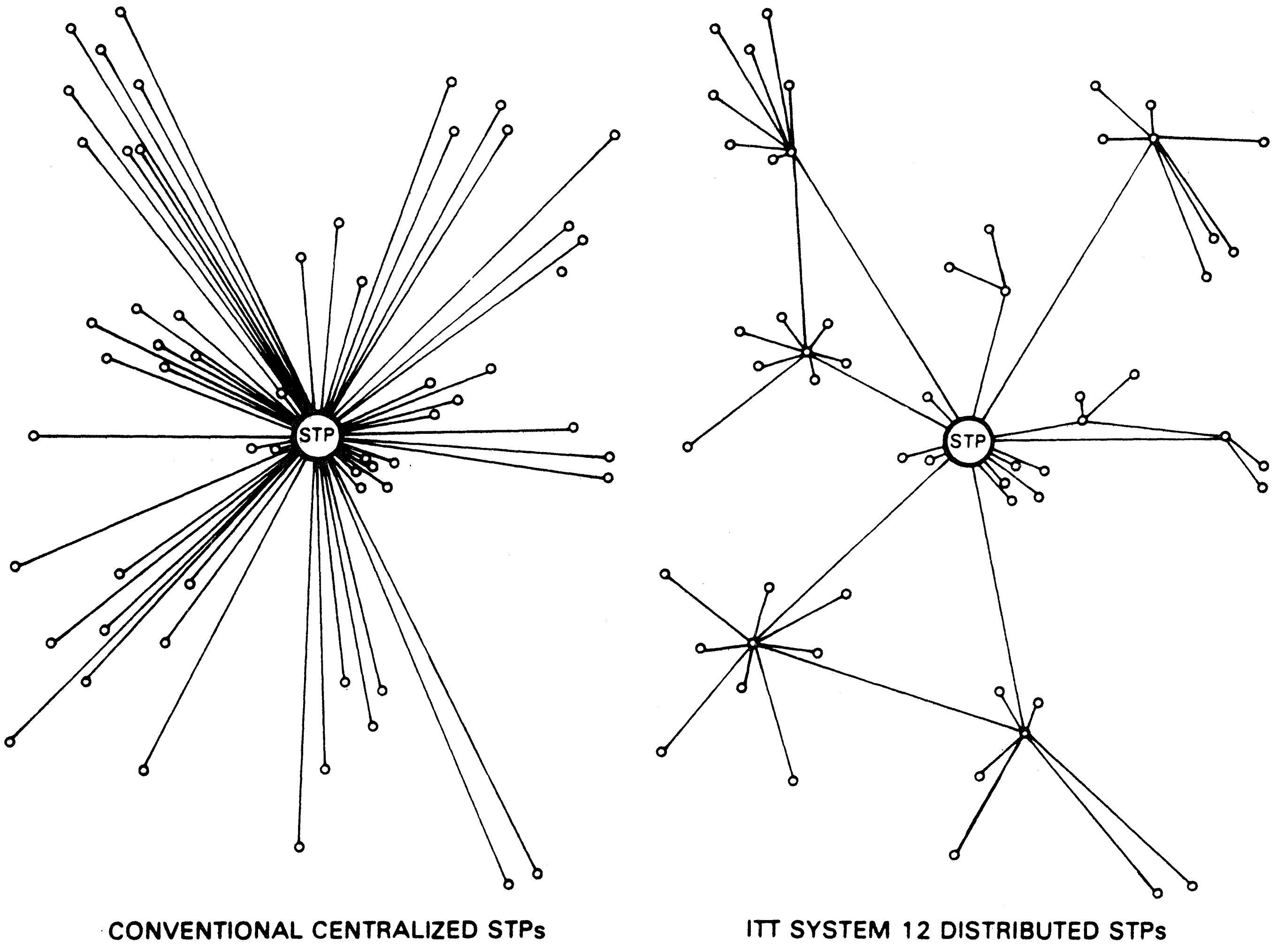


FIGURE 1 Signaling Network Topology

A distributed architecture will also provide a more robust network in that loss of individual nodes or links will cause less degradation than in a star architecture. The distributed architecture reduces investment in the STP, as well as reducing the network's message processing dependency on the STP. Alternate routing will reduce the impact of aberrant traffic behavior. Recoveries from faults will be much more manageable due to control capabilities in the distributed network.

A distributed network architecture has implications relative to data base administration, spare parts logistics, and remote maintenance. The planner should carefully consider trade-offs between economics, operational flexibilities and redundancies (robustness), and operational requirements [Operations, Administration, and Maintenance (OAM)].

Any portion of a signaling network can be typified as shown in Figure 2 by the following:

- Number of signal points in the network area. These may include inter-exchange carrier points of presence or Service Control Points (SCPs).
- Message volume to and from the signal points.
- Percentage of messages that originate and terminate within the area.

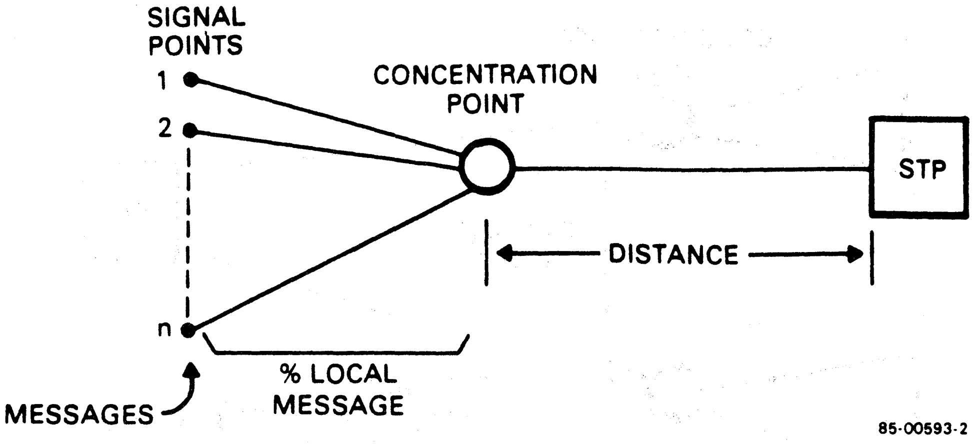


FIGURE 2 Signaling Network Model

- Placement of the concentration point. This point will usually be collocated with one of the signal points, based on centering considerations within the inter-office facility grid.
- Distance from the concentration point to the STP.

When extending this model to multiple network areas, consideration should be given to the establishment of inter-area links, as shown in Figure 3. To determine the deployment of these links, the planner should consider both economics and robustness. Such links will provide increased robustness wherever inter-area message traffic exists. If the traffic between two areas is low, it may be uneconomical to deploy inter-area links.

At each concentration point, the planner has the following options:

- STP pair
- Satellite STP pair (or single Satellite STP if the risk is acceptable)
- Multiple Mini STPs
- Single Mini STP
- Combinations of the above
- No concentration; take all links to the STP

In a distributed architecture, the number of STPs is expected to be very low. However, OAM, regulatory, or other considerations may result in deployment of additional STP pairs. The number of link terminations required is a key consideration in the determination of STP placement. Because placement of remote Mini STPs and Satellite STPs will reduce the link termination requirements at potential STP sites, the more remote areas should be planned first.

Deployment of Satellite STPs versus Mini STPs is largely a matter of link termination quantities at the concentration point. Deployment of multiple Mini STPs is more economical than deployment of Satellite STP pairs up to a point; however, there is an economic/robustness trade-off.

With multiple Mini STPs at a single site, ports which would normally be available for external link connections will be used to link the Mini STPs. The result is a practical limit of three collocated Mini STPs serving 12 signal points. Such a configuration is less robust than a pair of Satellite STPs since it involves more ports, links, and switching entities and has no capacity left for inter-area links.

Figure 4 depicts the results of an ITT analysis of the relative economics of Satellite STP versus Mini STP deployment. It can be used as a reference for development of first-cut distributed network deployment.

To use Figure 4, the planner should locate the intersection point representing the number of signal points in the network area and the distance of the proposed

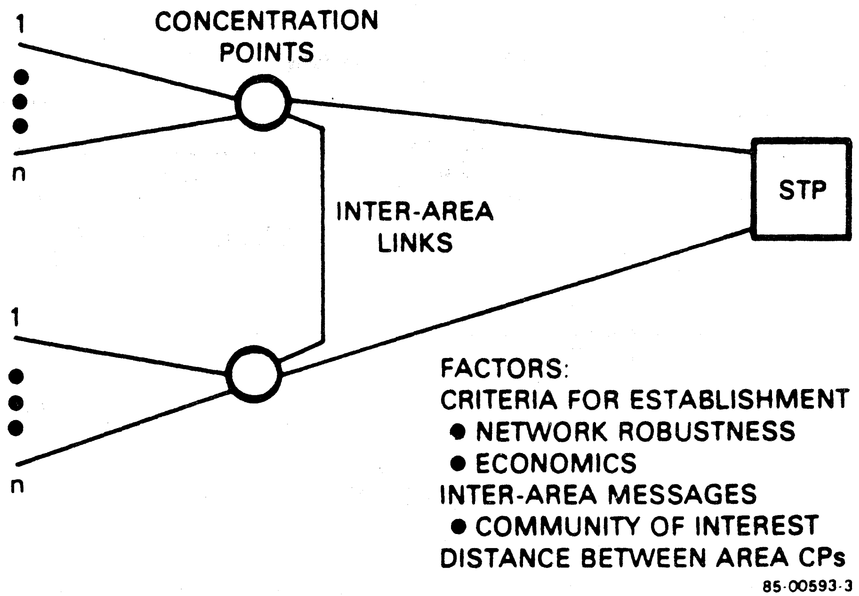


FIGURE 3 Multiple Network Areas

concentration point from the STP. This intersection point may be located in an area indicating a Mini STP (or multiple Mini STPs), a Satellite STP pair, or Mini STPs without inter-links. If the number of signal points is low and the distance short, Figure 4 indicates no application of Mini STPs or Satellite STPs.

Figure 4 represents general economic results. The operating company may wish to prepare a similar chart representing their own specific economic view, and perhaps more importantly, their OAM philosophy and robustness/economic criteria.

3.02 Capacities and Constraints. An STP pair is always required in a CCS7 network. Multiple STP pairs may be deployed and, if so, must be interconnected by bridge links. Direct links must also be provided to Satellite STPs and Mini STPs, if deployed. It is permissible for the STP to terminate access links directly from signaling points without concentration.

Every CCS7 signaling port in the ITT CCS7 products is designed for a 0.8 Erlang (28.8 CCS) traffic load. A maximum of 0.4 Erlang should be used for network design. This facilitates full backup capability in the event of a link failure or loss of one of the paired STPs.

4.00 STP EQUIPMENT ENGINEERING

4.01 Rack Elevations. The following five rack types are required for the STP (Figure 5):

- Power distribution rack
- Magnetic tape rack
- Common rack
- Digital Switching Network (DSN) rack
- CCS7 port expansion rack

One of each rack type is required for any size STP. The CCS7 port expansion rack is required as specified in Table 1. The maximum size STP is 210 ports and requires nine racks.

4.02 Floor Plan. Figure 6 shows a typical STP floor plan which is a 20 × 20 foot equipment bay consistent with New Equipment - Building Systems (NEBS) (PUB 51001) requirements. An STP with up to 84 CCS7 signaling ports can be equipped in a single, 6-rack row. An STP with more than 84 ports will require additional expansion racks as shown in Table 1. The ITT System 12 equipment practice allows for up to ten racks in one row. An alternative 210-port STP arrangement would be a single row with all nine racks. Rack dimensions are as follows:

Rack Height — 84 inches
Rack Width — 39 inches
Rack Depth — 18 inches

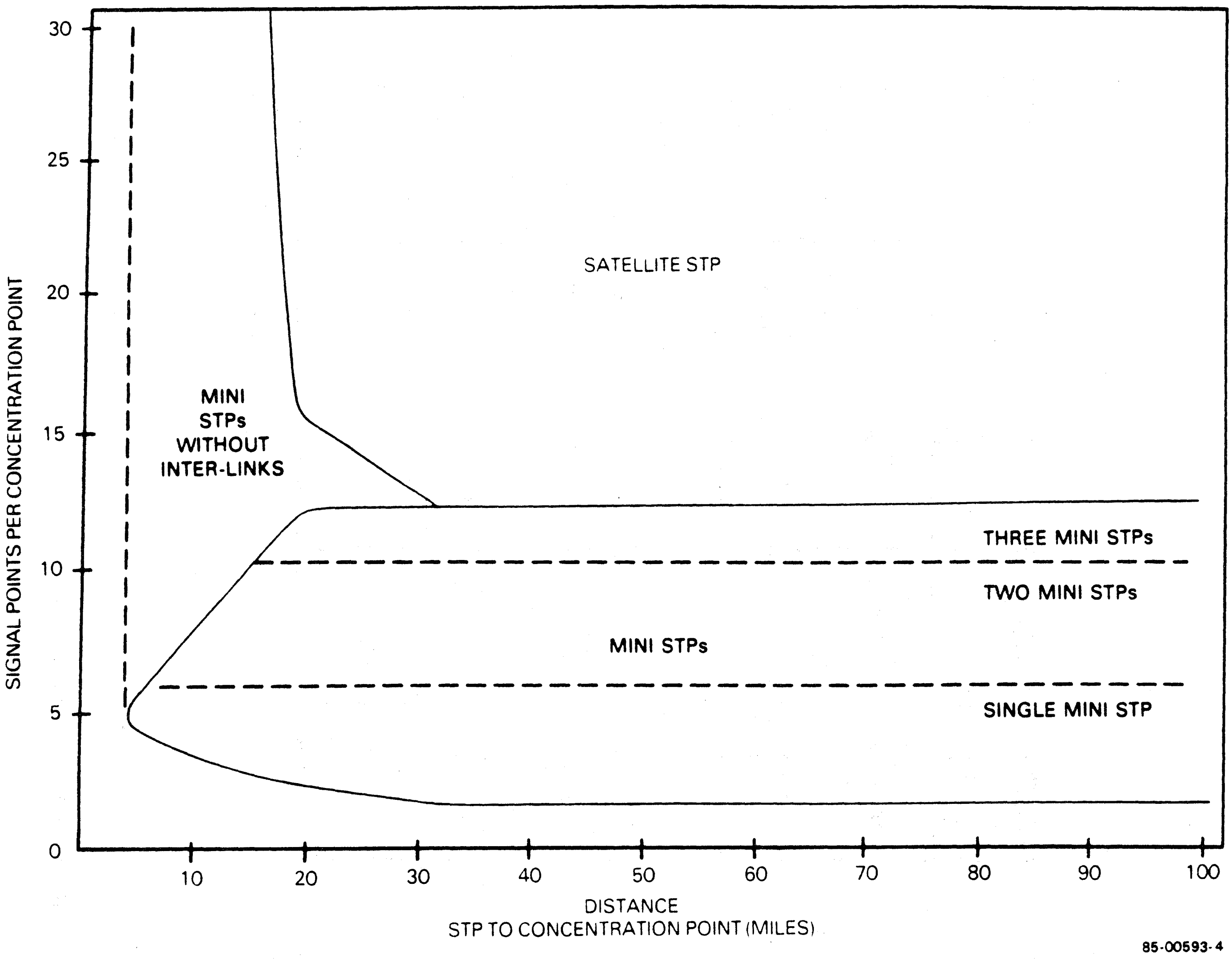


FIGURE 4 Satellite/Mini STP Relative Economics

TABLE 1 CCS7 Port/Expansion Rack/TSU Relationship

CCS7 Ports	CCS7 TSUs	CCS7 CEs	Expansion Racks
1-28	1	2	1
29-56	2	4	2
57-84	3	6	2
85-112	4	8	3
113-140	5	10	4
141-168	6	12	4
169-196	7	14	5
197-210	8	15	5

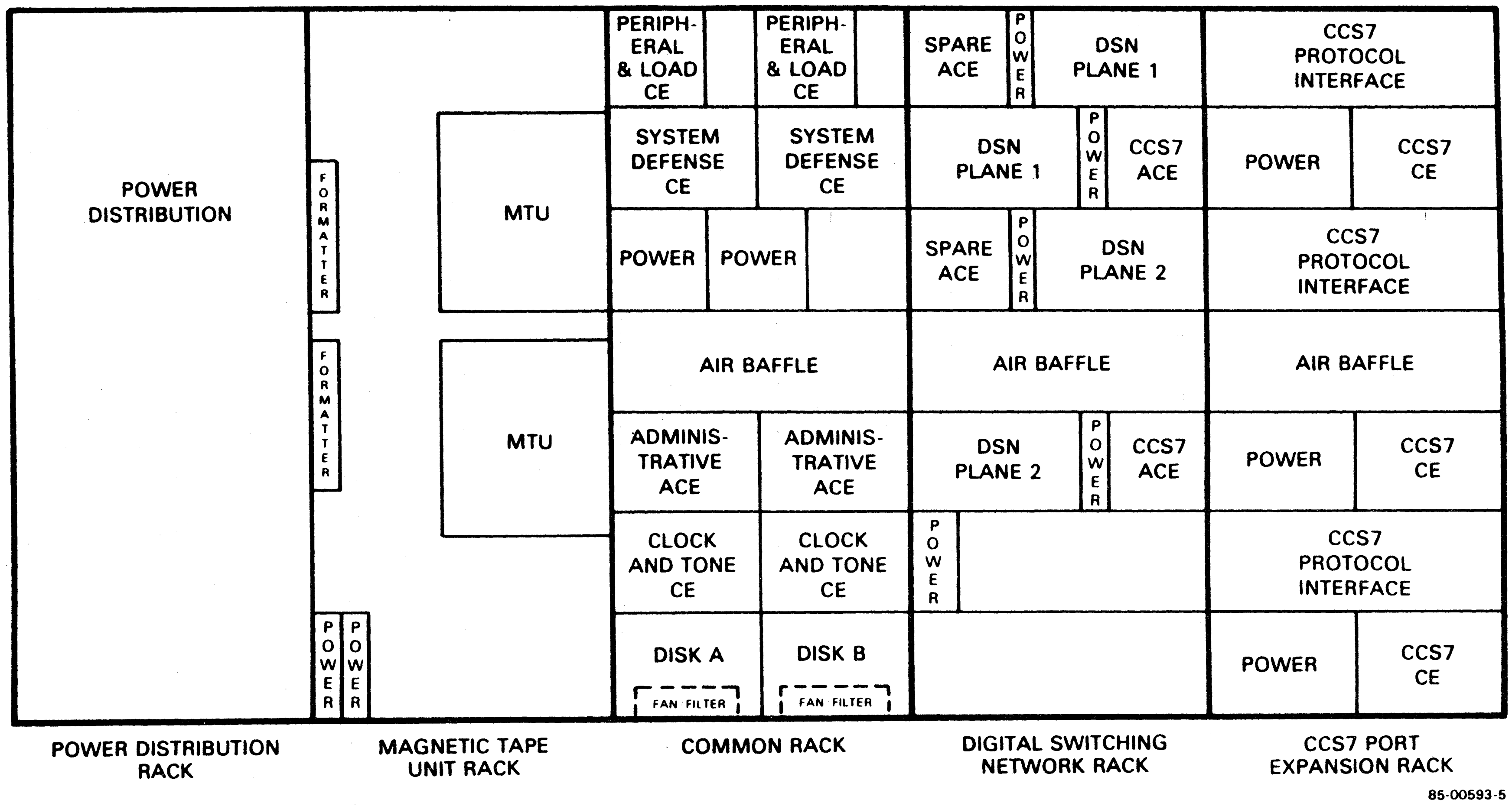
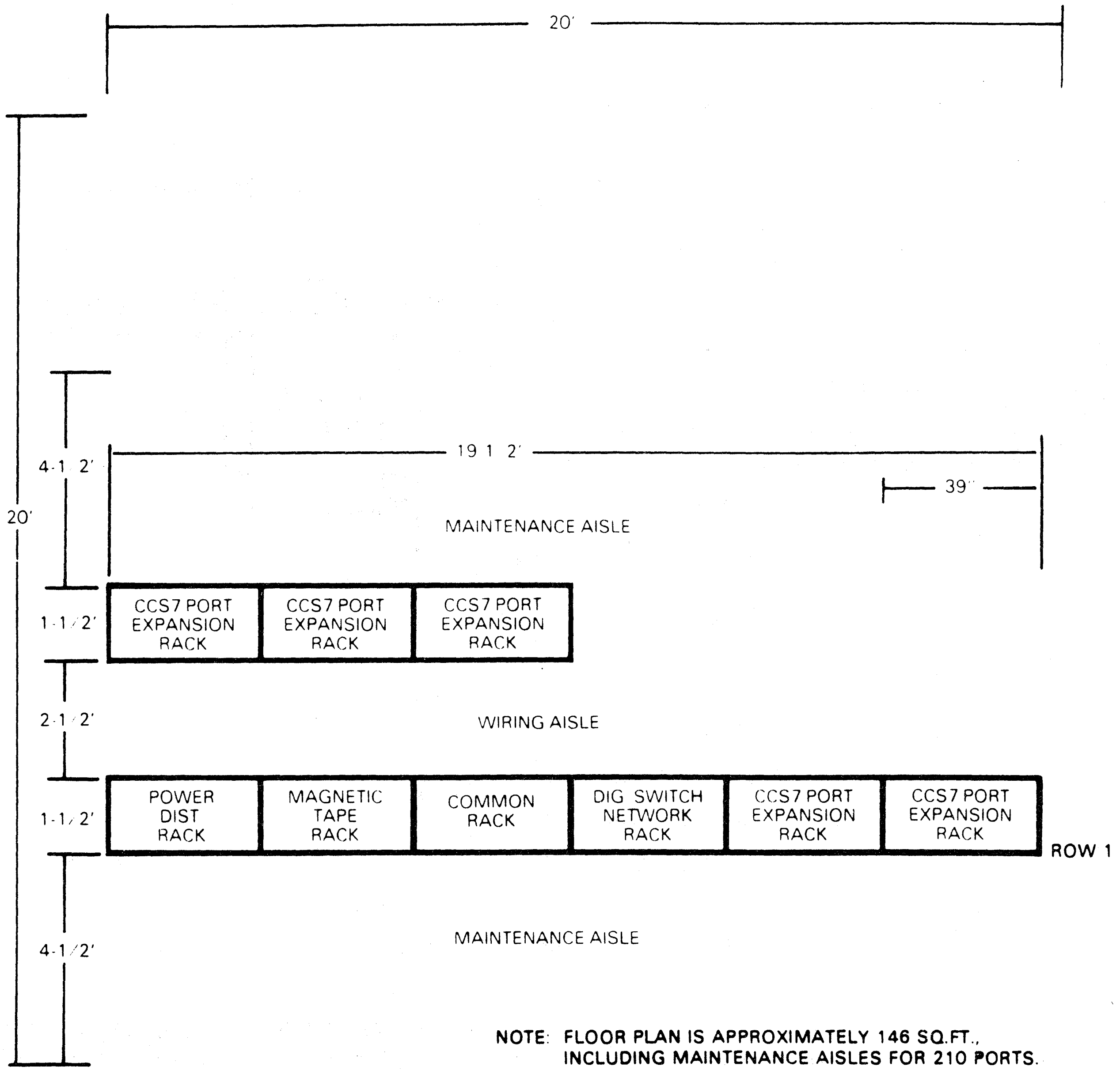


FIGURE 5 STP Rack Elevations



NOTE: FLOOR PLAN IS APPROXIMATELY 146 SQ.FT., INCLUDING MAINTENANCE AISLES FOR 210 PORTS.

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FIGURE 6 Typical STP Equipment Bay Floor Plan

5.00 STP DIMENSIONING RULES

5.01 General. The STP is relatively simple to configure from the equipment engineering perspective. Four basic interface parameters impact STP engineering.

- Number and type of CCS7 signaling links
- Number and type of Input/Output (I/O) ports
- STP synchronization requirements
- STP power requirements

5.02 Traffic Serving Unit Definitions. A Traffic Serving Unit (TSU) is the basic building block of all ITT System 12 products. In terms of hardware, a TSU consists of up to eight Control Elements (CEs) connected to the ITT System 12 group switch through a pair of Access Switches (ASs) (Figure 7). Individual

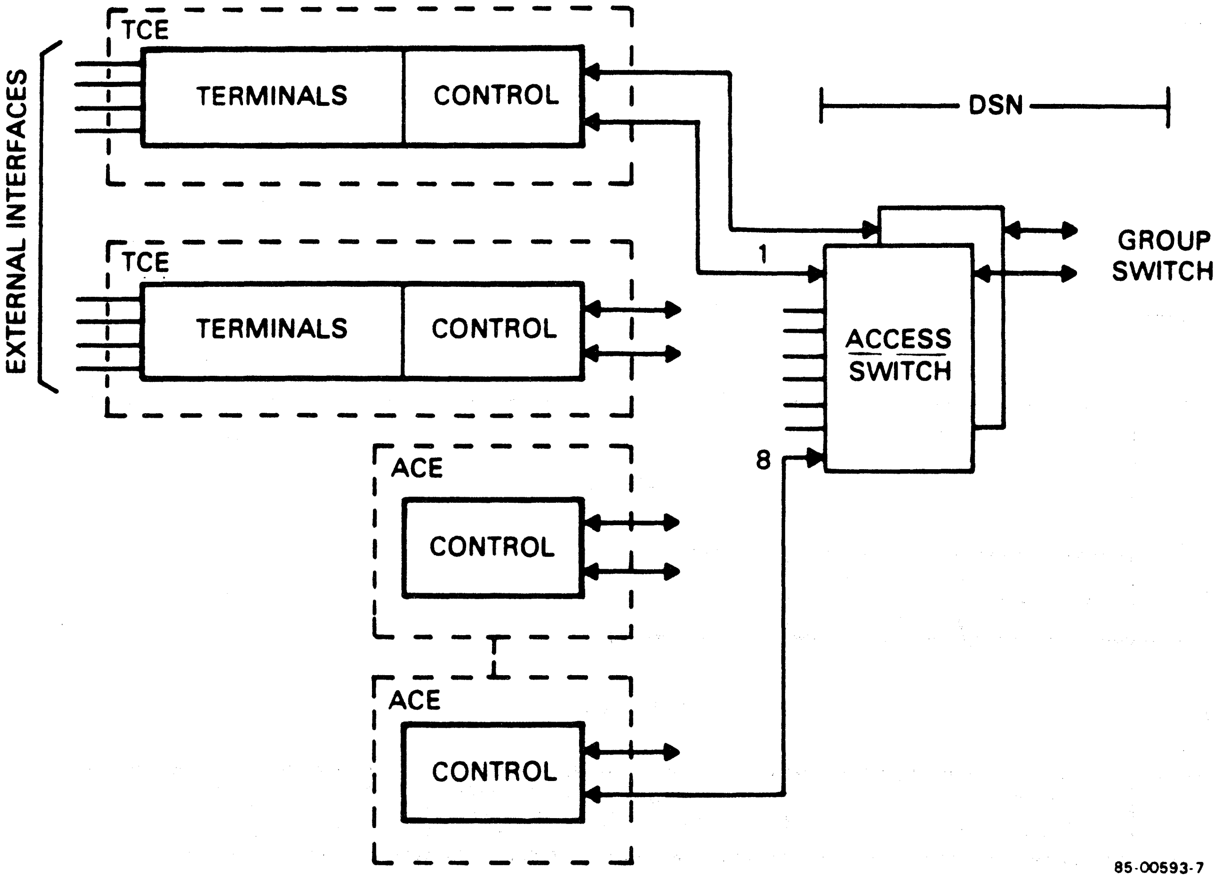


FIGURE 7 Traffic Serving Unit

CEs may be one of two types. Terminal Control Elements (TCEs) support terminals interfacing the outside environment (i.e., CCS7 signaling ports, I/O terminals, etc.). Auxiliary Control Elements (ACEs) do not interface the outside environment but provide additional processing support for ITT System 12 applications.

Functions performed by the TSU are determined by the hardware, firmware, and software within the TSU. The various types of TSUs configured and interconnected via the group switch determine product function. The quantities of TSUs dimensioned across the group switch define the product's size. Dimensioning of the group switch in terms of stages and planes is a function of the TSU quantity and the total traffic presented by the individual TSUs, respectively.

As shown in the STP block diagram (Figure 8), the STP is composed of four TSU types. These TSUs are, in turn, made up of CEs which are connected to the group switch through a pair of ASs.

5.02.1 System Defense Traffic Serving Unit. The system defense TSU (Figure 9) is composed of two CCS7 administration ACEs, two defense CEs, and two ASs.

Two administration ACEs are required in every STP. The administration ACE is made up of a terminal control processor with up to 1-megabyte of Random Access Memory (RAM) and a Terminal Interface (TI) for interconnection to the Digital Switching Network (DSN). Its basic functions are supporting measurement collection and reporting for the STP traffic measurements.

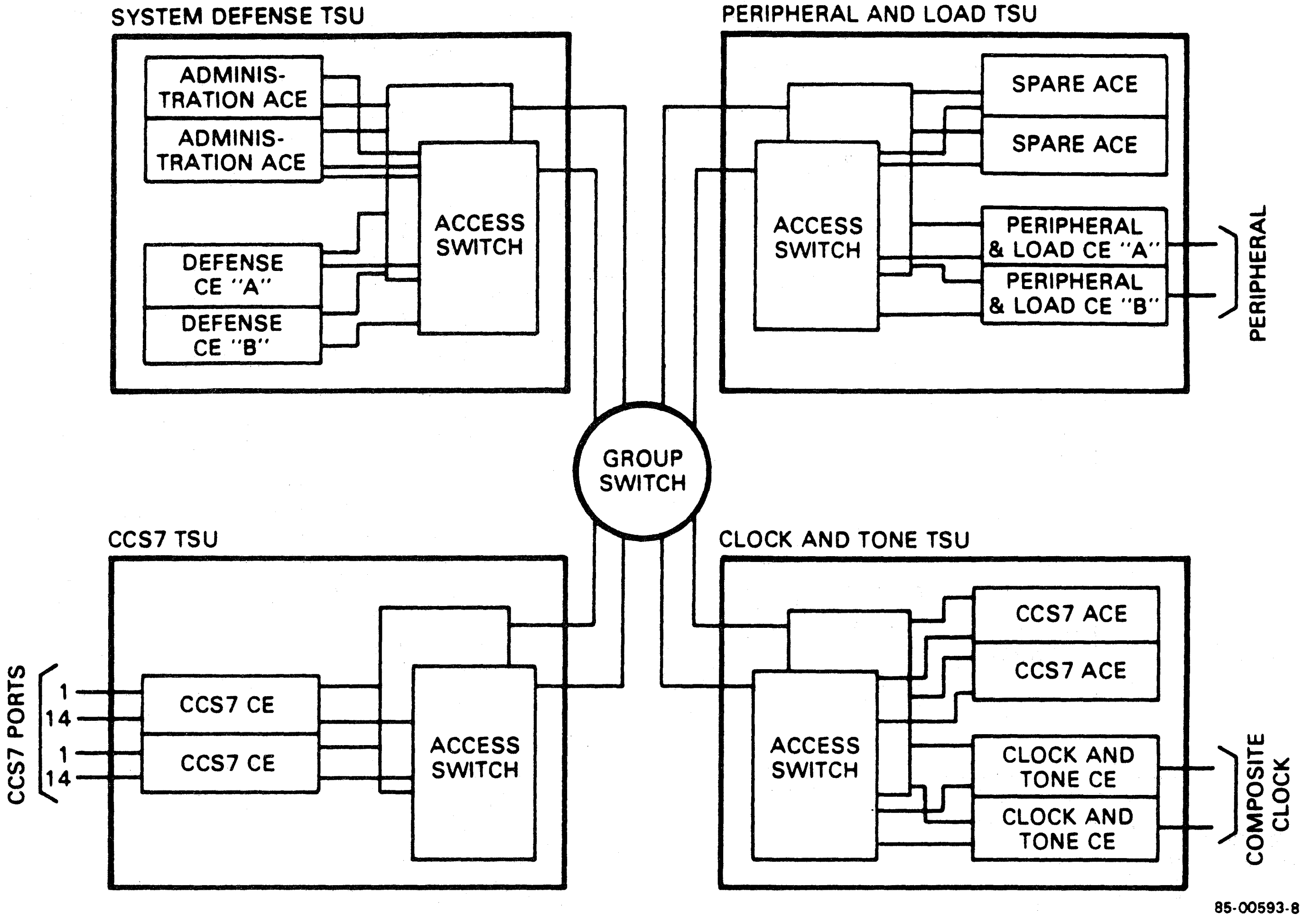


FIGURE 8 STP Block Diagram

The two defense CEs are provided in the system defense TSU. Each defense CE is composed of the following Printed Board Assemblies (PBAs):

- Switch element/Access Switch (AS)
- Terminal control processor
- Terminal Interface (TI)
- Lamp driver
- Display logic card
- Master alarm panel

The primary functions of the defense CE are as follows:

- Error/fault analysis
- Diagnostics scheduling
- System configuration/reconfiguration
- Any STP processor reload and restart

5.02.2 Peripheral and Load Traffic Serving Unit. The peripheral and load TSU (Figure 10) is composed of two spare ACEs, two peripheral and load CEs, and two ASs.

The spare ACEs are made up of a terminal control processor (with 1-megabyte of RAM) and a TI. The spare ACEs can be loaded with the software of any other ACE in the system. They are provided as a third level of backup in the event of a failure of one of the other two ACEs in an active/standby pair.

Each of the two peripheral and load CEs is composed of the following PBAs:

- Switch element/Access Switch (AS)
- Processor, type C
- Terminal Interface (TI)
- Auxiliary memory (three)

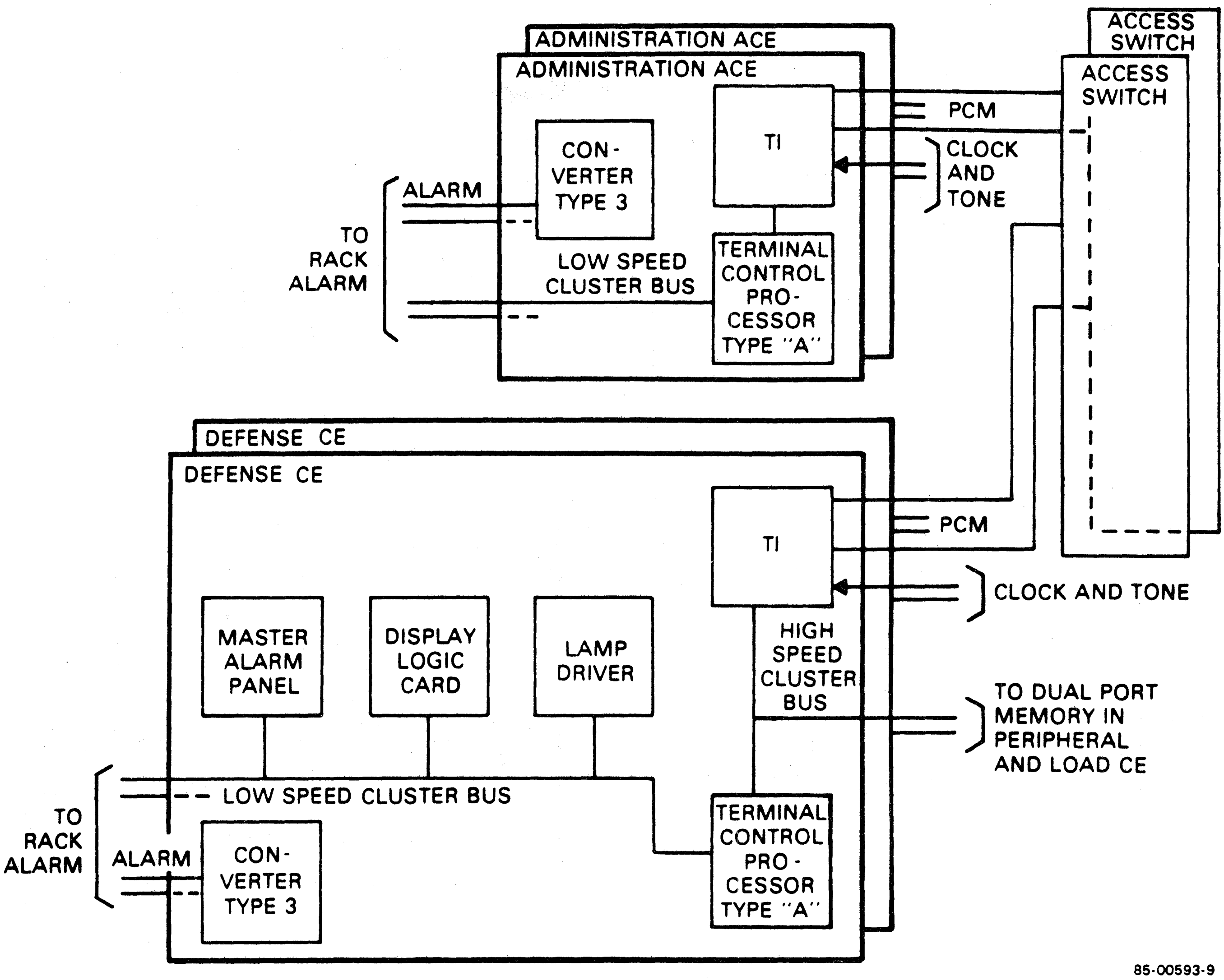


FIGURE 9 System Defense TSU

- Direct memory channel processor
- Magnetic Tape Unit (MTU) controller
- Winchester disk controller
- Craft/machine communication interface (up to four)
- Status unit
- Dual port memory

The primary functions of the peripheral and load CE are as follows:

- Bulk storage device access and control
- Craft/machine communications
- Data base management functions for the STP

5.02.3 Clock and Tone Traffic Serving Unit. The clock and tone TSU (Figure 11) is made up of two CCS7 ACEs, two clock and tone CEs, and two ASs.

The CCS7 ACE consists of a terminal control processor equipped with up to 1-megabyte of RAM and a TI card.

The primary functions of the CCS7 ACE are as follows:

- Signal management
- Link network management signaling
- Route network management signaling
- Route set test management control
- Link set management
- Link management reconfiguration
- Traffic flow control signaling
- Local data collection for CCS7 measurements

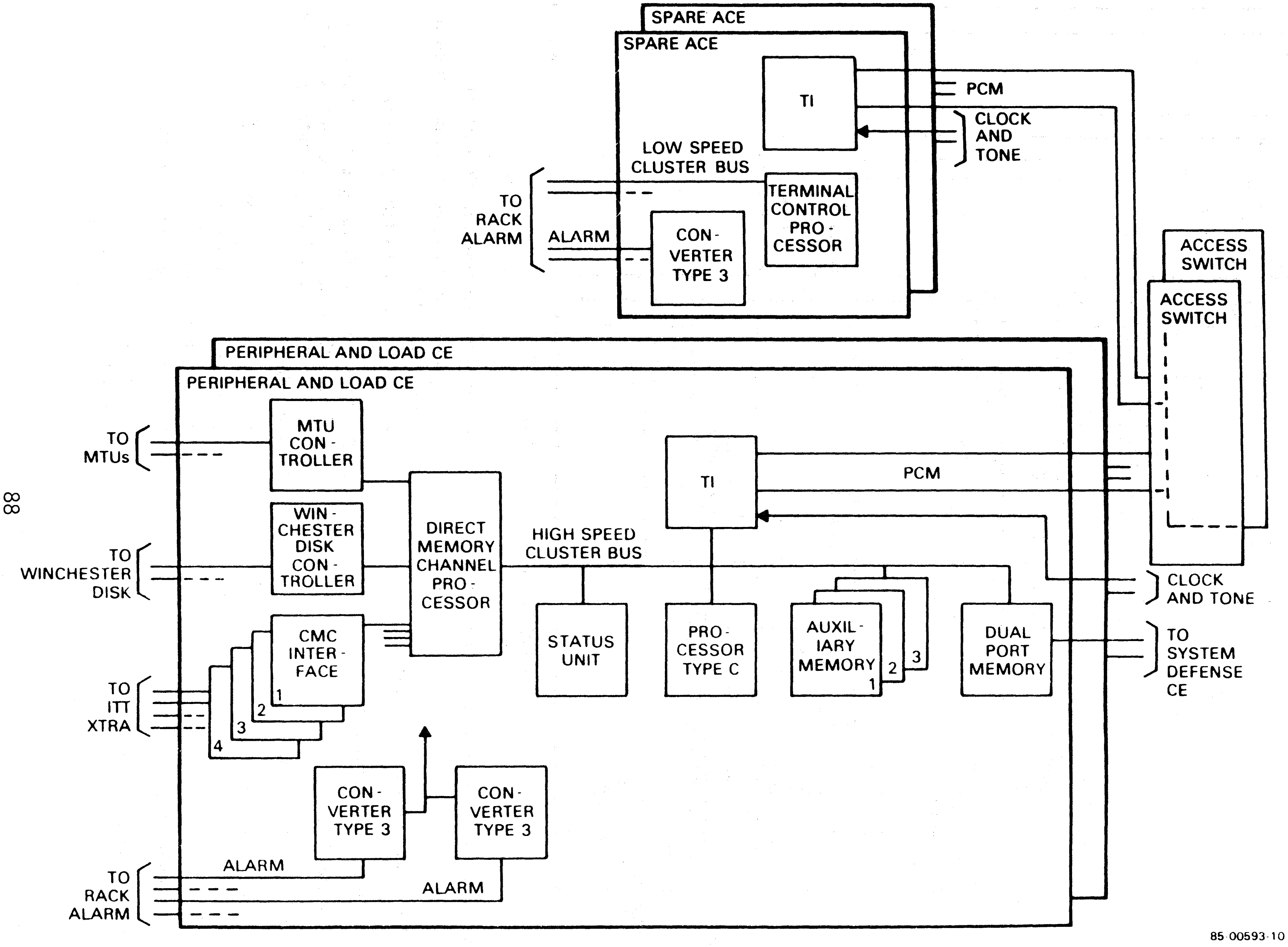


FIGURE 10 Peripheral and Load TSU

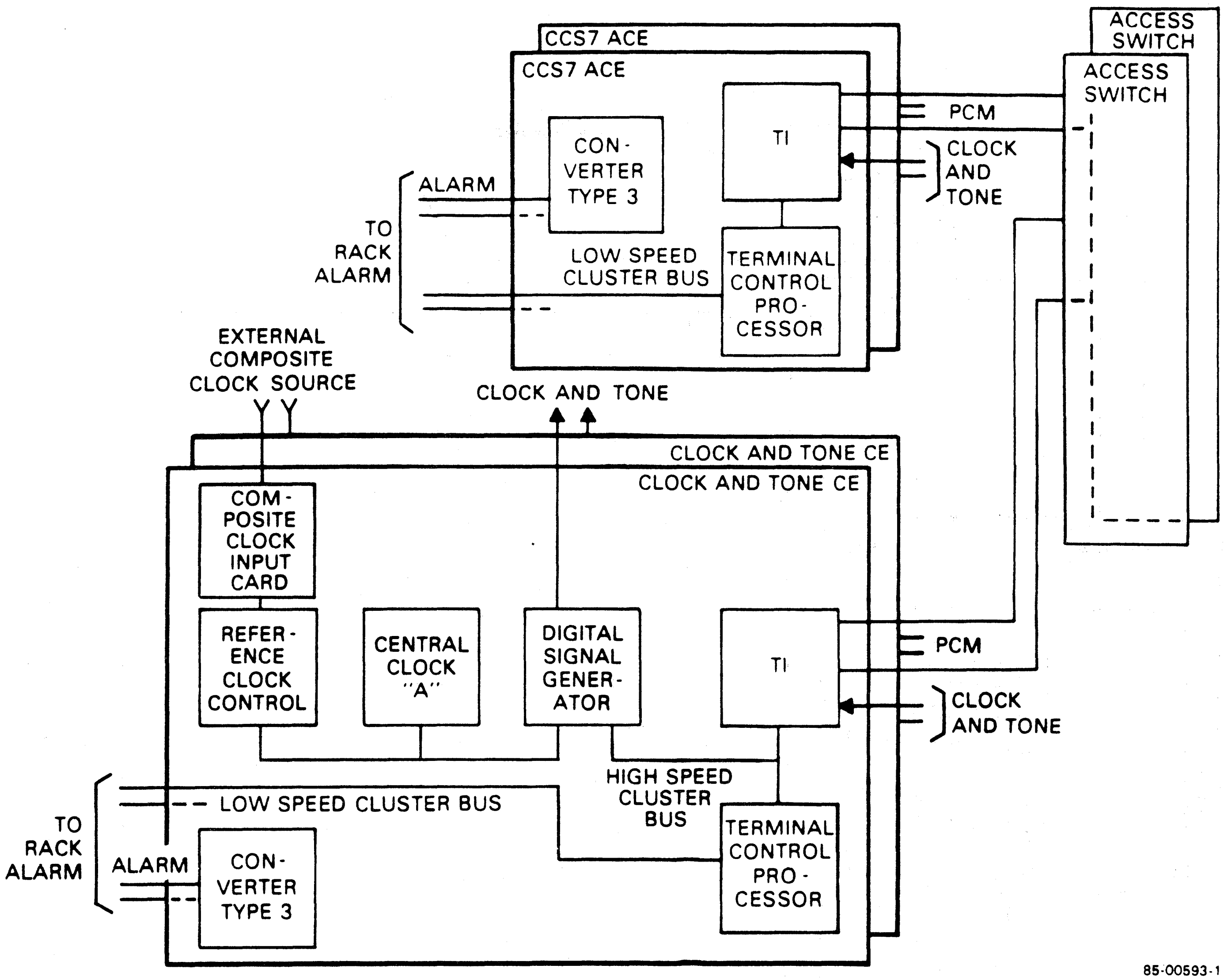


FIGURE 11 Clock and Tone TSU

The clock and tone CE is composed of the following PBAs:

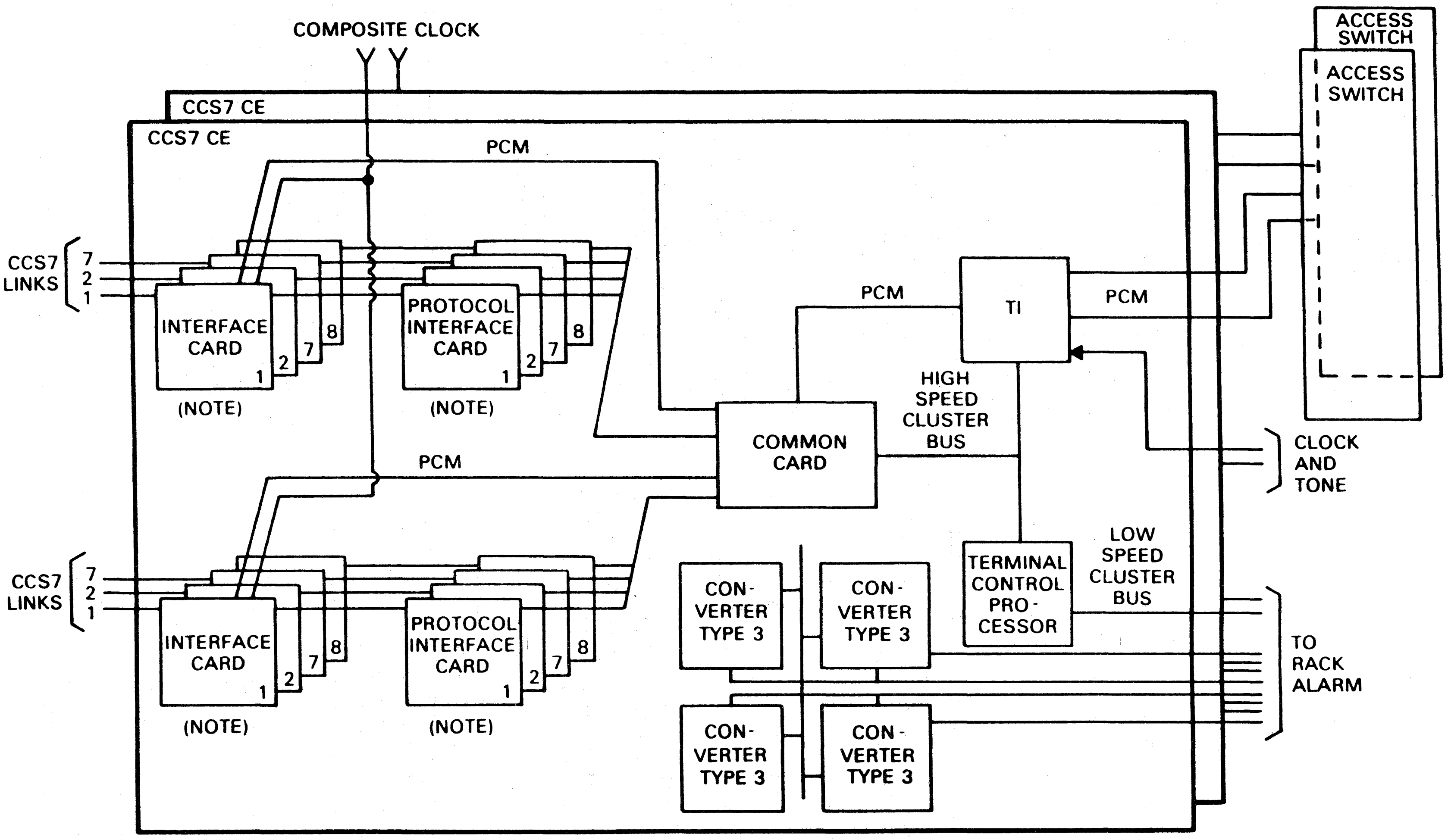
- Switch element/Access Switch (AS)
- Terminal control processors
- Terminal Interface (TI)
- Reference clock control
- Central clock "A"
- Digital signal generator
- Composite clock input card

The primary functions of the clock and tone CE are as follows:

- Termination of two office clock references
- Automatic configuration/reconfiguration of clock references
- Distribution of clock throughout STP

5.02.4 CCS7 Traffic Serving Unit. The CCS7 TSU (Figure 12) is made up of two identical CCS7 CEs and two ASs. The CCS7 CE is made up of the following PBAs:

- Switch element/Access Switch (AS)
- Terminal control processor
- Terminal Interface (TI)
- Protocol interface cards (up to 16)
- Common card
- CCS7 interface cards (up to 16)



NOTE: 8 CARDS ARE PRESENT; FIRST 2 AND LAST 2 CARDS ARE SHOWN.

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FIGURE 12 Common Channel Signaling No. 7 TSU

The primary functions of the CCS7 CE are as follows:

- Physical termination of up to 14 CCS7 signaling links
- Signaling link functions
- CCS7 message handling and routing
- Signaling link test and maintenance

5.03 STP Capacities. This section describes certain STP capacities and interdependencies.

- CCS7 signaling link capacity - 210 maximum
- I/O ports, RS-232C/asynchronous - 8 maximum

CCS7 port quantities determine the number of TSUs required which, in turn, determines the quantity of CCS7 modules and expansion racks needed. Incremental growth is listed in Table 1 and shown in Figure 13. Table 1 lists the CCS7 port expansion rack, module, and TSU relationships, and Figure 13 shows TSU and PBA relationships.

5.04 Getting Started. Each STP must be equipped with one power distribution rack, one magnetic tape rack, one common rack, and one DSN rack.

The power distribution rack is used to distribute duplicated power sources (A&B) to the STP equipment. The power distribution rack is equipped with circuit breakers and fuse links supporting the maximum size STP. No further dimensioning of these elements is required.

The magnetic tape rack is used to provide redundant Magnetic Tape Units (MTUs). The MTUs provide a secondary level of backup for memory images of program and data load segments and provide a bulk storage medium for the STP. The magnetic tape rack is fully dimensioned with two MTUs and their associated formatters. Again, no further dimensioning of this rack is required.

The common rack houses the support resources for the STP. Included are the peripheral and load TSU, the clock and tone TSU, and the system defense TSU. Redundant disk drives and Craft/Machine Interfaces (CMIs) are also located here. The common rack is shipped fully dimensioned with the exception of I/O ports. Two I/O ports are provided initially for redundancy. See Section 5.06 of this document for the provisioning of additional I/O ports.

The DSN rack houses the group switch for the STP. It provides the 2-plane, 2-stage switching network required to support a totally equipped STP. Additionally, the DSN rack provides physical mounting space for the spare ACEs and CCS7 ACEs. No dimensioning is required.

5.05 CCS7 Link Dimensioning. It is necessary to determine the number of links which require termination in order to dimension an STP. These links connect signal points (i.e., end offices, tandems, service control points, inter-exchange carriers, other STPs, etc.) to the STP. The CCS7 message traffic for each signal point should first be expressed in octets/second (8 bits or 1 byte) during the busy hour. This number is then divided by 2,800 octets/second, the capacity of a single CCS7 link in normal operation (56 kb/s ÷ 8 bits/octet × 0.4 Erlang = 2,800 octets/second). The result must be rounded up to the next multiple of 2. This number represents the total number of links required. Each signal point is always connected to both STPs of an STP pair, so the total number of links from the individual signal points must be divided by 2 to determine the port requirement on each STP.

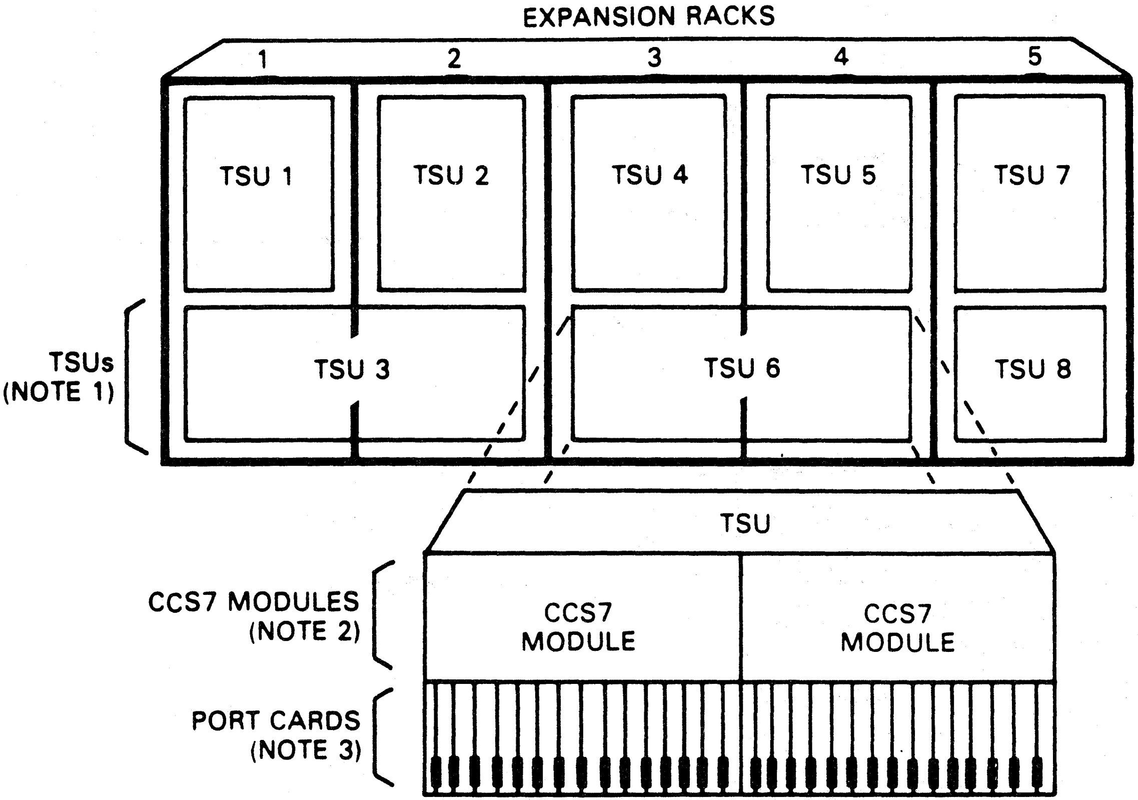
Minimal traffic is expected between the two members of an STP pair. However, a minimum of two links should be used as cross links between the two. These links require an additional two ports on each of the STPs. They carry messages on an alternate routing basis when individual link failures occur. More than two cross links are required only to provide a higher level of security.

The total number of links requiring termination on the STP is the sum of the links from signal points plus the required cross links.

Two separate interface alternatives are available for connecting CCS7 signaling links (Figures 14A and 14B).

Figure 14A shows a V.35 link connection via a Digital Service Unit (DSU) from a distant digital data system facility. Total cable length between the STP CCS7 module and the DSU is restricted to 100 feet. The cable to the DSU is terminated with a 34-pin Winchester connector compatible with an ITT Multirate DSU-A, which can be provided by ITT, or an AT&T-T 500A DSU.

Figure 14B shows a direct 56 kb/s, 4-wire DS0 connection to a DS0 data port in a locally provided Pulse Code Modulation (PCM) channel bank. The total cable



NOTE	DESCRIPTION	QUANTITY	TYPE
1.	TSU COMMON CARDS - TWO CCS7 MODULES/TSU	2	ACCESS SWITCH
2.	CCS7 MODULE COMMON CARDS	1 1 1 4	TI TERMINAL CONTROL PROCESSOR COMMON CARD CONVERTER
3.	PORT CARDS (PROVISIONABLE)	1—14 1—14	PROTOCOL INTERFACE CARD INTERFACE CARD

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FIGURE 13 Expansion Rack/TSU/PBA Relationship

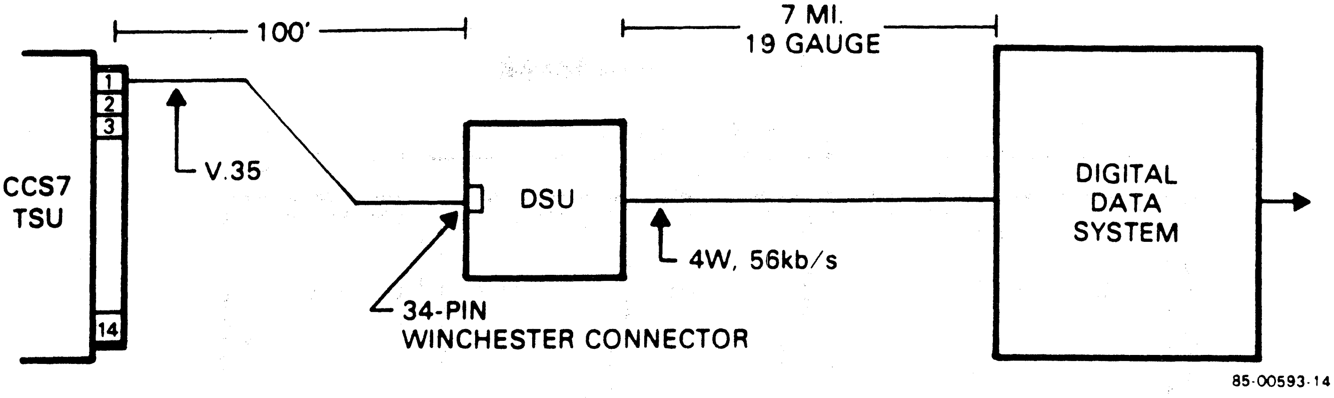


FIGURE 14A V.35 Interface Connection

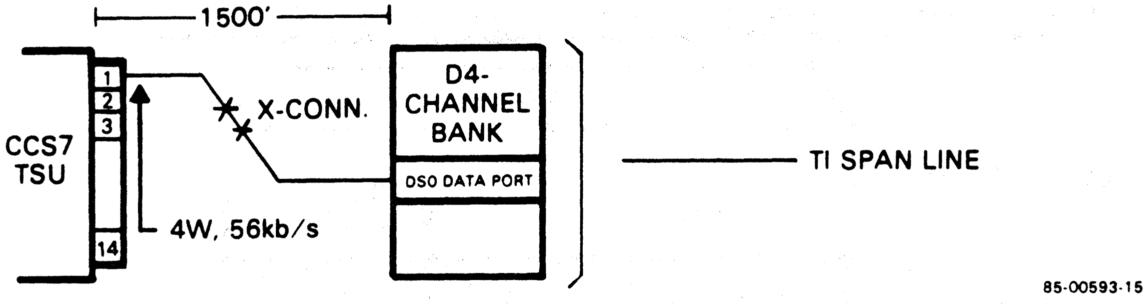


FIGURE 14B DS0 Interface Connection

length between the STP port and the DS0 data port is restricted to 1,500 feet. The channel banks and DS0 data ports can be provided by ITT.

When the quantity of CCS7 links and their respective connection arrangements is determined, Worksheet 1 is used to dimension CCS7 port expansion racks, CCS7 TSUs, and individual port cards (interface card V.35 or DS0).

The number of CCS7 links terminated via a V.35 interface is entered under "QUANTITY" for Item 1. The number of CCS7 links terminated via a DS0 interface is entered as Item 2. The sum of Items 1 and 2 is entered as Item 3 and represents total CCS7 links.

Based on Item 3, the number of CCS7 TSUs (Item 4) is calculated by dividing by 28 and rounding up. The number of CCS7 CEs (Item 5) is then determined by multiplying Item 4 by 2.

The required ports should be spread as evenly as possible over the modules to achieve an optimal traffic balance between the modules. Worksheet 1 provides the methods for load balancing, which should be observed in the initial installation, during assignment of ports, and as ports are added.

Some (or all) CCS7 CEs will have a minimum quantity of ports (Item 6) determined by dividing the total number of ports required (Item 3) by the number of CCS7 CEs (Item 5) and rounding down. The remaining CEs will have one more port (Item 6 + 1). To determine the number of CEs with ports (Item 6 + 1), subtract the product of Item 5 and Item 6 from the total number of ports required (Item 3). These remaining ports (Item 7) must be spread over an equal number of CEs. The remaining CEs (Item 8 = Item 5 - Item 7) will each have a quantity of ports (Item 6).

Item 4, CCS7 TSUs, is used to calculate the number of CCS7 port expansion racks from the table on Worksheet 1. This number is entered as Item 9.

The number of individual CCS7 interface cards is determined by simply restating the link requirements. In other words, Item 10 = Item 1 and Item 11 = Item 2.

Each interface card has an associated processor card. The quantity of processor cards (Item 12) is the sum of Items 10 and 11.

5.06 Input/Output Dimensioning. The method of connecting I/O ports involves using an RS-232C asynchronous interface. Up to eight I/O ports may be equipped for each STP.

Figure 15 shows an RS-232C asychronous connection. A maximum of eight craft/machine communication cards can be equipped in the STP's common rack, supporting ITT XTRA personal computers used as I/O devices. Each craft/machine communication card provides two RS-232C ports: A and B. For reliability purposes, the craft/machine communication cards are always provided in pairs with the A and B ports connected as shown in Figure 16, yielding a total of eight duplicated I/O ports.

This connection is subject to the cable length restrictions of the RS-232C connection (typically 50 feet). The craft/machine communication card can be operated at data speeds of 300, 600, 1,200, 2,400, 4,800, or 9,600 b/s. The data speed is a software option established and administered by the user.

Two I/O ports and ITT XTRA personal computers are provided as part of the peripheral and load TSU. Worksheet 2 is provided for dimensioning additional I/O port equipment requirements.

The quantity of additional I/O ports is determined and entered on Worksheet 2. Item 1 is additional RS-232C ports, up to a maximum of 6.

Rack space for the RS-232 is provided in the common rack.

Craft/machine communication cards are always installed in pairs. The first two are provided with the common rack as part of the peripheral and load TSU. To establish Item 2, the number of additional craft/machine communication cards to be installed in an STP, divide Item 1 by 2, round up to the next whole integer, then multiply by 2.

Additional ITT XTRA personal computers may be ordered by specifying the quantity desired as Item 3 on Worksheet 2. Each terminal specified comes with an associated printer.

5.07 Equipment Summary. Worksheet 3 summarizes the equipment dimensioned on Worksheets 1 and 2 and provides an item index to the STP Material Price List for detailed pricing.

Worksheet 3 is self-explanatory. Quantities are either already determined as a result of always-provisioned equipment or are restatements from one of the previous worksheets.

5.08 Equipment Pricing Summary. Worksheet 4 is provided for use with the STP Material Price List in order to translate the "TOTAL LIST PRICE" on Worksheet 3 to an actual discounted customer price. The appropriate volume discount rate can be obtained from the ITT sales representative.

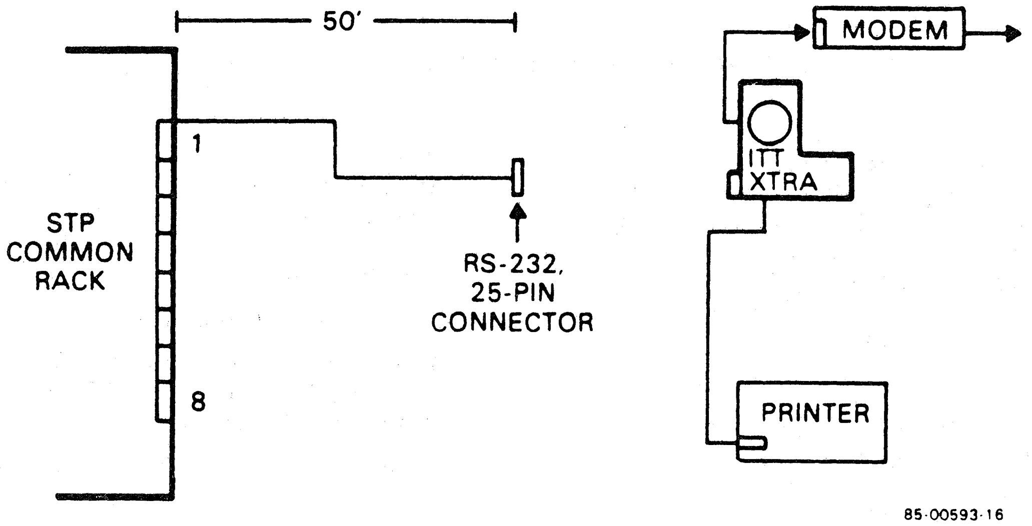


FIGURE 15 RS-232 I/O Connection

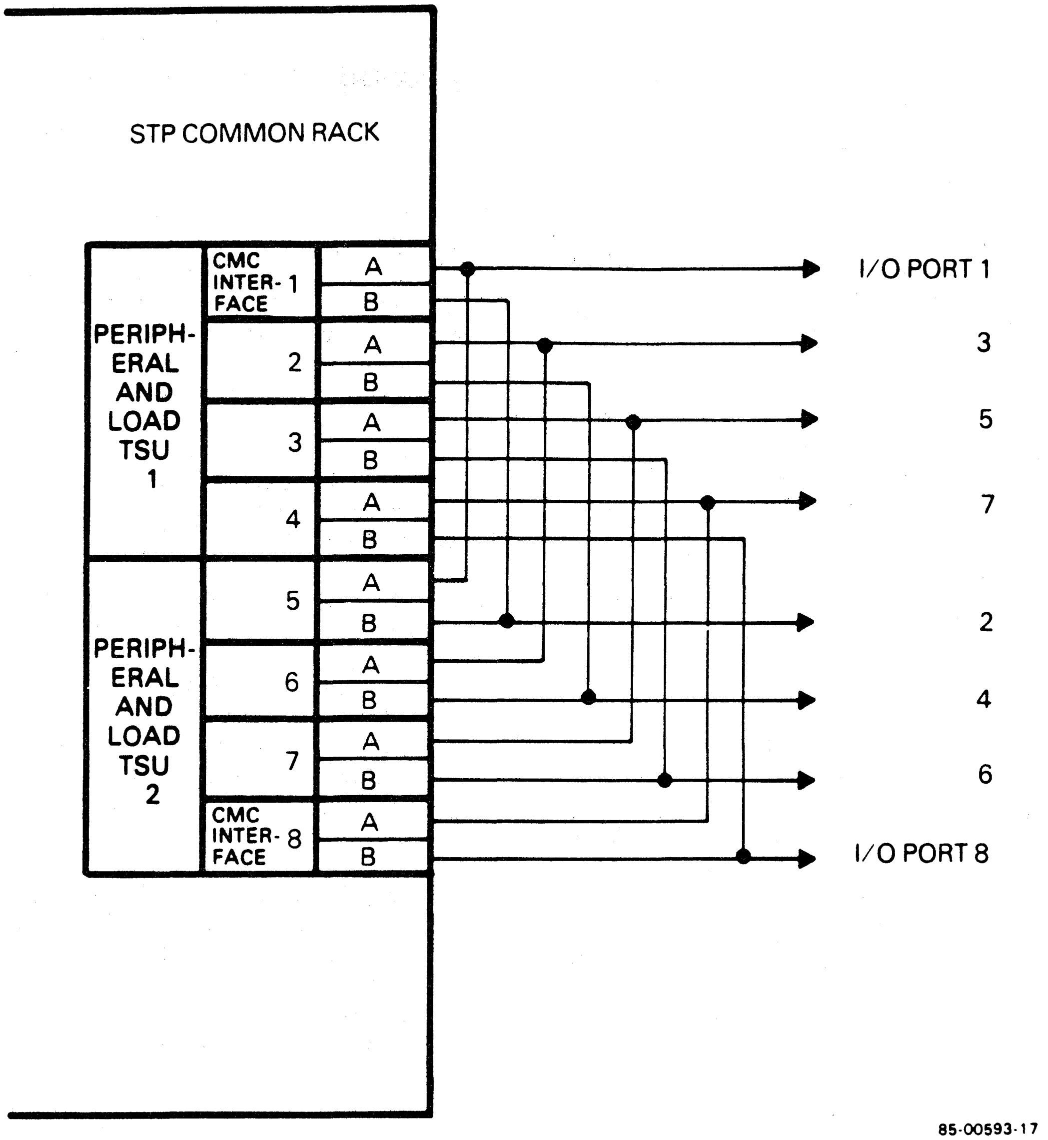


FIGURE 16 Craft/Machine Communication and I/O Port Relationship

5.09 Synchronization Requirements. The STP requires a redundant composite clock input. A composite clock is a 64-kb/s signal with 8-kb/s bipolar violations. This composite signal should be provided by the Building Integrated Timing Supply (BITS). Refer to AT&T Technical Reference PUB 60110, Digital Synchronization Network Plan, December 1983.

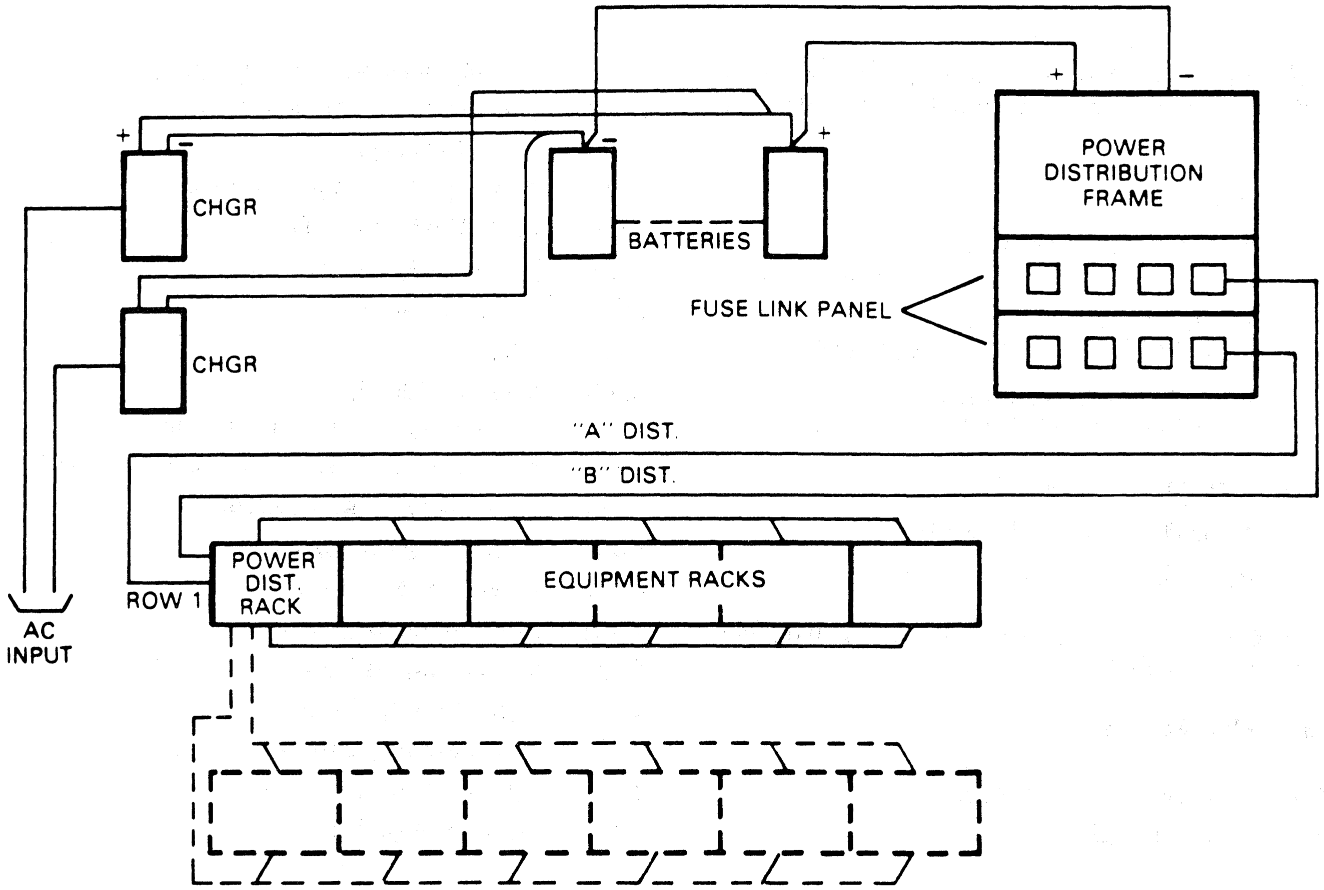
5.10 Power Requirements. The following information is provided for the purpose of estimating power plant requirements of the STP. Power consumption is stated for a fully equipped rack type, -48V power in watts.

Power rack	—	—
Magnetic tape rack	—	900 watts
Common rack	—	1,830 watts
DSN rack	—	1,110 watts
Expansion rack (each)	—	1,020 watts

Figure 17 shows typical power distribution for the STP.

5.11 Temperature and Humidity. The operating temperature range for the STP is 32° to 113°F (0° to 45°C). The relative humidity range is 10 to 80%.

5.12 Heat Dissipation. The following information is to be used in determining heat dissipation for dimensioning AC load.



NOTES:
1. " — " OR GROUND SHOWN ONLY TO THE POWER DISTRIBUTION FRAME.
2. FUSE LINK PANELS IN POWER DISTRIBUTION FRAME EQUIPPED WITH 200 OR 400 AMP FUSE LINKS AS REQUIRED.

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FIGURE 17 STP Power Distribution

Magnetic tape rack	— 3,077 BTU/HR
Common rack	— 6,257 BTU/HR
DSN rack	— 3,795 BTU/HR
Expansion rack	— 3,488 BTU/HR

6.00 STP OPERATIONS AND SUPPORT REQUIREMENTS

6.01 Maintenance and Administration Staffing. Maintenance of the ITT System 12 STP is estimated to require 80 hours each year plus 0.1 hour for each port every year. This maintenance will most likely be performed by craftpersons whose major responsibility is maintenance of a collocated switching system. To ensure 24-hour coverage, seven days a week, it will be necessary to train and assign four persons to each STP pair.

Administrative staffing levels for the STP should be developed based on 30 hours per 1,000 activities. At least two persons for each STP pair should be trained for this activity. Much of their time may be spent on other activities such as Service Control Point (SCP) data base administration.

6.02 Spare Parts. Four spare parts packages are available for the STP. Standard operating practice for spare equipment differs between operating companies. Basically, decisions to warehouse spares for a local signaling network or store them on-site is left to the operating company. The following recommendations are made:

- 1 standard STP spares package/STP
- 1 CCS7 port spares package/2 expansion racks

Spares packages are also available for the Magnetic Tape Units (MTUs) and Winchester disk drives.

6.03 Tools and Test Equipment. The following tools and test equipment are recommended for each STP pair:

A. Special Test Equipment

- No. 7 Signal Analyzer
  (TEKELEC-TE 707 or equivalent)
- Primary MUX Test Set
  (TEKELEC-TE 820-A or equivalent)
- General Purpose Data Test Set
  (HP-4955 or equivalent)

B. General Test Equipment

- Dual-channel oscilloscope
- Digital voltmeter

ITT can provide these items at suggested manufacturer's list price, if desired.

7.00 GLOSSARY

ACE	Auxiliary Control Element
AS	Access Switch
BITS	Building Integrated Timing Supply
CCS7	Common Channel Signaling No. 7
CE	Control Element
CMC	Craft/Machine Communication
CMI	Craft/Machine Interface
DSN	Digital Switching Network
DSU	Digital Service Unit
I/O	Input/Output
MTU	Magnetic Tape Unit
NEBS	New Equipment - Building System
OAM	Operation, Administration, and Maintenance
OSS	Operational Support System
PBA	Printed Board Assembly
PCM	Pulse Code Modulation
RAM	Random Access Memory
SCP	Service Control Point
STP	Signal Transfer Point
TCE	Terminal Control Element
TI	Terminal Interface
TSU	Traffic Serving Unit

WORKSHEET 1 Dimensioning CCS7 Link Equipment

QUANTITY

1. CCS7 links (V.35) ____________
2. CCS7 links (DSO) ____________
3. Total quantity of CCS7 links required (Item 1 + Item 2) ____________

CCS7 TSU/Module Dimensioning

4. CCS7 TSUs [(Item 3 ÷ 28), round up] ____________
5. CCS7 CEs (Item 4 × 2) ____________
6. Minimum ports/CE [(Item 3 ÷ Item 5), round down] ____________
7. CCS7 CEs with (Item 6 + 1) ports [Item 3 - (Item 5 × Item 6)] ____________
8. CCS7 CEs with (Item 6) ports (Item 5 - Item 7) ____________

CCS7 Expansion Racks

9. CCS7 expansion racks (per table below): ____________

CCS7 TSUs (Item 4)	Expansion Racks
1	1
2	2
3	2
4	3
5	4
6	4
7	5
8	5

CCS7 Port Card Requirements

10. V.35 interface (Item 1) ____________
11. DSO interface (Item 2) ____________
12. Processor cards (Item 10 + Item 11) ____________

CCS7 Port Interface Equipment

13. ITT Multirate DSU-A ____________
14. D448 PCM trunk carrier system ____________
15. DSO rate, data port, 56 kb/s ____________

WORKSHEET 2 Dimensioning I/O Port Equipment

QUANTITY

I/O Port Requirements Quantity

1. Quantity of additional

   RS-232C I/O ports (maximum 6) ____________

I/O Port Card Requirements

2. Craft/machine communication cards [(Item 1 ÷ 2), round up, × 2] ____________

I/O Terminal

3. Quality of additional ITT XTRA personal computers
   (printer, CRT, personal computer) ____________

WORKSHEET 3 STP Equipment Summary

ITEM	QUANTITY	UNIT LIST PRICE	TOTAL LIST PRICE (Quantity × Unit List Price)
Rack, TSU, or Card			
Power Distribution Rack (Always Required)	1	________	________
Magnetic Tape Rack (Always Required)	1	________	________
Common Rack (Always Required)	1	________	________
System Defense TSU (Always Required)	1		
Clock and Tone TSU (Always Required)	1		
Peripheral and Load TSU (Always Required)	1	________	________
Craft/Machine Communication Card (Worksheet 2, Item 2, Max. 6)	________	________	
DSN Rack (Always Required)	1	________	________
CCS7 Port Expansion Racks (Worksheet 1, Item 9)	________	________	________
CCS7 TSU (Worksheet 1, Item 4)	________	________	________
Interface Card V.35 (Worksheet 1, Item 10)	________	________	________
Interface Card DSO (Worksheet 1, Item 11)	________	________	________
Processor Card (Worksheet 1, Item 12)	________	________	________
CCS7 Port Interface Equipment			
DSU-A (Worksheet 1, Item 13)	________	________	________
D448 (Worksheet 1, Item 14)	________	________	________
DSO Data Port (Worksheet 1, Item 15)	________	________	________
I/O Terminal Equipment			
ITT XTRA Personal Computer (additional) (Worksheet 2, Item 3)	________	________	________
TOTAL LIST PRICE			________

WORKSHEET 4 STP Equipment Pricing Summary

VOLUME DISCOUNT RATE ____________________ %

Material

1. Total Material (List) (From Worksheet 3) $ __________
2. Total Material (System Level) = Item 1 × 0.7 $ __________
3. Spare Equipment = (No. Pkg. × Price/Pkg.) $ __________
4. Subtotal (Item 2 + Item 3) $ __________
5. Total Material (Volume Discounted) = Item 4 × (1-Discount) $ __________
6. Sales Tax = (Item 5 × Tax Rate) $ __________
7. Total Material = (Item 5 + Item 6) $ __________

Software Charge

8. Total Software Charge = (No. STP × RTU Fee) $ __________
9. Total Software Charge (Volume Discounted) = Item 8 × (1-Discount) $ __________

Engineering

10. Start-Up $ __________
11. CCS7 TSUs [No. TSUs (Worksheet 1, Item 4) × Eng./TSU] $ __________
12. Ports [No. Ports (Worksheet 1, Item 12) × Eng./Port] $ __________
13. Subtotal = (Item 10 + Item 11 + Item 12) $ __________
14. Total Eng. (Volume Discounted) = Item 13 × (1-Discount) $ __________

Installation

15. Start-Up $ __________
16. CCS7 TSUs [No. TSUs (Worksheet 1, Item 4) × Inst./TSU] $ __________
17. Ports [No. Ports (Worksheet 1, Item 12) × Inst./Port] $ __________
18. Subtotal = (Item 15 + Item 16 + Item 17) $ __________
19. Total Installation (Volume Discounted) = Item 18 × (1-Discount) $ __________

Total Price

Material (Item 7) __________

Software Charge (Item 9) __________

Engineering (Item 14) __________

Installation (Item 19) __________

Total = (Item 7 + Item 9 + Item 14 + Item 19) $ __________

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

There has been a significant international effort to develop standards for Integrated Services Digital Networks (ISDNs) at the same time that events leading to the divestiture of the American Telephone and Telegraph (AT&T) Company were occurring in the United States. The ISDN standards activity continues with end-to-end digital connectivity providing the basis for a myriad of new services for home and business as the objective. The divestiture has resulted in changed telephony markets and new network architectures for the Public Switched Telephone Network (PSTN). This report describes the PSTN operating structure as it existed prior to divestiture and as it now exists with new routing schemes, equal access principles, and Local Access Transport Areas (LATAs). Eight central office switches that are now, or have the potential to be, part of the new market and network structure in United States are also described. In essence, this report deals with the networks and switches that exist in the post-divestiture period and will become part of the anticipated ISDN era.

Key Words: access tandem; CCITT Signaling System No. 7; central office switches; circuit switching; common channel interoffice signaling (CCIS); common channel signaling (CCS); Dynamic Nonhierarchal Routing (DNHR); end office; equal access; Integrated Services Digital Network (ISDN); Local Access Transport Area (LATA); local office; Public Switched Telephone Network (PSTN); stored program controlled (SPC); tandem switch

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