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A COMPARATIVE ASSESSMENT OF WESTERN AND SOVIET DIGITAL SWITCHING TECHNOLOGY (U)

Draft Report No. M2011 ✓

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Section 1

(U) INTRODUCTION

This report presents a description of current and future digital switching technologies in the Western World and in the Soviet Bloc countries, as they apply to command and control networks. A complete set of references is provided at the end of the report. Each reference is identified in the text.

The first part of the report discusses the basic structure of a command and control system. This part is concerned with the structure of a common carrier network and a user network, and the transmission, switching and control of each network.

The second part of the report discusses the particular ____________ network that is the subject of this study. This is followed by a general discussion of switching technology, details of present and future switching technologies both in the Western world and in the Soviet Bloc world. Three specific areas of switching technologies that are discussed are circuit switching, packet switching, and computer switching. Lists of switching components are provided.

The final part of this report discusses the requirements and assessment of Soviet technology in the command and control of their networks. This part describes the requirements, key technology issues, Soviet derived and acquired technology for the next 10 years.

Section 2

(U) BASIC C^3 NETWORK STRUCTURE

A command and control system consists of two basic networks; namely, end user networks and common carrier networks. Each end user network has its own related communications network which in turn may rely on other common carrier networks. The basic end user network, whether data or voice, involves the interconnection of multiple facilities using either a point-to-point star or mesh configuration. Rerouting of the information in the end user networks is done by switching at the users facilities using dedicated alternate routes and/or by switching and patching at the common carrier facilities. Networks can consist of several layers with one common carrier network a subset of one or more other networks. The Soviet network, the subject of this study, is an end user network which makes use of common carrier facilities.

2.1 Common Carrier Networks

Common carrier networks have evolved over the years from manually routed analog systems to computer routed digital systems. This evolution is still in process with most if not all networks using hybrid systems. The driving factors that cause the old style network to change vary from country to country as well as between service companies. The two main technology areas, an all digital transmission system and a computer based network control, are not directly related, and can be implemented separately. For common carriers with a heavy investment in an analog transmission system the drive would be to first automate its routing for network management and reconstitution. Where toll circuits operate over long distances, digital transmission can be used to improve the quality of the communications without having to change the analog switches.

2.1.1 Transmission

The change from an analog transmission plant to a digital one requires a considerable investment in hardware [1]. It cannot be done in a casual way, because too many transitions between analog and digital trunks will produce an unacceptable noise level on the circuits. The main driving force for digital communications is the better quality at lower costs. Digital communications are also more easily maintained and reconfigured than analog. Digital communications are more likely to be used on circuits that are very long instead of short ones where the A/D noise on the digital circuit can be more than that of the existing analog circuits.

Whether or not fiber optics is used in a network is primarily a cost issue. If there is an installed base of other types of media such as radio or coaxial cable, then the tendency is to upgrade those first before installing fibers. Within the United States there is a major move to install fibers (except for AT&T which has a major investment in radio relay systems that they are upgrading to digital [2].) The developing countries are using more fiber than radio because they do not have a basic investment in any major toll systems. Radio systems are favored in some countries that have remote or mountainous regions due to the problems of maintaining long cable or fiber routes. However, the costs of installing fiber is dropping and by the early 1990s most all new toll transmission systems will be fiber, with radio and satellite systems confined to specialized markets [3], [12].

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[redacted]

There are presently few, if any, new long distance cable systems being installed except in the bloc countries. In the bloc countries new long distance fiber systems will likely start appearing by 1990 as they develop the capacity to produce the high data rate electronics required by the fiber systems [30].

2.1.2 Switching

The western world had their analog systems automated before the digital movement began [6]. As an example, ATT had the number 4A-ESS computer controlled switch before the number 4E-ESS was placed into service in 1976. The trend in the bloc countries, particularly in the Soviet Union, is to upgrade their existing analog systems to get an automated control network in operation before moving to all digital transmission.

The first part of a network usually to receive digital matrix switches is the subscriber or PABX level, while the toll (tandem) levels usually wait for the transmission to become digital. Once a major part of the toll transmission plant has been converted to digital, it is practical to convert the toll switches to a digital matrix instead of an analog type.

Today there are very few switches built in the western world that are not digital. Most switch development work presently is at the class 4 and 5 office (subscriber) level, but there is very little difference between digital switch types. The same basic digital switch is being used as a PABX, central office and tandem switch [4]. However, the new tandem switches do not have the major control systems that the older switches had. The new switches are moving toward a separate network control system using standard hosts and common channel signalling, thus reducing the amount of control capability each toll switch has to have.

By the late 1990's the digital matrix tandem switch will be combined with the multiplexers and distributed throughout the transmission system. The entire network will then be operated under a unified control system [5].

2.1.3 Control

The control of a switch, as well as of a network, was very limited until computers were added to the systems [9], [41]. Without the computers, functions were limited to simple operations with manual intervention when something went wrong. Users also were required to have detailed knowledge concerning the methods of routing their calls. Computer control of switches began with the analog matrix type and was carried over to the all digital switch [6]. Most of the control functions can be used with either an analog or digital matrix switch. As discussed above the trend now is to separate the control function from the switch. This is being accomplished by establishing separate signalling channels and control centers. This allows the path of the control information to be different from that of the users' communication [7], [39]. These new control centers are computer serviced by distributed data bases which permit the network to dynamically route calls based on such factors as network loads, circuit outages and customer requirements.

2.2 User Networks

User networks have evolved from the PABXs which were interconnected by lines leased from the common carrier networks. This technology remained much the same until the introduction of stored program controlled switching allowed these PABXs to control how the calls are routed as well as the capability to control other switches in the common carrier networks [8], [23]. The technology of the 1970s led to the establishment of packet switched networks for data [9], [40], and now in the late 1980s these two concepts (stored program controlled switching and packet switching) are being merged into the ISDN network [10], [11], [46]. In addition to the developments in the communications industry, the computer industry has established its own set of data routing (switching) systems [15]. These at first were only for the local area around the main host, but now technology is providing ways of interconnecting these local networks into wide area ones through the common carrier networks [9], [15], [21], [22].

2.2.1 Transmission

While the technologies in this area are the same as for common carrier networks, the employment of the transmission is somewhat different. The use of fibers is much more advanced in these networks because of the ease of installation and bandwidths they provide. Fibers are being used for building, campus and public subscriber networks [14], [18]. Existing western technology is sufficient to permit the use of fibers and related digital modems and multiplexers to be used for present users' requirements. Even in the bloc countries fiber is being used in these user networks, but advanced networks are limited by the lack of adequate microchips for the modems and multiplexers.

2.2.2 Switching

The switching in the user networks is more diverse than in the common carrier networks. It involves capabilities for many different types of information. Three basic types of switches are usually found in user networks. The first is the standard telephone voice switch, the second is the packet switching of data [8], [9], [13], [23], [40], and the third type is the switch used by the computer industry [15], [28]. The technology trend for the voice switch is to change it into a dynamic bandwidth switch which can handle all types of information [37], [39]. The packet switches are being pushed to higher data rates and more throughput. For the present, the packet switch is used for data rates below 56 Kbits and the circuit switch is used for data rates above 56 Kbits. This is rapidly changing with the use of packet switching at the 1.5 Mbit rate, but the packet technology probably will always be used at the lower data rates with respect to the circuit switched technology [16], [17]. The ISDN efforts are working to unify these two technologies and many of the end user switches are a hybrid design using both the packet and circuit switch technologies [36], [46]. While independent computer related technologies are still being developed, there are more efforts now to combine them with the communications industry technologies [15].

2.2.3 Control

Control of user networks is rapidly developing as the user and the communications supplier are integrating their control systems [7]. Common channel signalling and ISDN are part of this effort [38], [46]. When digital processors were added to the PABX the user became able to control the routing of his own voice (and data) communications [23]. Private packet switched networks have grown rapidly since the late 1970s which has led to the development of network control systems for them [24], [39]. The trend for the user networks is that of the common carrier network except that their networks are not as large or diverse in requirements.

Section 3

(U) ________________NETWORK MODEL

The main focus of this part of the study are the data and related voice networks which support the ____________________ command and control system. Both these networks are of the end user type and employ various forms of communications including common carrier circuits. The data network appears to use low speed circuits in the 1200 baud range. The use of these low speed circuits implies that there is a considerable amount of front-end processing. The use of data rates in the order of 1200 baud permits the data to be routed over standard voice channels of the common carrier network. These channels can be either the digital or analog type. The basic user network structure is also not well defined and could be of several types. The most basic type of network would consist of dedicated circuits interconnecting the various processing centers. This type of configuration probably would rely on the computers at the centers to route the information. The network also could use some form of packet switching instead of the computers. In either case the common carrier system could easily reroute the data circuits since they would appear to the network as standard telephone circuits using baseband modems. The related voice communications would use PABX switches at the user facilities and probably dedicated circuits between them.

In this arrangement the PABX switches would be responsible for the routing of the traffic. They could also work with the common carrier network in the routing and reconstitution functions.

The ____________________ common carrier network starting in the late 1970s has been reconfigured into a system that is similar to the United States toll network. It consists of a unified network using standard analog voice circuits for voice and data with rates up to 1200 baud. It is a multi-layered system of switches and transmission facilities extending across the entire country. Its structure basically follows the CCITT guidelines for telecommunications network architectures. Figure 1 shows the top two layers of this network that is called the MOC network. There is a third layer for the metropolitan (city) networks which access the national network through the AMTS switches of the regional network. A call placed through the three layers of this system cannot go through more than twelve switches (or eleven transmission segments) as shown in Figure 2.

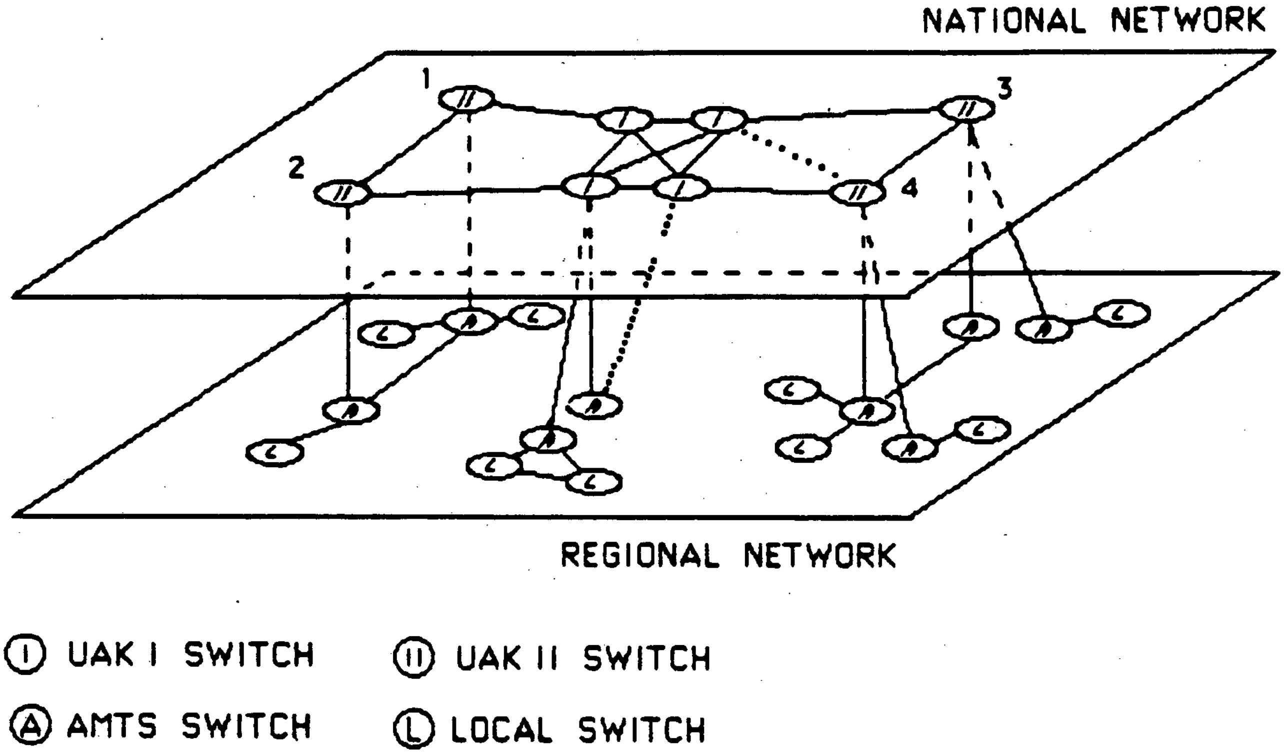

Figure 1. (U) National/Regional Network

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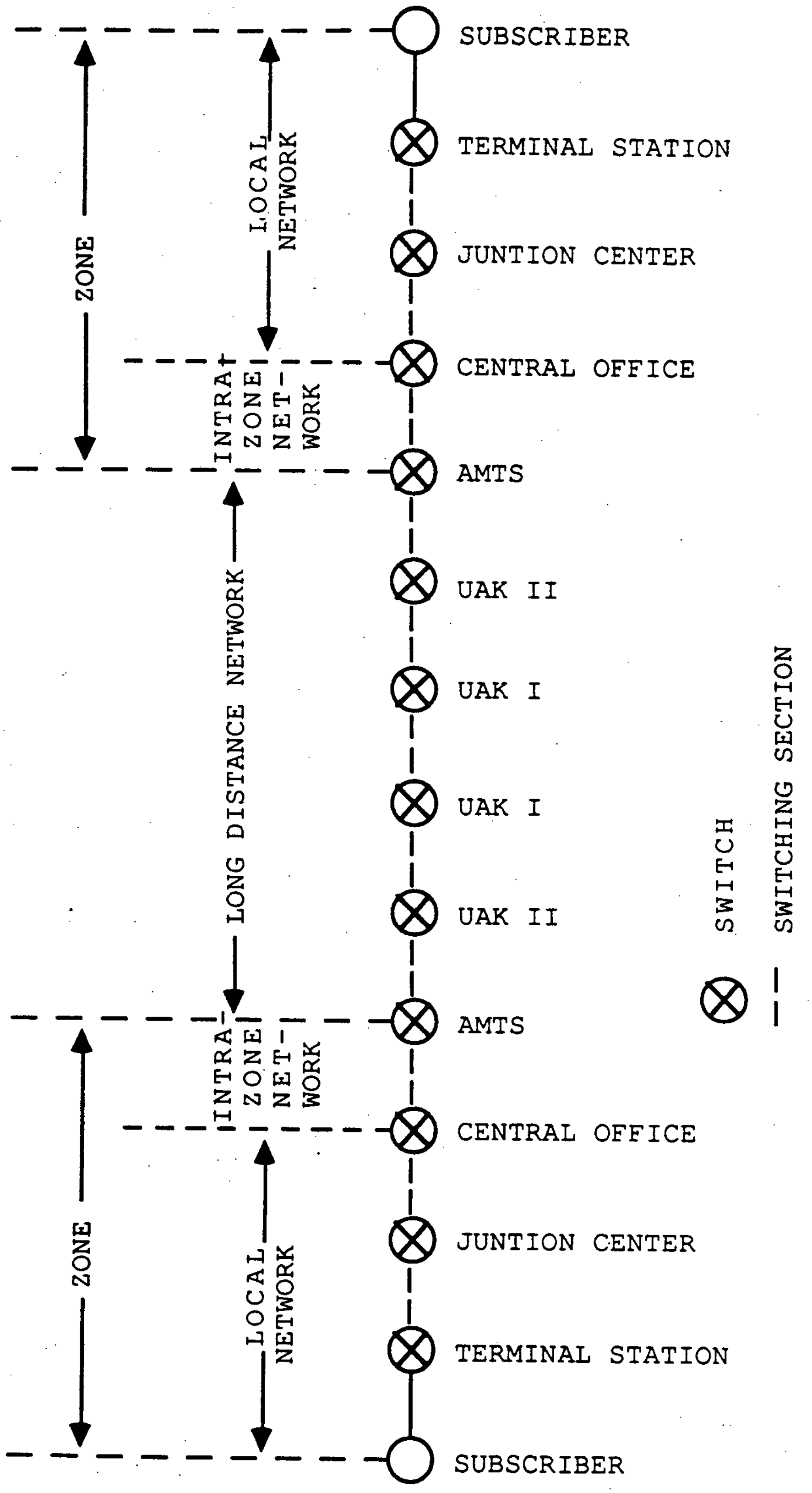


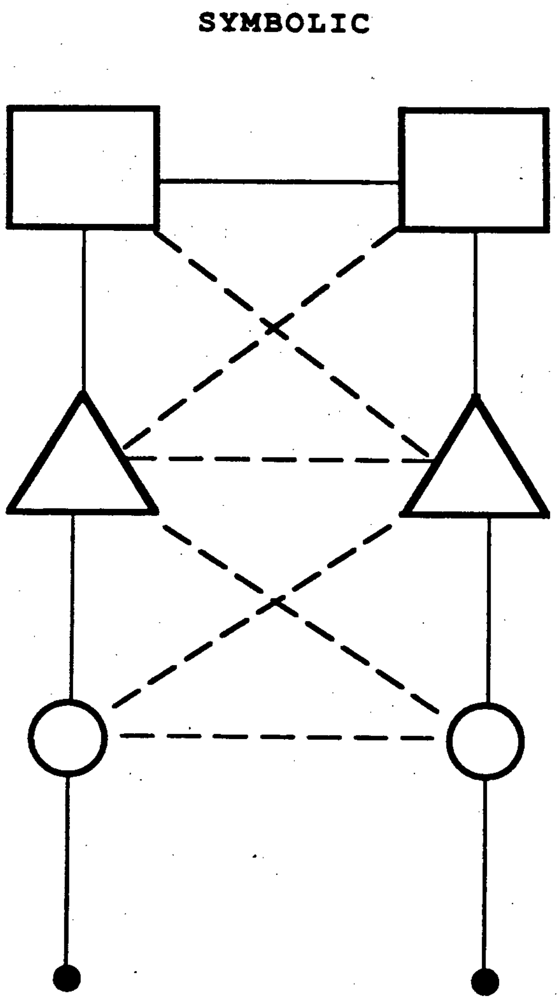
Figure 2. (U) Soviet MOC Network Switching

The _______________ has been divided into about 300 area codes which are represented by three digit codes. These are used with the subscriber numbers, which are all being converted to seven digit numbers, to select a particular subscriber. In Figure 1 these 300 areas are represented by the AMTS switches. Each area will probably have one or more AMTS switches within its boundaries. An AMTS switch will serve many local exchanges within the regional and metropolitan networks. Within the CCITT exchange structure the AMTS similar to the group (primary center) is shown in Figure 3. The AMTS switches are connected to one or more national level (UAK) switches. There will be a primary route, which is indicated by the solid lines of Figure 1, and probably a secondary route which is indicated by the dotted lines. Within an area there may be special AMTS switches for supporting the government's private exchanges. These special AMTS switches will also be connected to a respective UAK switch.

The national (YeASS) network is divided into 16 regions which are served by a UAK II switch. These are interconnected by a central hub which is made up of a number of (possibly six) fully interconnected (UAK I) switches. The UAK I switch does not serve a region, but only serves to interconnect the UAK II switches. However, the UAK II switches can be directly interconnected (switches 1 and 2, Figure 1) where traffic and geography permit. A UAK II switch also can be connected to an alternate UAK I switch

(switch 4, Figure 1). A UAK switch will have one primary route and up to four alternate routes to the selected region. The national network transmission systems consist of both radio relay and cable using, in most cases, analog multiplexed channels. The control appears to be in-band signalling between the UAK switches. The UAK (YeASS) switch has been configured for standard voice and data up to 1200 baud.

The above user networks are carried in the national network as shown in Figure 4. Since this traffic is separate from the commercial traffic it may not be switched by the UAK centers (shown by the heavy vertical lines). It enters the network in many cases at nodes that are only multiplexing points. It is not necessary for it to enter through an AMTS switch if the circuit uses a fixed route. However, if the user's PABX or data switch has the capability of an AMTS switch it could control the UAK switch directly. It would make it easier to reroute these circuits if they were able to be switched by the UAK centers. These centers have been designed to provide the capability to reconfigure the network due to traffic overloads and damage. While the system uses analog transmission, it still can employ the newer common channel signalling and control systems. This would greatly enhance their ability to reconfigure the network. The present AMTS-4 switch is an analog crossbar switch with inband signalling. It has a stored program capability, but all of its capabilities are not well understood. The newer switch for this function has gone to common channel signalling and possibly an improved control system. It is still an analog switch using reed relays.



INDUSTRY STANDARD (CCITT) DESIGNATION	SOVIET MOC DESIGNATION
DISTRICT (TERTIARY CENTER)	UAK I
ZONE (SECONDARY CENTER)	UAK II
GROUP (PRIMARY CENTER)	AMTS
LOCAL (TERMINAL EXCHANGE)	ATS

Figure 3. (U) Soviet MOC Network Hierarchy

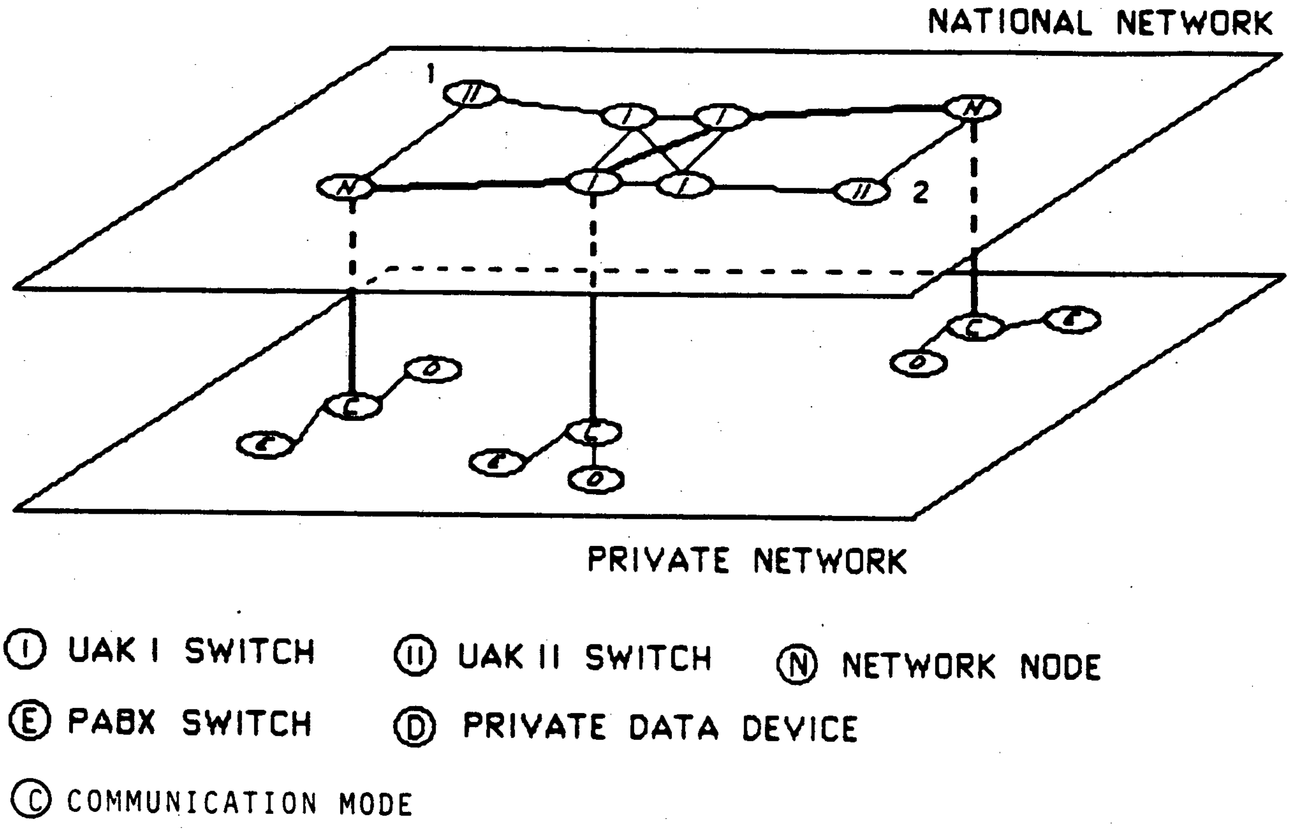


Figure 4. (U) National/Private Network

Section 4

(U) SWITCHING TECHNOLOGIES

For the purpose of this study switching technologies are divided into the areas of circuit, packet and computer. The computer switching area is considered separately because it is being approached differently by the computer industry [15]. The circuit and packet technologies are based on the telecommunication industry. Table 1 shows the general developments in transmission, switching and control for the United States telecommunications.

TABLE 1

US TRANSMISSION, SWITCHING, CONTROL CHARACTERISTICS

YEAR	TRANSMISSION	SWITCHING	CONTROL
1930	Baseband Analog	Manual	Operator
1940	Baseband Analog	Step X step	Implied (user)
1950	FDM Analog	Crossbar	Electronic logic
1965	FDM Analog	Reed relays	Computer
1975	PCM Digital	Packet (data)	Computer
1980	PCM Digital	Digital	Special computer
1985	Fiber optic	Digital	Common channel sig.
1990	1 Gbit fiber	Distributed	Separate control sys.
1995	ISDN (dynamic BW)	Optical	Separate EO control system

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4.1 Evolution of Switching

Telephone networks began with switchboards and copper wire. Each line was a hard copper path for the information which was changed by patch cords. The first change came with the introduction of the electromechanical selector switch controlled by electric pulses from the subscriber telephone. The routing of the telephone call was controlled by the numbers dialed by the subscriber. Since there was no automatic route selection capability in those early days the interconnection of these exchanges was accomplished by the dialing of access codes . The transmission system was also limited to a pair of wires per call. Later advances introduced audio amplifiers in the circuits between exchanges, but the subscriber had to be within a limited distance from the exchange due to the direct current control of the selector switches.

The analog system lasted well into the 1950's when digital systems began to make their appearance in the control of these very complex switching machines. The digitally controlled systems used cross bar switches instead of selector switches and had automatic route selection which did away with the access code. Each switch could check a number of different routes for the subscriber. Interoffice lines were now using various analog multiplex schemes and had developed an extensive toll network to interconnect the local offices.

The private users' network during this time had developed in a manner very similar to the public network. However, very few had dedicated long distance lines because of their cost. Most of the private systems were confined to a local area. The data networks by the 1950's were also getting automatic switching, but they were still limited to the standard teleprinter systems. The 1950's also saw a rapid growth in radio relay systems and the start of coaxial cables. These items marked the start of good quality and inexpensive long distance circuits. The information was still carried in an analog format.

Digital electronics began to appear in the telephone systems in the 1950's, but was limited in use to its control of the switches. By the 1960's there were a few low capacity digital transmission links. Technology in telecommunications had reached a plateau. Digital circuits using vacuum tubes or discrete solid state components were not cost effective.

The introduction of the microchip made it possible to do away with the old mechanical switch matrix and use an all digital switching approach. It also gave the control processor more power and capability. However, the digital transmission was held back because of the low operating speed of the early microchips. As the speed increased digital multiplexers were able to operate at higher and higher speeds and be produced at lower cost.

In the 1970's digital technology was rapidly emerging and the next problem was to integrate it into the existing analog networks [49], [50]. This integration process was not uniformly achieved because each country and network are actually governed by different and various factors which are not all technical. Such things as present investment, overall costs, type of system philosophy and the politics are factors that affect the potential conversion to a digital network (the technical factors are the same across all networks).

Technically, the two factors to be considered in analog versus digital disciplines are the digitizing noise and the loss of the number of information channels compared to analog multiplexing. The use of fiber optics and the improved modulation schemes such as 64 QAM reduced the number of information channels lost, but the digitizing noise still has to be considered on a case-by-case basis.

The digital switches first started to appear in the end office level because of the increased features they offered the subscriber. They were also smaller and permitted the expansion of the capacity of these offices without having to expand the buildings. The end office level also included the PABX for private exchanges [8], [23].

Digital multiplexing began in two areas. One area involved the trunks for the end offices and the other area involved the very long distance circuits where digital transmission improved the channel signal-to-noise ratio because of its ability to be regenerated instead of amplified.

The development of digital transmission proved to be more important than fiber optics in improving the quality of a network and reducing its operational costs. The use of computers in network control also produced major changes in services and network utilization [9]. Computer control can be applied to both analog and digital networks [7], [39], [41].

By the 1990's there will be much more distinction between the regional networks and the long distance ones [37]. The regional networks will be moving in a direction to integrate many new services into the basic telephone offerings through ISDN [36], [38], [42], [43]. The local carriers will vigorously pursue the increased bandwidth capabilities by handling data rates of 90 Mbits to every subscriber using fiber optic lines [26]. Switching will probably be distributed throughout the network and be of both the packet and circuit switch types. Channels will be allocated on both a time and bandwidth (or service) basis [5], [45]. Network control will be handled separately and will permit the customer many more options. The long distance networks are already developing separate network control systems which allow the customers to configure their service features. During the 1990's optical switches will start replacing the digital switch matrixes [19], [27].

4.2 Present Technologies

Digital technology has created new opportunities for innovation including the integration of digital transmission and switching, the combination of voice and data services in one switching entity, and the design of switching systems which are economical over a broad range of sizes.

In the strict sense, the term "digital switching" refers to a system which establishes a message channel between two terminals where information is represented in digital form. In more common usage a digital switch usually contains a time-divided network composed of logic gates and digital memory to accomplish the switching function. Two major techniques are involved in implementing time-division switching. These techniques are time-slot interchanging (T-stage) and time-shared space division (S-stage) switching. In constructing networks, the architecture may contain T-stages, S-stages or a combination of both. Details are described in McDonald (1983).**

For the Soviet Bloc, the procedure followed to assess the current status of digital switching technology was first to identify relevant documents in the Defense Technical Information Center (DTIC) on-line data base. Secondly, selected documents were located and/or obtained. In general, the identified documents were difficult to obtain; however, personnel at the Defense Intelligence Analysis Center (DIAC) provided for onsite viewing of several potentially relevant documents.

Romanov (1982)** provides a trip report on a visit to the "International Specialized Fair Systems and Means of Communications - 'Svyaz'-81." He describes exhibits of digital transmission systems that were displayed by the following countries and respective firms: Hungarian Peoples Republic (HPR), (Vudavox Firm); German Democratic Republic (GDR), RFT; Italy, Marconi Italiana; Finland, Telenokia; France, CIT Alcatel; Federal Republic of Germany (FRG), AEG Telefunken; Yugoslavia, Elektronska Industrija; Japan, Nippon Electric Company.

On page 2 of the above reference Romanov states, "The interest of the specialists was aroused by equipment of the primary digital transmission systems with the use of single-channel codes, realized on large-scale integrated circuits (BIS) which is one of the latest achievements in the technology of digital transmission systems." This probably indicates that the USSR does not have such large-scale integration (LSI) available. On the other side, the existence of such a trade fair could mean that the Soviets can purchase digital transmission equipment from the vendors.

Romanov (1982)** continues, "In the equipment of the primary digital transmission system of a number of countries (HPR, GDR, Finland, etc.) it is planned to use devices which ensure the joint operation of digital transmission equipment with switch stations. The greatest interest in this respect lies in the matching devices' unit DS30, which was developed in Finland. As a result of its use in a processor for control of the matching devices it ensures the interaction of PCM-30 equipment with switching stations of different types, and the matching devices of the DS30 unit can operate simultaneously on different algorithms with different signalling systems."

Additionally Romanov (1982)** describes optical digital line circuit equipment (16, and 896 Mbit/sec.) using GaAs diode lasers which were displayed by the GDR. An optical digital line circuit with a transmission rate of 34 Mbit/sec. was displayed by the Japanese.

The digital communications system DIKOS (FRG) was of interest. It ensures the bringing up to the subscriber of a switching digital channel with a carrying capacity of 32, 64, or 128 kbit/sec. The coding of the telephone signal is done by delta-modulation with digital companding.

Romanov's final paragraph is particularly revealing as to the status of digital switching technology in the Soviet bloc. Romanov (1982)** states, "In conclusion it should be noted that the communications administrations of the leading capitalist countries (USA, Japan, Great Britain, France, Canada) have made the decision of the primary introduction of digital transmitting and switching equipment in the communications networks. The possibility of using single-channel codes in digital transmission systems considerably facilitates the supplying of the digital channel to the subscriber, which in turn makes it possible to organize a number of new communications services." This seems to indicate that there is essentially no such service at the time of **his** writing, which was around 1981-1982.

4.2.1 Circuit Switching

For circuit switching applications, ICs are replacing discrete components in many applications. ICs, or chips, can be placed into three broad categories: Logic chips, memory devices, and microprocessors. Logic chips contain circuits that process, convert and direct electronic signals in predetermined patterns. These circuits are designed to perform specified tasks and functions, upon request, by an appropriate electronic signal. Peripheral logic chips are also used to manage interconnections between the various elements of an electronic system. Memory chips store data and commands for processing activities. Microprocessors combine logic and memory functions on a single chip.

Logic chips account for the largest segment of the IC market. These chips are silicon-based circuits. The greatest users of logic chips are the computer and communications industries, which together consume about 40% of the total world output. (Davidson, 1984.)**

Memory chips find wide application in message switching, where information is transmitted from node to node in a block message transfer approach.

Memory products accounted for about one-third of the total IC market in 1982. This market can be further segmented according to the type of process technology used in creating memory products and the type of memory product. The three main technologies are also the three principal processes used to produce logic chips. The three techniques are known as bipolar, MOS (metal oxide semiconductor), and complementary-MOS or CMOS. The bipolar technique is the original process used to produce adjacent positive and negative charged areas in a silicon substrate. Current flowing from a positive "emitter" to a negative "collector," or vice versa, activates semiconductor circuits for logic or memory purposes. The MOS approach differs in the use of a "gate" between charged areas. When the current flow through the gate reaches threshold levels, the circuit switches on.

MOS devices are superior to those produced by bipolar techniques in terms of density and power requirements -- two critical performance criteria for semiconductors. MOS technology dominates the memory area, accounting for about 75% of all memory devices. CMOS technology permits the use of a single charged area as both the emitter of one circuit and the collector for another, and thereby dramatically reduces power usage of the chip. CMOS chips are particularly useful in battery-powered applications.

The four principal types of memory product applications are: (1) random access memory (RAM), (2) read-only memory (ROM), (3) programmable ROM or PROM, and (4) erasable PROM or EPROM.

Microelectronic chips that contain nearly a half-million circuit elements and which are hundreds of times faster than currently available devices are being developed for a wide range of uses. The first Very High-Speed Integrated Circuits (VHSIC) are made using photolithography and have device geometries as small as 1.25 micrometers.

The importance of microprocessors lies in their major cost savings for digital switching. Equally important is the role microprocessors play in making remote, unattended switching possible. Finally, microprocessors are a major driver in future distributed switching architectures.

4.2.2 Packet Switching

Packet switching was originally created to serve a class of users primarily concerned with the transmission of data. The characteristics of this user group is typified by bursty transmissions to other data users or host computers with the possibility of long delays before a response is returned. It was not cost effective to establish a permanent virtual circuit for this type of user. Therefore the X.25 protocol was established for connecting asynchronous terminals to other terminals or host computers over a network based on packets. Because each packet contained address and protocol information as well as the data the possibility of connecting literally thousands of terminals and computers over a single network exists. The user then only requires time on the network for the length of his data request and when the receiving station returns a response.

The type of users and data now sent over packet switch networks is increasing daily due to the higher packet through put rates, the establishment and enhancement to the various levels of protocols, and the proliferation of other digital services that can be integrated into a packet switched network.

The major impediment to packet switch networks was the establishment and refinement of protocols at several layers and the development of vendor hardware. The government sponsored APRANET and private research have been successful over the past decade and a half at developing very sophisticated networking protocols and extensive, diverse hardware. This has led to packet switch networks now serving a wide array of users for every application imaginable. Private companies, institutions, government agencies, and telecommunications companies have established and operate packet switched networks running over in-house local area networks, regional teleco lines, and international networks.

The major protocols associated with packet switching are:

-X.25: network protocol
-X.3: packet assembly/disassembly (PAD)
-X.28: Data Terminal Equipment (DTE) to PAD protocol
-X.29: PAD to host protocol
-x.75: Intranet interconnection protocol for packet switch networks

It is the interworking of the above protocols that allows for the wide variety of terminals and host computers to be networked. Due to the variety of terminals and computers it also took a very long time to establish and refine the protocols so that the interconnections could take place. Once the protocols had been established the hardware vendors began to produce an extensive selection of equipment for packet switching. Currently there are several options for implementing packet switching:

- -smart terminal with all protocols resident
- -stand alone PAD serving one to several terminals
- -PAD integrated into an on premise PBX/CBX
- -PAD integrated into and offered by a regional telephone company switch
- -PAD and network offered and run as a value added service by a third party

By having all protocols resident within a terminal a user may access any available PSN through a standard modem connection and with proper authorization. This consumes the memory and power of a terminal and may not be the most efficient implementation. This led to stand alone PADs that interact with several terminals thus becoming the access point for multiple users into the PSN. Eventually the stand alone PAD was integrated into the switch, whether it be a PBX or Class 5 regional switch. This allowed users simply to call the PAD number on the PBX and gain access to the PSN. This also allowed access to multiple networks by having numerous PADs on the switch, each serving different PSNs. Finally, by integrating the X.75 protocol into major gateway switches a user can reach practically any other user in the western world who is also connected through a major gateway.

The advancement in protocols and hardware has freed network designers from the typical point to point circuits and even from the number of users on the network. Network designers can consider any public switch as part of his network topology. This is primarily due to the high reliability of packet transfer that has been established due to network control and packet accounting procedures that have been developed. Lowest cost routing algorithms have been combined with node switch traffic loading algorithms to allow for a free flow of packets across the country by multiple routes. This means that sequenced packets from one user may not take an identical path enroute to the addressee. This has eliminated single points of failure within the system, which, of itself has major military implications.

Future trends in packet switching will be towards better integration of the various packet switched networks and in the streamlining and refining of protocols to allow for easier terminal access to the network. Also the capacity and processing speeds of the hardware used for packet switch networks is rising rapidly. This will lead to other types of services being offered or used over the PSNs. These services will include packetized digital voice and packetized digital slow scan video. The packetized voice is possible due to the high packet through put rates. This allows packets to be transferred and reassembled at a rate fast enough to pass voice traffic.

Soviet and East Bloc countries are currently researching and implementing PSNs at a very basic level. Current efforts may be equated to what the ARPANET was 10 or more years ago. All though the mathematics of network control and control/interface protocols are open source, it is the hardware implementation that is and will remain to be a major stumbling stone. To have a diverse, robust collection of intraconnected PSNs requires sophisticated micro-processor controlled hardware for implementation. No East Bloc country has the plant capacity nor the advanced capability to produce microprocessors in the quantity or quality necessary for systems similar to the Western Nations. PSNs that are established will be for specific users (Ministries, special defense, KGB), be tightly controlled (security paranoia), and be constrained in their network topology. An effort on the level of the US's JTIDS is unforeseeable. Even if the production and quality of micro-processors was significantly upgraded the competition between user entities for these components is so great that the communications faction within the Eastern Bloc would still not obtain required hardware to implement any major intraconnected networks.

4.2.3 Computer Switching Technology

Communications between computers and other machines is being developed using a set of standards formulated by the International Standards Organization (ISO). The standard network model used is a local area network (LAN), defined as a communication system to interconnect different computers, terminals, and office machines in a geographically bounded area for the purposes of resource and data sharing [15].

Communications hardware is reasonably standard and presents few problems. However, when communication is desired among heterogeneous (different vendors, different models of the same vendor) machines, the software development effort can be a nightmare. Different vendors use different data formats and data exchange conventions. The task of communicating in a truly cooperative way between different applications on different computers is too complex to be handled as a unit. The problem, then, must be broken down in manageable parts.

In 1977, the ISO established a subcommittee to develop a layered architecture. Communications functions are partitioned into a hierarchical set of layers. Each layer performs a related subset of functions required to communicate to another system.

Figure 5 defines in general terms the set of layers and the services performed by each layer.

FIGURE 5

(U) The Seven Layers of the OSI Protocols

LAYER	TYPE	DESCRIPTION/SERVICE
1	Physical	Concerned with transmitting unstructured stream over physical link; involves such parameters as signal voltage swing and bit duration; deals with the mechanical, electrical, and procedural characteristics to establish, maintain, and deactivate the physical link.
2 channel	Data Link	Converts an unreliable transmission into a reliable one; sends blocks of data (frames) with checksum; uses error detection and frame acknowledgment.
3	Network	Transmits data packets through a network; packets may be independent (dynamic routing) or traverse a preestablished network connection (virtual circuit); responsible for routing and congestion control.
4	Transport	Provides reliable, transparent data transfer between end points; provides end-to-end error recovery and flow control.
5	Session	Provides means of establishing, managing, and terminating connection (session) between two processes; may provide checkpoint and restart service, quarantine service.
6	Presentation	Performs generally useful transformations on data to provide a standardized application interface and to provide common communications services (examples: encryption, text compression, and reformatting).
7	Application	Provides services to OSI environment users (examples: transaction server, file transfer protocol, and network management).

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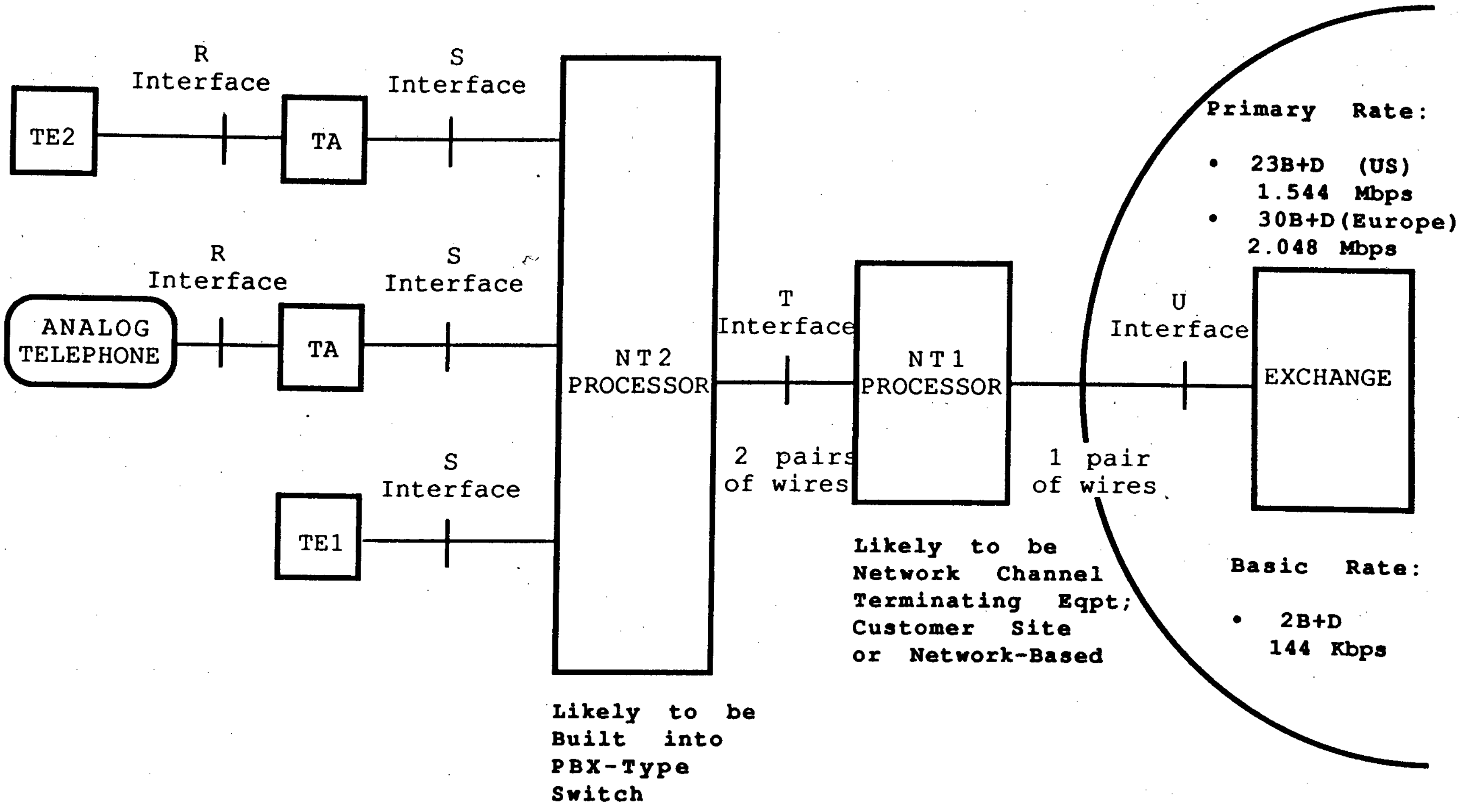
A global effort has been underway to establish a digital network to transport voice and nonvoice information as needed. The architecture of this network closely follows the OSI reference model and may be considered a prototype for the evolution of the OSI standards. It is called the Integrated Services Digital Network (ISDN). It provides end-to-end digital connectivity to support a wide range of services through a limited set of standard multipurpose user-network interfaces.

Figure 6, a representation of an ISDN functional block diagram, is provided for purposes of terminology and understanding. Four interfaces (R, S, T, and U) are shown. The "R" interface is between the non-ISDN terminals, such as analog telephones or terminals that do not conform to ISDN standard or terminal adapters. The "S" interface is between ISDN- compatible terminals or terminal adapters and the Network Terminal (NT)-2 processor. The NT2 will handle layer 1 protocols; i.e., getting the signal on the wire. The NT2 can act as a PABX and many terminals can be attached to it. The NT1 will handle the layer 2 and 3 protocols, with just one connection between it and the NT2. The NT1 will not be able to act as a PABX; it will go over the U interface to the central office. There can be several different network configurations.

Companies involved in component-building for this type of network are already selling them and setting up fabrication factories in other countries. The same is true of other switch manufacturers. Refer to Section 4.3.4. ISDN switches used as ordinary central office switches are currently in place throughout the world, specifically in the West and Japan. When ISDN truly becomes a reality, these switches could be easily converted to a complete ISDN system. The ISDN cutover can be expected to occur very quickly.



TE2 = **Terminal Equipment (non-ISDN Terminal)**

TE1 = **Terminal Equipment (ISDN Terminal)**

NT2 = **Network Terminal 2 (will handle Layer 1 Protocols)**

NT1 = **Network Terminal 1 (will handle Layer 2 and 3 Protocols)**

TA = **Terminal Adapter; connects the S/T interface to the non-ISDN but standard R Interface. Examples of the R Interface are X.25 and RS323C.**

Figure 6. (U) ISDN Block Diagram

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Because the data will be digital, it can be very easily encrypted. Data encryption standard algorithms are already developed. Two methods of encryption that are referenced by the Pacific Bell Company are the Product Cipher encryption method and the Cipher text encryption method.

Two types of ISDN switches are being designed: the stimulus response switch and the functional response switch. Northern Telecom is developing a stimulus response switch wherein the network intelligence will be in the switch. The switch will have the ability to block calls, transfer calls, and handle ISDN services. ATT is designing the functional response switch. This will be a "dumb" switch, with the intelligent part of the ISDN network to be located in other ISDN equipment. The rationale for these two designs is derived from the market sectors these two companies pursue. Northern Telecom is mainly in the business of selling central office equipment, while ATT primarily directs its business activities in telephone sales and other forms of terminal equipment.

The Japanese are very far ahead of the United States and Europe in digital communications. They did not wait for the CCITT to publish its recommendations to start work on their digital communications system. They first performed trials in Singapore in 1985, and are performing trials in the Tokyo area. Their first trial was to connect a suburb of Tokyo with the downtown area. The communications technology worked very well, and the problems they did have related more to providing the proper services to the right people. Some individuals received services they did not want, and others were not given services they did need. The national plan is to make digital communications available throughout Japan by the year 2000, through the Information Network System (INS).

The published difference between INS and ISDN is that ISDN focuses on the network structure while INS places more emphasis on usefulness to the user. General requirements for the INS user-network interface are the same as those identified for the ISDN: support for a wide variety of voice and nonvoice services, support of point-to-point, multi-drop and other multiple terminal arrangements, compatibility between calling and called terminals, and easy plug-in, plug-out operation. As currently configured, the INS model system serves approximately 400 digital telephone sets, 1,100 nonvoice digital terminals, and 9,000 analog terminals.

The NADIR Project is a French pilot-project jointly sponsored by the Ministry of PTT and the Ministry of Industry. It aims at fostering the use of satellite communications systems in the data transmission area. In particular, this project uses the TELECOM1 French satellite. This satellite offers three types of services: a military service, a telephone and television service, and an intracompany communication system service. The NADIR Project has several applications: a photograph broadcast application, a distributed Videotex mailing application, a distributed stock management application, and a file transfer link application. The photograph broadcast application is operational and the other applications are still under development. The project ended in December, 1985, but was continued under support of the Bureau d'Orientation de la Normalization en Informatiqque (BNI).

In checking with various sources - GTE's library, Mr. John Fields, a paper by Mr. Robert Golightly, and conversations with Dr. Horst-Edgar Martin of Siemens - the Eastern Bloc has done very little with respect to this type of networking. These countries are primarily still concerned with analog telecommunications. While the Hungarians and Romanians have done some work, it is very little compared to the rest of the world. The Soviets say they will conform to CCITT recommendations for the first three layers when they do get around to ISDN. They will use their own design for the other four layers.[53,54]

4.2.4 Components and Switching Systems

Table 2 is a list of the digital switching systems manufactured by the nations of the west. In Table 2, the system code, the country of manufacture, the type and source of additional information (in the form of a paper number or appendix identification) are given. The additional information refers to papers and/or appendices in Amos (1976), (1981).**

Table 3 is a partial list of 4.5th and 5th generation PBX's (private branch exchanges) taken from Joel (1985A, p. 494).

Table 4 is a list of three western military DSS.

Table 5 is a listing of the top suppliers of western central office switching equipment for the U. S. marketplace in 1984.

Table 6 is a listing of the top suppliers of toll switching equipment for the U. S. marketplace in 1984.

Table 7 is a listing of the world's leading semiconductor companies as of 1982.

TABLE 2 (U) LIST OF DIGITAL SWITCHING SYSTEMS +

SYSTEM CODE	COUNTRY	TYPE	PAPER OR APPENDIX +*
AFDT 1	Italy	Local/Toll	20
AXE 10	Sweden	Local/Toll	29/25*,B
D 1210	U. S. A.	Local	B
DCO	U. S. A.	Local/Toll	7,A
DMS 10	Canada/U. S. A.	Local	8,A
DMS 100	Canada/U. S. A.	Local/Toll	13,A
DMS 200	Canada/U. S. A.	Toll	12,A
DMS 250	U. S. A.	Tandem	B
DMS 300	Canada	Toll	B
DS 1	Japan	Tandem	B
DSC	U. S. A.	Local	B
DSS/1210	U. S. A.	Local/Toll/Operator	9,A
DTN 1	Italy (Sudan)	Tandem	B
DTS	U. S. A.	Tandem	B
DTS 1	Japan	Toll	28
DTS 2	Japan	Local	B
DTS 500	Netherlands	Tandem	B
DX 100	Finland	Local/Tandem	B
DX 200	Finland	Local	B
ENSAD	E. Germany	Local	23
EWS-D	W. Germany	Local/Toll	22
E10	France	Local/Tandem	20*/22*
E10 B	France	Local	16
E10 S	France	Local	B
E12	France	Toll	17
FETEX 150	Japan	Local/Toll	27
FOCUS 5	U. S. A.	Local	B
GTD 5 EAX	U. S. A.	Local/Toll	14
HDX 10	Japan	Local	26
IFS	Switzerland	Local	B
ITS 4/IMA2	U. S. A.	Toll	5,A
ITS 4/5	U. S. A.	Local/Toll	10,A
ITS 5A	U. S. A.	Local	B
I2000	Yugoslavia	Local	B
LCS 4/5	U. S. A.	Local	B
MSU	U. S. A.	Local	B
MT 20/25/35	France	Local/Toll	18
NEAX 61	Japan/U. S. A.	Local/Toll/Operator	11,A
NO. 3 EAX	U. S. A.	Toll	6
NO. 4 ESS	U. S. A.	Toll	4/6*,A
NO. 5 ESS	U. S. A.	Local	15
PROTEO	Italy	Local/Toll	19
PRX-D	Netherlands	Local/Toll	21
SPC 2	India	Local	B
SX8	France	Local	B
SX 2000	Canada	Local	B
SYSTEM X	U. K.	Local/Toll	25
SYSTEM 1(1210)	U. S. A.	Local/Toll/Operator	9
SYSTEM 12(1240)	Belgium/U. S. A. /W. Germany	Local	24
TDDSS 1/2	Rep. of China	Tandem	B
TN 5	Italy	Tandem	B
TP4/III	U. S. A.	Packet	N/A
TROPICO	Brazil	Local	B
TSS 5	U. S. A.	Local	B
UT 10/3	Italy	Local	B
UXD 5	U. K.	Local	B
1220/PCM-B	Belgium/France	Tandem	B

\+ Electronic Switching: Digital Central Office Systems of the World -- IEEE Press 1981

* Electronic Switching: Central Office Systems of the World -- IEEE Press 1976.

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TABLE 3. 4.5TH AND 5TH GENERATION PBX'S

After Joel (1985A, p. 494)

CODE	MANUFACTURER	DATE	CAP.	LOOPS	MAX. DATA RATE
20/20L	Harris	1984	1.9K	2	56K
3100	ITT	1981	1.4K	2	19.2K
5300	ITT	1981	352	1	80K
5500	ITT/STK	1977	10K	1	64K
ABSU501/MD110	Ericsson/Honeywell	1983	20K	2	19.2K*C
BX(I)	Rolm/IBM	1982	4K	2	19.2K
CBX II	Rolm/IBM	1984	8K	1	64K
D1200	Harris	1983	1K	2	9.6K
DAVID	David	1985	250	1	19.2K*
DIMENSION 2000	AT&T Technologies	1981	2K	2	19.2K
DIMENSION 75	AT&T Technologies	1982	800	2	19.2K
DIMENSION 85	AT&T Technologies	1983	7K	2	64K
DX50	Hitachi	1984	3K	1	56K
FOCUS	Fujitsu	1983	400	2	19.2K
IBX	Intecom	1982	8K	4	56K
IOX	Anderson/Jacobson	1984	1K	1	19.2K*
NEAX22	NEC	1982	.2K	2	19.2K
NEAX2400	NEC	1983	23K	2	19.2K*
OCS300	ITT/UK	1983	300	1	9.6K
OMNI	GTE	1983	2K	1	19.2K*
PNX	ZTEL	1983	10K	1	56K
ROSE	CXC	1983	12K	2	19.2K
SL 1	Northern Telecom	1982	5K	2	19.2K
SL1XN	Northern Telecom	1984	9K	2	19.2K*
SPECTRUM	OKI	1983	128	2	?
SX2000	MITEL/BT	1982	10K	4	19.2K*
TELENOVA 1	Telenova	198?	188	2	9.2K
UTC1001	United Technologies	1983	2.5K	2	4.8K

---

* also synchronous at 64K bits/second.

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TABLE 4 (U) LIST OF THREE MILITARY DIGITAL SWITCHES

SWITCH IDENTIFICATION	MANUFACTURER(S)	REFERENCE(S)
ZODIAK Switch	Philips Signall & GTE	Rineerson (1985)
AN/TTC-39 Circuit Switch	GTE	Gallagher (1979)
ABM 301 SPC Field Telephone Exchange	Ericsson	Anon. (1985)

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TABLE 5 (U) TOP SUPPLIERS OF CENTRAL OFFICE SWITCHING EQUIPMENT FOR THE UNITED STATES MARKETPLACE IN 1984

(From IEEE Spectrum, Nov. 1985, Centerfold)

COMPANY	HEADQUARTERS
AT&T Technologies, Inc.	New York, New York, U.S.A.
Northern Telecom	Mississavga, Canada
GTE Corporation	Stamford, Connecticut,U.S.A.
Plessey Telecommunications & Office Systems Ltd.	Liverpool, England
ITT Corporation *	New York, New York, U.S.A.
CIT-Alcatel, Inc. *	Reston, Virginia, U.S.A.
NEC Corporation *	Kawasaki, Japan

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* The first four companies contain the major market share.

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TABLE 6 (U) TOP SUPPLIERS OF TOLL SWITCHING EQUIPMENT FOR THE UNITED STATES MARKETPLACE IN 1984

(From IEEE Spectrum, Nov. 1985, Centerfold)

COMPANY	HEADQUARTERS
AT&T Technologies, Inc.	New York, New York, U.S.A.
Northern Telecom	Mississauga, Ontario, Canada
GTE Corporation *	Stamford, Connecticut, U.S.A.
DSC Corporation *	Richardson, Texas, U S.A.
ITT Corporation *	New York, New York, U.S.A.

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* The first two companies contain the major market share.

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TABLE 7. LEADING WORLD SEMICONDUCTOR COMPANIES' SALES (DISCRETE AND INTEGRATED DEVICES, 1982)

COMPANY	TOTAL ($ MILLION)
Motorola	1310
Texas Instruments	1227
Nippon Electric	1220
Hitachi	1000
Toshiba	810
National Semiconductor	690
Intel	610
Philips	558
Fujitsu	475
Siemens	420
Matsushita	340
Signetics (Philips)	384
Mitsubishi	380
Mostek	335
Advanced Micro Devices (Siemens)	282
Sanyo	260
AEG	196
Thomson-CSF	190
Sharp	155
SGS-ATES	150
Oki	125

SOURCE: Davidson (1984), p. 103

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While the relative order of ranking may have changed, the list in Table 7 is useful for identification purposes. It is important to note, however, that two of the world's largest producers of semiconductors do not appear in the 1982 table. IBM, the world's largest semiconductor producer, manufactured solely for internal usage. Western Electric, with 1982 production valued at almost $400 million, also produced solely for internal use at that time. General

Electric, GTE Micro Circuits, General Motors, among others, have significant production for internal use.

A review of what is known about systems and components in the Soviet Bloc countries follows.

Telefax and smart telephones have appeared in Hungary, but service remains limited according to a news item in Telephony, 23 September 1985, page 85.

.Pervyshin (1984) ** produced a book on the Soviet information transmission industry.

.Kleinau, et al. (1981) **discussed digital telephone networks and their problems, and Prager, et al. (1981)** authored a book on digital computer technology in communication.

.A compendium of standard terms and definitions in regard to Soviet integrated digital communication networks was published in 1978 (Anon. 1978.)**

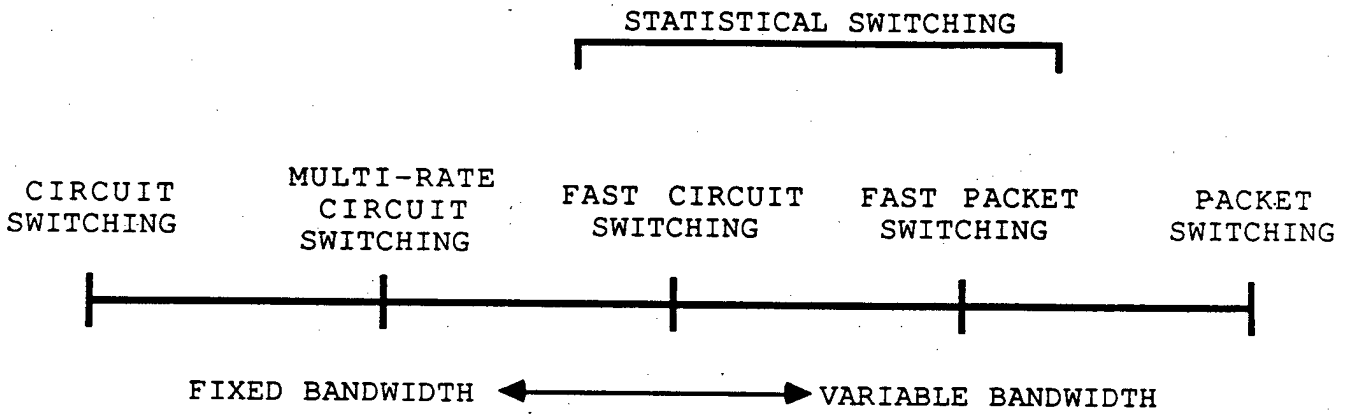
As far as the Soviet semiconductor industry is concerned, W.H. Davidson, who has recently completed a definitive study of the U.S. technorivalry with Japan, states: "The United States is engaged in a two-front war against specialized rivals. It competes with the Soviet Union in the military arena and with Japan and other nations in the industrial arena. The Soviet Union neglects its industrial activity to focus on military endeavors " (emphasis added). [Davidson (1984)**, page vii.]

The Soviet semiconductor industry is no exception. According to Melvern et al. (1984)**, there are numerous examples of Soviet block nations purchasing semiconductor and IC producing equipment (for example, the 1975 bankruptcy event of Hugle International (Melvern, et al., page 246))**.

4.3 Future Technologies

It is fortuitous, for the purposes of this report, that the Institute of Electrical and Electronics Engineers (IEEE) issued a special issue of their IEEE Spectrum in November 1985 on the future of telecommunication (edited by Edward A. Torerro, 1985). In the issue, Kaplan, senior technical editor, discusses the present and future of telecommunication services in Great Britain, Japan, West Germany, France, Italy, and China. These discussions include the potential uses of digital switching systems.

What are some of the options available to would-be designers of next-generation communications systems? Kulzer and Montgomery** (1984) discuss several possibilities, placing them in the spectrum shown in Figure 7. Techniques toward the right end of the spectrum provide increasing flexibility to handle variable rate information, but require more processing. The region near the center of the spectrum is labelled statistical switching and contains technologies that can transport bursty information streams without the full functionality of conventional packet switching.



- MULTI-RATE CIRCUIT SWITCHING
  - BANDWIDTH IN MULTIPLES OF BASIC RATE;
  - BEST FOR SMALL BANDWIDTH VARIATIONS;
  - NOT GOOD FOR BURSTY CHANNELS.
- FAST CIRCUIT SWITCHING
  - HYBRID (PACKET/CIRCUIT);
  - HANDLES BURSTY CHANNELS WELL;
  - REQUIRES SUPER-RATING FOR HIGH SPEED CHANNELS.
- FAST PACKET SWITCHING
  - STREAMLINED FORM OF PACKET SWITCHING;
  - SIMPLE PROTOCOLS AND SWITCHING SYSTEMS;
  - HANDLES VARYING BANDWIDTH ACROSS LARGE RANGE.

Figure 7. (U) Switching Technology Spectrum

The following paragraphs provide quotes from two Bell Laboratories experts in the field of digital switching about their views of the projections of digital switching technology in the West through 1995. The title and/or location of the persons quoted are at the time the statement was made.

a. Matthew F. Slana, of Bell Laboratories, Naperville, IL, stated:

"Digital switching makes use of the most advanced semiconductor components. Hence, new technological developments play a significant role in the development of the three major elements required for a digital switch - control, memory, and network fabric. Semiconductor technology is undergoing rapid changes with substantial effect on the design of these elements. For example, the control portion of the system is proceeding more and more towards a distributed architecture. Microprocessors are providing more flexible and intelligent peripheral controllers. Some form of central control will probably be retained but it will become more like a system manager. More of the diagnostic and maintenance functions may also be distributed on a per frame basis. Some overall maintenance and control functions will still be done by a central processor.

"Memories are becoming less expensive and faster. One problem which exists for time-division networks lies in the configuration of semiconductor memory components. The trends in chip architectures are toward larger word structures, such as 256K words by 1 bit, which are not useful for 128 or 256 time-slot systems. These systems need 256 x 8 or 256 x 10 memory structures. Technology trends toward faster memories will lead to more time slots per channel.

"Similar trends help the network fabric. Faster logic gates will allow more time slots in the system. This will lead to smaller systems and lower propagation delays, which again leads to faster systems. Systems will be fabricated in smaller and smaller spaces which will continue to handle the same number of lines or trunks. The advent of high-speed, economical fiber optic links will alleviate the problems associated with communication between frames, and may also lead to new architectures, such as distributed or remote network components." [McDonald (1983) p. 173] **

b. John S. Mayo, executive vice president, Network Systems, Bell Laboratories, Murray Hill, NJ, stated:

> "The ability of communications networks to deal with data is well advanced in the telephone network. The thousands of existing space division electronic switching systems in the telephone network can be equipped to switch a 56 kbit/sec. signal on each voice circuit. Time division switching systems are also being introduced, and they readily switch 56 kbit/sec. on each voice channel." Mayo (1982).**

The twelve papers in the Special Issue on Serving the Business Customer Using Advances in Switching Technology, published in July 1985 (Joel, 1985A)**, show that telecommunication switching technology and the system architecture it supports now encompasses and integrates switching and data processing. The result has been that these twelve papers not only view some of the current systems, but also provide a glimpse into the future, including the extension of telecommunications into office automation.

4.3.1 Circuit Switching - Future Technology

To those countries with a background in telephony, Multi-Rate Circuit Switching (MRCS) seems a natural choice for new communications systems. MRCS provides connections having bandwidths equal to an integer multiple of some basic rate, such a 8 or 64 kbs. The user specifies a transmission speed when the call is set-up and the network provides enough channels to satisfy the request. As Kulser and Montgomery point out, there are several problems with MRCS. First is the choice of the basic rate. Many services require a low rate such as 1 kbs, but this can imply a long delay due to the large frame size required for time-division multiplexing. It also implies a large overhead for establishing high speed connections, since these must be implemented using multiple channels, each of which must be set-up individually. Even with a fairly large basic rate of 1 Mbs, a video connection might require the establishment of 100 channels. MRCS is also ill-suited to applications with bursty transmission characteristics. Applications such as remote file access require occasional transfer of bursts of data at high rates such as 10 Mbs. Dedicating a high speed connection to such applications is costly and inefficient. Using a lower speed channel yields efficiency, but only by sacrificing performance.

If we take the next step to the right on the spectrum in Figure 1, we come to Fast Circuit Switching (FCS). As with MRCS, customers request connections having bandwidth equal to some integer multiple of a basic rate. In FCS however, the system does not allocate the required channels until the user has some information to send. Thus FCS, allocates bandwidth dynamically among a group of users, allowing efficient sharing of the transmission facilities. Of course, there may be occasional peak traffic periods when the network cannot satisfy all user's requests. When this happens, one or more requests are denied. This kind of switching has been termed "burst switching" by Amstutz (1983) and Haselton (1983), (1984).

4.3.2 Packet Switching - Future Technology

Fast Packet Switching (FPS) is the next option on the spectrum. As in conventional packet switching, FPS uses the transmission facility as a "digital pip," which carries short packets of information one after another. Information in the header of each packet identifies which of many logical connections the packet belongs to. With this multiplexing scheme, connections of arbitrary bandwidth are accommodated in a simple and natural way. A key aspect of FPS is the recognition that the high speed and low error rate of modern digital transmission facilities allow simplification of the communication protocols used in conventional packet switches. These simplifications make possible the construction of hardware protocol processors. High speed transmission facilities also dramatically reduce the queueing delays inherent in packet switching. Another key element is the observation that high speed computer interconnection networks originally designed for large parallel computer systems, as in Feng (1981)**, are ideally suited to large high performance packet switching systems. FPS has been developed by a group at Bell Laboratories and is described in Hoberect (1983), Jeng (1983), Kulzer and Montgomery (1984) and Montgomery (1983). **

4.3.3 Computer Switching - Future Technology

Joel (1985A, p. 495)** concludes that the state of switching technology to serve the business customer is advancing rapidly. It is in this area of application where there is the greatest current need for combined voice and data service to the same stations or terminals. This technology is in all likelihood a precursor of the future central-office switches for the so-called ISDN-Integrated Service Digital Network.

M. Schwartz, director of the Center for Communications Research at Columbia University in New York City, was quoted on the state of ISDN. "It's the future of telecommunications, once in place, ISDN will offer ubiquitous, coexisting voice, data, and video networks." (IEEE Spectrum, Nov. 1985, p. 83, Fischetti (1985)).

Siemens A G Telefunken estimated that, by the year 1990, there would be 600 million subscribers to analog circuits worldwide and 125 million subscribers to ISDN. By the year 2000, the company envisions a reversal with only 250 million subscribers to analog and 750 million to ISDN. (IEEE Spectrum, Nov. 1985, p. 83).

Roy Weber, AT&T Bell Laboratories is quoted as follows: "ISDN today (Oct. 1985) is where we were 10 years ago with common channel signalling." "Now we can't live without it. . . and flexible signalling is the heart of ISDN. . . .Every (AT&T) No. 4 ESS will have the primary rate interface by 1987

- not a trial but a service." [Telephone/Oct. 28, 1985, p. 83.]**

Moving to ISDN is not a purely technical issue and will take the joint efforts of regional operating companies, interexchange carriers, state and federal regulators and equipment manufacturers. In addition, ISDN requires a receptive marketplace ready to buy.

"The major trend appears likely to be the continuing convergence of computers and communications." Bell (1985), IEEE Spectrum, Nov. 1885, p. 111.)**

"The ultimate blueprint for world telecommunications by the turn of the century is a new socket in the wall of every home and public place, as standard as the sockets for electrical current. Into this new socket a person could plug a telephone, television set, computer, or other terminal from any manufacturer to instantly send or receive voice communications, video images, or high-speed data." (Bell, 1985, p. 111.)** Such universal communications over an ISDN depend on three key prerequisites: large bandwidth, digital processing, and protocol standards.

4.3.4 Components and Switching Systems - Future Technology

Recognizing the ISDN as the wave of the future, this section gives a list of the major ISDN switch manufacturers and some additional information about their switches. In general, these are the companies involved with completing the last four layers of the OSI protocols.

ITT sells System 12. Although they have dropped out of the U.S. marketplace, they are still building and selling these switches abroad. ITT has performed many switch trials throughout Europe. Their most responsive customer is the Deutsche Bundespost in West Germany. According to ITT, ISDN equipment will be regularly introduced into the Bundespost's network by 1988, and within a few following years, ISDN will be available throughout Germany.

GTE sells the GTD-5EAX. GTE, together with Mountain Bell, is involved in trials in Phoenix, Arizona. GTE has a division preparing for the International Switching Symposium in March 1987.

Northern Telecom has two switches involved in ISDN trials: the DMS-100 and the DS-10. They are working with several U.S. telephone companies.

Ericsson sells the AXE-10. They are active in Europe and have spent $70 million to break into the United States market. Ericsson ran trials in Sweden and Italy starting in 1984. They recently won a contract to supply Mexico with central office switches. Ericsson is also working to connect all of Sweden with digital communications by 1995.

ATT is selling the 5ESS, and is involved in a trial with McDonald's and Illinois Bell. The company is constructing a functional response switch, but the software is taking longer to prepare than first estimated.

Siemens offers two switches, the DE5 and the EWSD. The EWSD is their top-of-the-line ISDN switch. Siemens is currently involved in trials with several U.S. telephone companies and is also entering the United States market. GTE is forming a business venture with Siemens.

NTT, with its D-5 switch, is conducting trials in Japan. The company plans to make digital communications available throughout Japan by 1995.

Fujitsu has the FETEX switch. They are very advanced insofar as ISDN technology is concerned, having conducted a trial in Singapore and Tokyo in 1984. They are supplying the ISDN terminals for the McDonald's trial in Illinois, and working with GTE to develop and market PBX's. As the only company offering ISDN features as part of their communications system, they won the contract to upgrade communications for Texas.

The following list is provided to show which companies have been in the news for selling digital terminals or ISDN equipment. This list is a starting point for locating ISDN terminal equipment vendors.

a. NEC -- Terminals for Pacific Bell's trial
b. IBM -- ISDN compatible terminals
c. AMBI -- Digital Communications Device
d. DAVOX --IBM 3270 compatible Integrated Voice and Data Terminal (IVDT)
e. MITEL of Kanata, Ontario, Canada
f. COMPAQ Telecommunications of Dallas, Texas
g. TELEVIDEO Systems, INC.
h. SIEMENS AG

i. NORTHERN TELECOM

j. GTE TELENET -- Digital Telephone for digital PABX system

In regards to chip components, the principal ISDN chip manufacturers are ATT, Advanced Micro Devices, Siemens, and Northern-Motorola.

ATT has been selling ISDN chip sets for some time. The company is currently making chips called UNITE, a transceiver conforming to CCITT I.430 specifications. The transceiver will support the basic data rate interface standard for transmitting voice, data, and video over two pairs of telephone wire. Commercial production of this chip will be available in the first quarter of 1987. ATT is also working on a U interface chip.

Advanced Micro Devices will put its four primary ISDN chips into production by the first part of 1987. These are the 793X family - the 79C30 Digital Subscriber Controller (DSC), the 79C31 Digital Exchange Controller (DEC), the 7935 Subscriber Power Controller (SPC), and the 7938 Quad Exchange Power Controller (QEPC).

Siemens is the foremost ISDN developer. The company is trying to design the fewest number of standard chips possible to be used to build different types of ISDN telecom equipment. The company has designed what it believes is the optimum set of generic subfunctions: the Siemens codes filter (SICOFI), the ISDN communications controller (ICC), the S-Bus interface circuit (SBC), the ISDN echocancellation circuit (IEC), and the ISDN burst controller (IBC).

Intel, National Semiconductor, Rockwell, and Northern-Motorola are expected to have chips soon. By late 1987, Motorola will be producing its ISDN universal digital loop transceiver (UDLT), the 245471, and the S/T transceiver, the 25474. A universal data-link controller for the ISDN data channel, the 1588, should be in production late in 1987.

Competitive pressures have contributed and will continue to contribute to an acceleration of memory technology. The Japanese presence in many market segments has led to a dramatic reduction in prices and profit margins. (Davidson, 1984, p. 239.)** The 64-k RAM reached commercial volumes in late 1981, but pilot production of 256-k RAMs commenced in late 1982. The 512-k RAM was being used in laboratory applications in 1984. (Davidson, 1984, p. 239.)**

Shott and Meindl (1985)** believe that ultra-large scale integration (ULSI) technology will be successfully coupled to advanced system architectures by the second half of the 1990s.

Section 5

(U) REQUIREMENTS AND ASSESSMENT OF SOVIET TECHNOLOGY

The following assessment of Soviet technology is based on a continuing evaluation of their telecommunications and computer developments. It is very difficult in a closed society to identify the exact impediments to research and development efforts, but they should have to deal, one way or another, with the same technology problems as the United States did. There is not any good single source as to what the issues were in the United States as the frontiers of communications networks were explored. The information is available in the years of published articles which is beyond the scope of this effort. However, much information can be gained by talking with the technologists that explored those frontiers.

5.1 Key Technology Issues

Unless one can produce good quality microchips at reasonable cost, it is not cost effective to go to digital communications [42], [43], [44]. Both switches and multiplexers are practical only if microchips are used. Also, high data rates can be implemented only by using microchip technology [35]. The actual circuit technology is not a major problem since most of the circuit information, except for that directly related to the manufacturing of the microchips, is published in engineering journals or standards. All the major western countries are manufacturing digital switches and multiplexers with rates up to 140 Mbits/second. The United States, Japan, Germany and France have capabilities at 560 Mbits/second and are working on systems above one Gigabit/second. The data rates will probably level off for the next several years at 560 Mbits/second because of the need for GaAs technology for the higher data rates. The 1 to 2 Gigabit per second rates will begin to appear in the early 1990's.

Without the microchip technology Soviet and Eastern bloc data rates are going to be limited to the 34 Mbit/second level, which also is too low to make fiber installations practical [30]. A review of the brochures of their present equipment [29], [30] indicates that most of the equipment does not use microchip technology, but employs thick and thin film processes. This level of technology will not support the deployment of multiplexers much above 34 Mbits/second and switches with large digital matrixes. While they have some capability at 140 Mbits/second, they probably will not have an operational capability until the early 1990's [30], [32].

Computer control of switches, whether it is part of the switch or a separate host, is very software intensive [39]. To develop the programs to control networks and switches, software developers with special backgrounds [41], [47] are required. This key area has been a major impediment for the bloc countries. Software development and quality control is a key technology required by them to permit them to manage their network resources effectively. Much of the basic information about their technology is gained from articles published in technical journals [33] and also by foreign nationals attending school and working in the West [25].

The above two technology areas (microchips and computer control) are also concerns for packet and computer switching. However, microprocessor development is an additional technology which affects these systems. The data rates and the throughput of these switches are directly related to the power of the microprocessor used. This is not as critical for the circuit switch since its information is not switched through the microprocessor.

5.2 Soviet Developed Technology

The Soviets do not appear to be able to satisfy the three critical technologies of:(1) developing microchips; (2) providing software control; and (3) providing microprocessors, without outside assistance. They have or could have the technical data to design the required switching systems. They have the MT20 switch from the French which should give them the required technical data for stored program controlled PABX switches [29], [48]. This would include both the hardware and the software, but there is some question as to their capability to manufacture the switch. However, the software will give them a base to build their control technology. In the area of packet switching, the

Indians designed a packet switching system using their own indigenous computer and software [33]. This information is available. Also, information on a standard computer based packet switch can be obtained through legal imports of X.25 boards for hosts [34] and the published information on X.25 protocols. With the control of switches going to standard hosts, the software becomes more available and the Soviets could develop their own designs. However, software designed to run on a specially designed processor, as has been done with switches like the MT20, is harder to adapt to different operating environments.

It is very probable that the network control software will become a Soviet developed technology by the early 1990s. It will find its roots in information and software that has been obtained from the west, but due to the uniqueness of each network control situation, they will have to develop their own capability. It is more than likely that it is one of their higher priorities since it can significantly help their present analog switches and network [31].

5.3 Soviet Acquired Technology

Of the above three critical technologies the one of greatest need for the Soviets appears to be the acquisition of the knowledge of how to manufacture high speed microchips. The manufacturing knowhow has always been their biggest problem because of their quality control. If they can ever get an adequate microchip production capability in place, it will impact on far more than just their telecommunication problems. The actual purchase of the required microchips is not a very good solution because of the quantities required and the special designs which are not commercially available. Samples of the microprocessor chip probably will have to be acquired in order for the Soviets to study and learn its physical design <u>once they establish a capability to manufacture it</u>.

Section 6

(U) EMP

EMP, as a propagated signal, can damage equipment or cause RF interference. A surface burst generates an EMP due to the rapid ionizing radiation effects. The EMP can be divided into two regions; i.e., a source region which is associated with the air volume and ground current returns where the EMP is generated, and the radiated region. Within the source region, which extends to 3-5 kilometers, electric fields may exceed 100 kV/meter. The EMP energy coupled to a system must be treated as a survivability issue because permanent damage may result. Beyond this 3 to 5 kilometer distance, the radiated fields are less intense, and less than those fields due to high altitude EMP. High altitude EMP is generally specified as 50 kilovolts/meter from a system survival requirement viewpoint. The source of high altitude EMP is ionization at the top of the atmosphere caused by X-rays and GAMMA rays moving downward from the nuclear burst points. Residual GAMMA radiation can travel over 2000 miles.

The Soviets have done a number of studies on radiation hardness of optical fibers and components. Degradation of fiber optics transmission systems due to nuclear radiation is of major concern. While fiber optics are attractive for use in High Altitude EMP mitigation, it must be made clear that fiber optic media is not completely insensitive to EMP. It is, however, less sensitive than metallic or atmospheric transmission media. Single mode fiber exhibits the best recovery; with additional attenuation (path loss) being 3 dB to 10 dB over benign levels 10 to 15 minutes after EMP exposure. Multi-mode and plastic fiber is much worse and may be destroyed by the intense heat deteriorating the light guide capabilities of these fibers. [51,52]

As far as digital switching components are concerned, solid state components are susceptible to EMP. Different radiation hardening techniques are being considered. These alternatives or combination of alternatives are listed below:

1. Use of switching materials (GaAs instead of silicon) and shielded enclosures to make the equipment resistant to EMP;
2. Creation of backup power sources for circuits and terminal equipment;
3. Reduction of the number of switches employed in a network;
4. Employment of widely dispersed switches and circuits, away from known targets;
5. Improved methods of testing to better quantify baseline problems and design improvements.

During the next 10 years, it is expected that the number of switches will decrease significantly. This expectation is based on the observation that switching and computing devices are becoming so efficient that the number of switches used by public telephone companies has already decreased in a steady manner (the trend has been established).

Another area of improvement will be the standardization in the testing for EMP effects. Currently, different laboratories frequently come up with divergent results making it difficult (if not impossible) for the engineering community to devise uniform proposals for improving the resistance of switching components and networks.[55]

Section 7

(U) CONCLUSIONS

The Soviets are at the threshold of deploying digital systems. They have implemented it in small steps, but appear not to have the capability to make major installations. They have made low capacity digital transmission systems and appear to have produced their first all digital exchange for end office use [29], [30], [48]. They have also implemented simple, but effective automated network control schemes [31], [32]. The major factors that appear to be holding them back are the ability to produce quality microchips in the numbers required and the sophisticated software to make the robust network and switching control systems that the new networks require. They appear to be where the United States was 15 years ago, but should be able to implement this technology within the next 10-20 years.

The dynamics of the development and implementation of high capacity digital transmission systems, with throughput capacity equivalent to existing and developmental analog systems carrying tens of thousands of channels for mainline communications links, provide no basis to assume that the entire primary mainline network will be switched over to digital transmission methods within the next 20 years. However, the creation of a mainline primary digital network with limited throughput capacity (based on switching medium-capacity balanced cables, coaxial and radio relay lines over to digital transmission systems), in parallel with the existing high capacity analog network, can solve the problem.

Two of the greatest needs for the Soviets are: (1) the ability to manufacture good quality microchips needed for high bandwidth digital switching; and (2) the ability to develop network control software that will lead to high bandwidth network communications management. By the early 1990s the Soviets should be able to acquire sufficient production capability to manufacture a digital circuit switch of the MT20 technology level and switches of the packet and computer type equivalent to the early 1980 western technology. Network control software will become Soviet developed in the early 1990s. Early development efforts will be spurred on by acquisitions from the western world.

The future of telecommunications for both the West and Soviet bloc is the merging of computer and communications technologies. The Western countries are beginning to experiment with networks of the ISDN type, with Japan in the lead. The Soviets have announced that they are developing a limited version of the ISDN layered concept. Since digital switching technology is an essential part of any ISDN, then digital switching technology must be considered a critical technology for Soviet and Western telecommunication advances.

As far as fiber optics is concerned, it is expected that by the early 1990s all new toll transmission systems will be of the fiber optics type. In the Soviet and bloc countries, new long distance fiber systems will likely appear by 1990. EMP can affect fiber optics and solid state components' transmission quality and signal intensity, and the Soviets are conducting research in this area.

Section 8

(U) REFERENCES

This section is divided into **two** lists of references. The first list is given by **number** and these numbers are referenced in the text. The second list which follows the first list is referenced by **author** and **year** and each reference in this second list is flagged by a double asterisk in the text.

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APPENDIX A

Next-Generation Switching: System Characteristics and Industry Implications

by Jerry Gechter, GTE Laboratories Inc.

Introduction

GTE, as both manufacturer and provider of a wide variety of network services, has been particularly well-placed to observe the evolution and implications of switching technology.This paper reviews results of a recent corporate tasks force study of the characteristics and implications of next-generation switching. We feel the subject is of particular relevance for this conference, since the conference itself will influence the directions the industry will take.

Briefly stated, the conclusions we reached are the following:

1) By the 1990's network service providers will require network capabilities going beyond the potential of current digital switching systems. Motivations include new service options as well as cost-effectiveness of network operations, administration, and maintenance.

2) Switching implementation issues are increasingly bound up with other aspects of the network service provider's business. Traditional switching control is only one part of the real-time data management necessary for automated provisioning of network services in the 1990's.

3) In the future switching control and information transport structures will be conceived and evolved separately. Benefits will include enhanced service capabilities, easier introduction of new switching technology. A further consequence will be reduced dependence of network service providers on switching manufacturers for implementation of services.

This paper will discuss the motivations and technical capabilities on which these conclusions are based.

Motivations for Next-Generation Switching

For our study we viewed network service provider needs as the high-level definition of next-generation switching. We put these needs in two categories:

1) New switching capabilities

2) Cost and performance improvements

In the first category we placed distinctly new switching functions which cannot be provided by evolved versions of existing central office technology except by overlay. In the second were next-generation system advantages for the implementation of current as well as future services.

As noted in Figure 1, the emphasis in new switching capabilities was on the high-bandwidth side. As is also evident from the figure, it is difficult to specify upper bounds on the bandwidth needs of switching systems required in the 1990's. Furthermore, the bandwidth will be used in applications ranging from long holding time circuit connections (entertainment video) on one hand, to interactive bulk transfers (CAB/CAM applications) on the other. Our technology assessment concluded, finally, that braodband switching will not remain an overlay add-on as it is today, but will be fundamental to the capabilities of a central office or PBX in the 1990's.

For cost and performance improvements, our emphasis was on advantages of integrated systems. While such systems have been described in conference and trade publications by GTE, AT&T and others, the intent in our study was to be as specific as possible about the advantages they bring to network service providers.

Figure 2 gives an indication of the degree of complexity which will be implicitly or explicitly present with evolved versions of current technology by the late 1980's. Some of these network switching functions are already present in carriers' networks; others are only in the planning stages. Hence it is somewhat difficult today to quantify the cost of complexity in this proliferation of networks.

Our first conclusions are given in Figure 3. The figure identifies five specific areas of benefit: service software, switching hardware, OAM costs, networking capabilities and economies, and universal interfacing. The benefits which we identified in these areas are also described and are not necessarily the ones which first come to mind. Expanding on the text in the figure, they are as follows:

Service software: Whatever other benefits may arise from new software structures in next-generation systems, we feel the strongest demonstrable motivation will come from integrated services. Coordination problems in multi-media services will be far greater in non-integrated networks, translating to cost and responsiveness advantages for integrated systems.

Switching hardware: While we felt it was difficult to demonstrate cost advantages for integrated systems on a port-for-port basis, we did see a significant *provisioning* advantage for integrated systems, particularly in an environment where new services will be introduced with uncertain demand. In the early part of the 1990's one would like to be able to handle the entire service mix with switching capabilities sized incrementally over voice requirements.

Operations, administration, maintenance: Integration of networks translates immedaitely to a reduction in staff requirements for OAM.

Network capabilities and economies: The greatest networking advantage of integrated system appeared to us *not* to be in transmission saving, but in support to distributed processing applications. The point, briefly stated, is that once one folds control message communication into the common transport network, then the system software of an integrated switch becomes available as support for more general distributed applications on the network. Such applications will be typical in the 1990's operating environment.

Universal interfacing: Current access interfaces, including the ISDN interfaces, will not exhaust the requirements for switches introduced in the 1990's. Switching approaches chosen today must impose as few constraints as possible on system ability to adapt to currently unspecified interface standards. An integrated system, in that it is can uniformly handle all information types, imposes fewer constraints on the interfaces it can economically accept.

With this classification of potential advantages of integrated system, we attempted some quantification of advantages on the basis of available data, current and projected. The result was the list of qualitative conclusions given in Figure 4. As noted, the two major items were considered to be the OAM and networking advantages, in that these impacted *total network* operating cost, quality, and responsiveness.

Next-Generation System Characteristics

We next attempted to further define the nature of next-generation switching by looking in detail at carrier business objectives, at characteristics of next-generation system options, and at various future scenarios. The results were as follows:

1) Business objectives

Figure 5 gives a list of eight fundamental architectural requirements deduced from carrier business objectives. The descriptions are largely self-explanatory, and the conclusions which we drew from the list are indicated in the following figure. The main message is that these objectives have both control and transport implications, and in fact that any technological solutions must deal separately with the control and transport structures necessary to meet the objectives.

Proceeding further, we came to the next-generation network model given in Figure 7. Here we have formalized the control/transport boundary. This allows the transport network to evolve with hardware technology and service-bandwidth demand, while retaining the control capabilities in the higher layer. Moreover, it enforces a common context on all control considerations in the network, including call processing, customer input, and network administration.

It was noted finally that such a formal boundary, analogous to what exists for LAN's today, has consequences for the business relationship between switch vendors and network service providers. Today the switch vendor produces a bundled offering of transport and control hardware and software. The formal boundary allows feature software to exist as an independent product: separate from transport hardware and governed by standards arising in the data processing area. The introduction of common channel signaling, for current generation switching systems, should hasten such an evolution in the industry.

2) Next-generation system options

Our analysis of next-generation options considered a number of proposed systems from our own corporation and others. In qualitative terms we concluded that it appears possible to develop a system with the following combination of properties:

- Full integrated system advantages

- Minimal limitations on total throughput capacity

- Satisfies currently-formulated central office requirements, including delay performance

- Allows functional circuit and packet approaches to video and other broadband services

We feel that these capabilities are highly desirable in economically meeting future needs of network service providers.

3) Scenario variables

Our treatment of scenario variables identified certain other evolvability or flexibility requirements which had not been identified from the other points of view. Examples included

- VLSI to optical component evolvability
- Efficient switching and multiplexing capabilities
- Phased system implementation

These, added to the conclusions from other areas, gave us a reasonably clear idea of what a next-generation system should be. Looking from the network service provider's and from the technologist's point of view, what we see is a system that is most easily imagined as an "enhanced" local area network.

Like a LAN it has a formal boundary between control and transport functions, thereby turning control software into a separately sourceable product in a data processing context. Also like a LAN, the transport function handles all its applications within the same information transfer mechanism.

The required enhancements to LAN operation apply to both transport and control aspects. The transport system must be so conceived as to carry voice, data, and video subject to the performance requirements of each. Further ~~then~~ there should be no geographic limitation on the extent of the network.

The control requirements include extended system-software capabilities for reliable, distributed, real-time operation, as well as the necessary application processes for telephony and other services. Further the entire system must be testable and maintainable on a fully-distributed basis. We emphasize that while these control capabilities represent a considerable advance over the current state of the art, the problems are not unique but belong to the mainstream of distributed data processing.

Conclusions

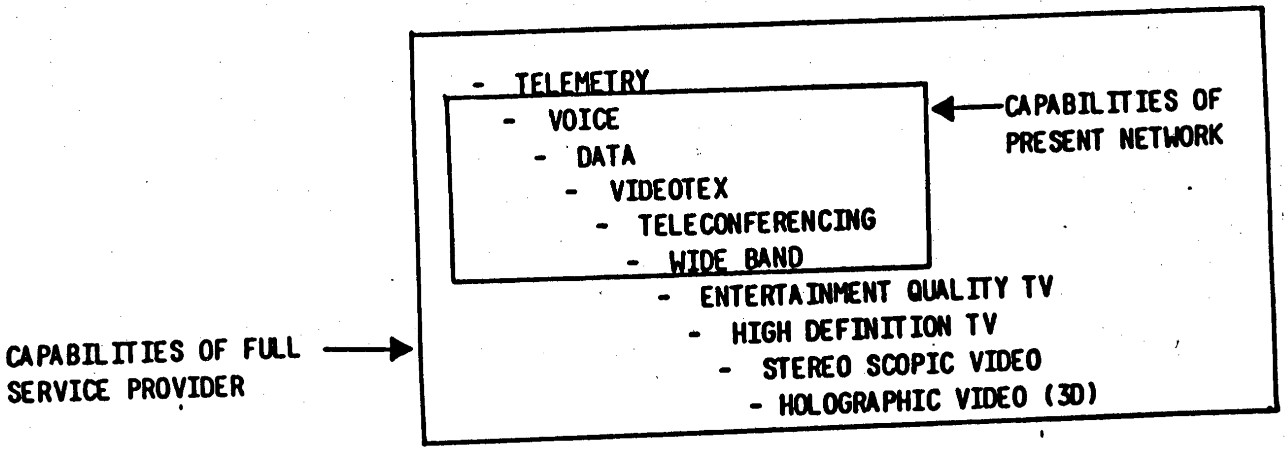
The message we would like to leave is that there is such a thing as next-generation switching, defined by applications of evolving technology to the perceived needs of network service providers.

For carriers such as ourselves the consequence is clear: the industry should evolve so as to provide the kind of next-generation systems we see as necessary. This has implications most directly in standards. The control/transport boundary should be formalized and control software should join the broad range of distributed computing applications.

Beyond that we see a need to encourage the develop of independent, application-specific software vendors. As communications services become ever more closely entwined with our own and our customers businesses, the industry must provide these services with the responsiveness and flexibility the customer expects in all areas of his business. For ISDN and for services beyond ISDN, the industry will only be successful if it is also entrepreneurial.

We at GTE intend to encourage such an evolution through our commitment to the standards process, through an open system approach to our own network architecture, and through presentation of our views at public fora such at this one.

New Switching Capabilities



- TELEMETRY
  - VOICE
    - DATA
      - VIDEOTEX
        - TELECONFERENCING
          - WIDE BAND
            - ENTERTAINMENT QUALITY TV
              - HIGH DEFINITION TV
                - STEREO SCOPIC VIDEO
                  - HOLOGRAPHIC VIDEO (3D)

CAPABILITIES OF PRESENT NETWORK

CAPABILITIES OF FULL SERVICE PROVIDER

Candidates for Network Integration

Circuit switching

Packet switching

Wideband switching/cross-connect

Broadband (video) switching

D-channel message handling

CCS message handling

DSI switching (speech spurts)

Channel rate adaptation (voice and data)

Remote unit control-message handling

OAM message handling

Billing message handling

BENEFITS OF INTEGRATION: COSTS AND CAPABILITIES

BENEFIT	VALUE
Service software	Reduced system complexity for integrated services
Switching hardware	Integrated switch sized for *total* demand
Operations, Administration, Maintenance	Single network to administer, manage, and maintain
Network capabilities and economies	Coordination and flexible allocation of control resources
Universal interfacing	Adaptable to interface requirements beyond ISDN

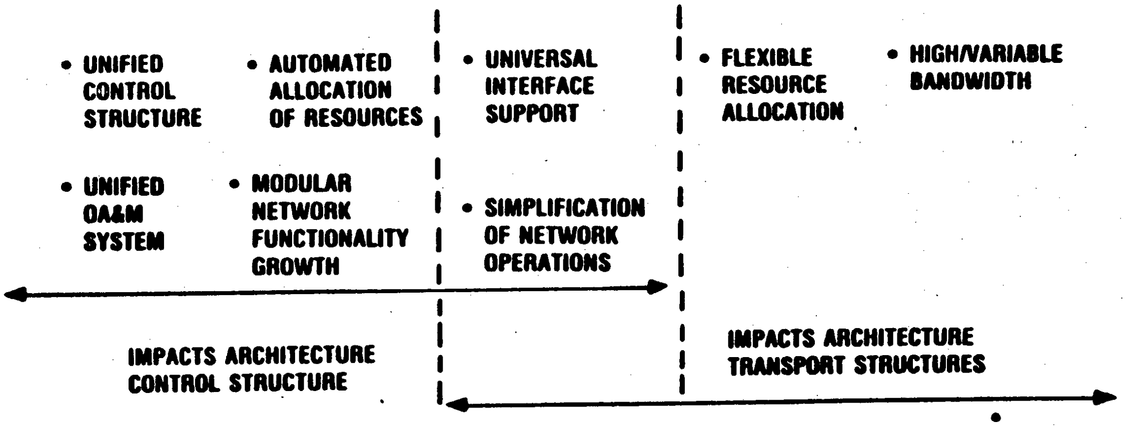
INTEGRATION — PRIORITIZING OF BENEFITS

BENEFITS	IMPACT
Service software	Incremental impact: Advanced services development
Switch hardware	Incremental impact: Advanced services deployment
Operations, Administration, Maintenance	PRIMARY DRIVER: Impacts *total network* operating cost
Network capabilities and economies	PRIMARY DRIVER: Impacts *total network* quality and responsiveness
Universal interfacing	Depends on market evolution; Wideband Packet may be a required interface

SYNTHESIS OF CUSTOMER FOCUS AND COST MANAGEMENT VISIONS YIELDS EIGHT FUNDAMENTAL ARCHITECTURAL REQUIREMENTS

• Unified Control Structure	Allows multiple processing systems to work together and share resources
• Automated Allocation of Resources	Capability to automatically assign transport resources to satisfy network and customer requirements
• Unified OA&M Systems	Ability to operate and maintain the network as a single entity
• Universal Interface Support	Ability to accept diverse standard and customer-specific interface protocols
• Simplification of Network Operations	Reduction in the overall complexity of the network as seen by the network operator
• Flexible Resource Allocation	Capability to assign bandwidth to fulfill customer and network requirements in whatever granularity requested
• High/Variable Bandwidth	Defines the upper limit of allocatable bandwidth
• Modular Network Functionality Growth	Ability to add processing capabilities (switch attempts, services) in a graceful and economic fashion

ARCHITECTURAL REQUIREMENTS: CONTROL AND TRANSPORT



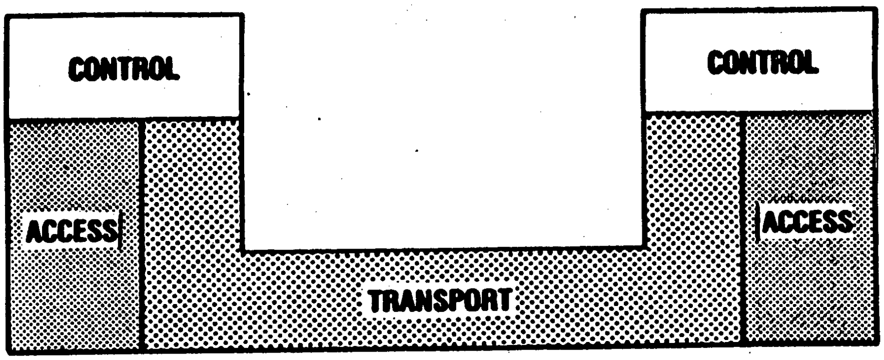
- UNIFIED CONTROL STRUCTURE
- AUTOMATED ALLOCATION OF RESOURCES
- UNIVERSAL INTERFACE SUPPORT
- FLEXIBLE RESOURCE ALLOCATION
- HIGH/VARIABLE BANDWIDTH
- UNIFIED OA&M SYSTEM
- MODULAR NETWORK FUNCTIONALITY GROWTH
- SIMPLIFICATION OF NETWORK OPERATIONS

IMPACTS ARCHITECTURE CONTROL STRUCTURE

IMPACTS ARCHITECTURE TRANSPORT STRUCTURES

IMPLICATIONS NETWORK ARCHITECTURE TECHNOLOGY PLANNING DEALS WITH TWO INDEPENDENT, FUNDAMENTAL STRUCTURES: ***THE CONTROL STRUCTURE***
THE TRANSPORT STRUCTURE

NEXT-GENERATION NETWORK MODEL



Transport

- Provides basic transport functions
- Transport of voice, data, video, and control
- Emphasis on integration of switching and transmission
- Emphasis on unified transport structure
- Nonstandard protocol conceivable

Access

- Accommodates standard access interfaces
- Provides interface to network functions and resources
- Emphasis on unification of access

Control

- Provides all network signaling, high-level functions, feature logic, and interface to information processing
- Interprocessor communication through the transport structure
- System functions distributed across transport network
- Control structure is independent of transport and access