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THE SAVANNAH RIVER SITE LOCAL AREA NETWORK* (UNCLASSIFIED)

by

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INTRODUCTION

The Savannah River Site (SRS) consists of thirteen separate operating or administrative facilities, or areas, spread out over 300 square miles of a federal reservation. A facility of this size presents rather unique difficulties to anyone attempting to provide a comprehensive and high performance computer network, or local area network (LAN). Figure 1 is a diagram of the SRS and indicates the approximate number of "knowledge workers" (i.e., managerial, professional, and clerical staff) which are located in each site area. The goal of the SRS LAN project is to have each of these workers connected to and using the computer network by the end of 1990. By mid 1989 SRS is three quarters of the way to completing this goal.

The fundamental LAN strategy for Savannah River is the integration of personal computers with mid size "departmental" computers located within each site area with links to the site's mainframe computer systems and offsite databases for information access. This integration is being provided by baseband local area networks in each of the site areas joined together via a broadband and digital telephone communications system to form one sitewide internetwork. The site internetwork is used to connect the departmental and mainframe computers together as well as provide workstation to computer access between site areas.

AOSS AT THE SAVANNAH RIVER SITE

The Savannah River LAN was primarily developed in support of the site Automated Office Support System (AOSS) strategy. The AOSS strategy is centered around Digital Equipment Corporation's (DEC) ALL-IN-1 office automation software installed on DEC VAX computer systems located in each of the SRS areas. In each area a LAN is to be used to connect the terminals and personal computer workstations of the area's knowledge workers to the ALL-IN-1 system. A major part of this strategy is to integrate personal computers with the ALL-IN-1 systems. Most substantial word processing operations are done on the personal computers as opposed to ALL-IN-1 (WPS Plus) based word processing. SRS has a large (over 4000) number of personal computers. These consist primarily of systems from Apple Computer and IBM with smaller numbers from DEC and others. There are several word processing software packages which are used on these systems. Most common are Word (Microsoft), MacWrite (Claris), WordPerfect (Wordperfect Corp.), and Multimate (Multimate International). Integration of the personal computers to ALL-IN-1 requires that the word processing format files (binary files) be transported from the personal computers to the ALL-IN-1 VAX system and, as an option, translated to another word processing software format. In this way, a personal computer user is able to send via electronic mail a document to another ALL-IN-1 user and have it arrive in a usable (i.e. revisable) format.

This strategy of integrating personal computers to a network of departmental AOSS VAX computers and the information resources provided by the site central computer facility and offsite data resources requires the following network services:

- Each personal computer must have a fully functional VT100 or VT200 terminal emulator in order to use the AOSS computers. Connectivity to the host computers must be supported by RS-232 device terminal servers or by connecting the personal computer directly to the Ethernet. In the later case the host VAX must support a remote terminal log-on service which is compatible with that used by the personal computer.

- Each personal computer must have the ability to use the network to exchange word processing files at adequate transfer rates with the VAX hosts.

- The network must link the VAX computers together so that electronic messages route in a manner transparent to the user between areas.

- The network must provide terminal emulation and file transfer services for the site central computer facility (IBM and Cray).

- The network must provide dial-out links to offsite data services.

The SRS LAN, although designed for AOSS support, now is used as a general purpose, unclassified computer network. There are currently over 200 host computer systems attached to the LAN of which only a score are directly related to AOSS. The other systems, ranging in size from the smallest MicroVAX computer to a Cray XMP, support departmental information systems, scientific and engineering calculations, computer aided design and drafting, plant process control, and laboratory experimentation and data acquisition.

THE SRS INTERNETWORK COMPONENTS

The SRS LAN, often called the internetwork, as it is a collection of individual LANs, consists of local area networks in each site area linked together by a CCTV broadband cable system or digital telephone circuits. Each area LAN is an Ethernet (IEEE 802.3) baseband system. The Ethernets consist of one or more coaxial cable segments with fiber optic cable extensions in the larger site areas. Ethernet repeaters and bridges are used to extend the networks from single segments to multiple segments providing network connections to multiple buildings within a site area. Figure 2 shows an SRS LAN of moderate size. Multiple coaxial cable Ethernet segments are joined together by repeater or bridge devices. Outlying buildings are connected to the LAN via fiber optic cable and repeaters or bridges. Repeaters and bridges extend the geographical coverage potential of Ethernet so that it is possible to install a physically contiguous Ethernet network in any of the SRS areas. The largest single area LAN at SRS is much more complex than the one shown in Figure 2 and will support over 3000 workstations and over 1000 Ethernet devices.

Attached to each area Ethernet are VAX AOSS computers, personal computers, terminal servers, and other area computer systems (for example, area computer aided design computers). The terminal servers allow any device which supports RS-232 asynchronous serial communications to connect to the LAN at speeds up to 19,200 bits per second. At this time most workstations attach to the LAN via terminal servers.

Personal computer networks providing shared file services and printer queues for work groups are only recently becoming a significant factor for the internetwork. Two products today are dominant in this area, AppleShare from Apple Computer and Novell's Netware. AppleShare is primarily for Apple Macintosh computer work groups, but IBM PCs can participate. Netware was originally for the IBM personal computer lines, but now AppleShare workstations can participate in a Netware. Each product can be ported to the VAX/VMS server environment which means these are good tools for continued integration of the personal workstations (work group computing) to the VAX mid-size systems (departmental computing). These PC LANs require either direct Ethernet attachments or attachments to an Apple LocalTalk LAN with bridging to the site Ethernet LANs.

Most of the area Ethernet LANs are interconnected to each other via the site wide CCTV broadband cable system. (Figure 3) This system consists of over forty miles of cable TV trunk coaxial cable. The farthest LAN from the "head end" of the CCTV system is over 14 miles away. There are over 120 amplifiers on the system. With a site of this size, standard LAN access techniques will not work. Fortunately, the Applitek Corporation makes devices with a network protocol (UniLAN) that can be adjusted for very long distances. At SRS size distances the protocol becomes a form of time division multiplexing, whereby each Applitek device is given a time slot at regular intervals to transmit data and each device listens to all the time slots for incoming messages.

The Applitek devices are Ethernet MAC layer bridges. There is one of these bridges attached to each area LAN. Each bridge will broadcast via UniLAN on the broadband cable any Ethernet data packet which is addressed to a node which the bridge determines is not on its local Ethernet. In this case, each of the other bridges "sees" this packet. The bridge that has the destination Ethernet device on its Ethernet will take the packet from the UniLAN format and insert it on the Ethernet. Each bridge determines which devices are on its network dynamically by "listening" to all Ethernet packet traffic and recording in a memory-based table the Ethernet addresses of all devices heard transmitting. These bridges are capable of sustaining interarea data transfer rates in excess of two million bits per second. By their very nature the bridges are protocol independent. That is any higher level Ethernet protocol (e.g. DECnet, TCP/IP, XNS) will work across the bridges.

A recent addition to the broadband for interarea communications is the use of digital telephone T1 circuits and T1/Ethernet bridges. This provides a more reliable data path between areas when used in conjunction with the broadband links.

INTERNETWORK INTERFACES TO THE CENTRAL COMPUTER FACILITY

The unclassified portion of SRS's central computer facility (CCF) consists of an IBM 3090 running the MVS operating system and an IBM 3081 under the VM operating system with an MVS guest operating system. The IBM 3081 is also a host for the PROFS AOSS package. The LAN internetwork is connected to the IBM in four ways: file transfers via an Interlink Computer Sciences Gateway; ALL-IN-1/PROFS mail exchange via a Softswitch gateway, network terminal access to the CCF via DEC Terminal Servers attached to an IBM 7171 terminal protocol converter and via LAN SNA gateways; and IBM terminal user access to the VAX computers via Telex Terminal Communications, Inc. terminal controllers (See Figure 4.)

The Interlink gateway is a DEC MicroVAX computer which attaches directly to the Ethernet and to a high speed communications channel of the IBM 3090 computer. The product also includes IBM software which conforms to DECnet protocols for file transfers with the VAX computers. File transfers can be initiated from either the DEC or the IBM systems, and the file transfer rate is on the order of 1,000,000 bits per second. Interlink also supplies DECnet task-to-task communications software, support for VAX to IBM distributed database inquiries and updates, and terminal emulation software (both DEC terminal to IBM system and IBM terminal to DEC system).

The IBM 7171 protocol converter converts DEC VT100 terminal protocols to IBM 3278 format. That is, a user with a VT100 terminal (or a personal computer which emulates a VT100 terminal) attached to a DEC terminal server can "connect" to the network service, "7171" and begin accessing either the IBM 3090 or the IBM 3081 as an IBM 3278 terminal user. The LAN SNA gateway devices are personal computers attached directly to the LAN and which connect via private phone circuits to the IBM CCF. Personal computers attached directly to the LAN are provided IBM terminal emulation via the gateway.

The Telex terminal control units are plug compatible with IBM 3174 control units. The Telex units have, as an option, asynchronous RS-232 communications ports and protocol conversion so that an IBM 3270 type terminal can connect to the LAN with a VT100 terminal emulation. In this way SRS personnel who are primarily users of the CCF and who have IBM terminals on their desks can participate in the VAX based AOSS. The Telex control unit allows users to create an maintain "windows" into multiple computer systems (DEC or IBM) simultaneously.

At the first of the year SRS's Cray X/MP supercomputer became operational. This system is supported by an Network Systems Corporation Hyperchannel high performance LAN. Cray's UNIX operating system, UNICOS, supports the TCP/IP protocol stack for linking the system to other site computers. The Hyperchannel is connected to the site Ethernet via an NSC Internet Protocol (IP) Router. Thus any workstation or host computer on the LAN which supports TCP/IP can provide Cray interactive sessions and file transfers to their users via the well supported TCP/IP applications TELNET and FTP. (See Figure 5.)

NETWORK INTERFACES TO OFFSITE DATA

One of the major goals of Savannah River's AOSS is to provide access to the data that our employees need to accomplish their jobs. Much of this data is located in offsite commercial databases. For example, managers need access to the Official Airlines Guide to plan their trips while research scientists require information about chemicals found in the online Chemical Abstracts service. These data are made available by database suppliers on large computer systems which can be accessed (for a fee) by the public via dial-in modems or public data networks such as Telenet and Tymnet.

A bank of dial-out modems has been placed on the LAN and communications scripts developed for ALL-IN-1 so that any SRS LAN terminal user is able to use the LAN to connect to ALL-IN-1 and from there connect to the database he requires.

FUTURE PLANS

SRS's plan for the immediate future is to complete the LAN network by the end of 1990 so that each of the over six thousand knowledge workers at SRS will have access to the AOSS network and the CCF hosts as well as the many departmental and process computers attached to the LAN. The trend for the future will be for more devices directly connected to the LAN rather than through terminal servers in order to be able to transfer large amounts of data at faster data rates. This is becoming economical due to our ability to utilize existing unshielded telephone cable pairs for Ethernet connections. In this environment personal computer networks providing work group integration tools will become increasingly important.

The CCTV broadband cable system will be replaced by a fiber optic cable ring for network applications during 1992. This fiber optic network will link each of the site areas at speeds on the order of 100 megabits per second. Ethernet bridges to the fiber optic cable will be used to join the area LANs to this site wide trunk system. During the 1990s the individual area LANs will be augmented or replaced by fiber optic LANs using the emerging Fiber Distributed Data Interface (FDDI) standard. This move is necessary as the increasing power of the individual workstations is already beginning to tax the data transport capability of an Ethernet based LAN.

NETWORK MANAGEMENT

Management of large local area networks such as SRS's presents a large challenge. The location and characteristics of thousands of devices must be maintained and readily assessable to network managers. Ideally, computer-based expert systems would utilize this data as well as network device management software to determine problem causes and suggest solutions to network management personnel. SRS is systematically documenting its LANs using an Intergraph Corporation computer aided drafting (CAD) system and Intergraph software originally developed for telephone companies to document their wiring sites. Using an Intergraph CAD workstation network managers will be able to graphically zero in on problem areas and retrieve the pertinent information about the associated network devices.

LESSONS LEARNED

Need for Centralized Control

Large local area networks can cut across many organizations. In our case the site LAN absorbed several smaller departmental LANs. In these cases it was not unusual for the original LAN owners to feel proprietary about their networks. However, for a LAN to be effectively managed, there must be a single organization in control. The trick is convincing LAN users to give up some degree of local control for the benefits of more global access. The problem is compounded in a peer network, as all participants must agree to common rules; i.e. a centrally administered configuration policy must be enforced for the common good.

Routing Networks Provide More Control Than Bridged Networks

Bridges operate at level two of the Open Systems Interconnect (OSI) network protocol model. That is a network bridge will pass data packets in a content independent manner. In a bridged internetwork every device has equal access to every other device in the internetwork. This can cause internetwork wide problems when a single node can broadcast packets which could impact every other node using the same protocol. In Routing networks the internetwork is broken down into specific geographical locations or subnets. Each subnet links to the other subnets by "Routing Nodes". Routing nodes are particular to specific protocols (e.g., DECnet, TCP/IP, and XNS). Nodes on a subnet communicate via the Routing Nodes to nodes outside the subnet. Thus communications protocol errors by the non-routing nodes are restricted by the Routers to the subnet. Of course, routing nodes can have problems too, but it is much more likely that the Routers are under the direct control of the communications department, while non-routers can belong to anyone.

Solutions Do Not Always Scale up

One of the traps of integrating a large LAN is that of choosing solutions which appear reasonable in test or pilot environments, but which are not practicable when scaled up to hundreds or thousands of users. This problem is compounded by the fact that most LAN solutions come from the PC LAN vendors, not from the large computer vendors. To many people a LAN is used to connect workstations of a dozen or less users. Software developers tend to write packages with this model in mind. Unfortunately, predicting when a package is not robust enough for your environment is not always reliable from pilot tests or the experience of others in less complex environments. The message here is to be careful about introducing new technology on a large scale, if the particular technology has not been proven out in an environment similar (ideally identical) to yours.

Workstation Technology Is Outpacing LAN Technology

In 1982 a state of the art LAN operated a 10 megabits per second (mbs); a state of the art minicomputer processed on the order of a million instructions per second (mips); and a state of the art personal computer was an order of magnitude slower than the minicomputer. Today a state of the art LAN goes at 100 mbs; the minicomputer around 50 mips; and some personal workstations are operating at speeds approaching 100 mips. Clearly, the LAN will increasingly become the bottleneck. LANs are part of an organization's infrastructure, and large LANs are expensive and time consuming to upgrade, especially where backwards compatibility is an issue. (And it almost always is.) Individual workstations, on the other hand, are easily upgraded. To satisfy the speed requirements of the new workstations, LAN hierarchies must be developed. Fast subnets for the fast workstations will connect to a backbone LAN (hopefully also fast) as will the older, slower subnets. This will only increase the complexity of the LAN management problem.

Heterogeneous Network Management Is Manpower Intensive

It is not unfair to say that there is no single day on our network where some device does not "break". We are devoting an increasingly large staff to monitoring the network, detecting failures, and resolving problems. We have developed several tools to aid our operations staff, but the problem keeps growing as our internetwork grows in size and logical complexity. There is no single comprehensive network management system on the market today that fits our needs. We are hopeful that Digital Equipment Corporation's Enterprise Network Management (ENM) program, which is based on the OSI network management model, will be the tool with which we can turn the tide. We expect to begin testing this software sometime this year.

We Now Understand How to Wire the Facilities

In the early days of Ethernet we wired our building in a typical Ethernet bus manner, with coaxial cable segments throughout the buildings and taps at many locations along the segments. Today we prefer the approach used by the telephone company. That is, each office is wired with multiple unshielded twisted pair (UTP) cables for data applications. The UTP cables are run from the office to a central "phone closet", or equipment room, and terminated on punch down blocks in the same manner that the office telephone cables are terminated. The network equipment, if at all possible, is located in the equipment room as well. In most cases the LAN for the building consists of a fiber optic cable joining the building to the area backbone and which terminates in the equipment room. All building network connections are made via the UTP and termination equipment located in the equipment room.

This scheme supports virtually every required data connection including RS-232 links to LAN terminal servers, IBM 3270 type terminal connections to the IBM control unit, Ethernet transceiver connections, IBM token ring connections, and AppleTalk personal computer LANs. Our site standard today for wiring facilities is to include three UTP cables for each office occupant. This gives us a great deal of flexibility in providing data services as the office occupants move and require different services. The scheme also has the advantage of centralizing the network equipment for security and ease of location for problem corrections and maintenance.

One consequence of wiring buildings this way is the need for large, well ventilated, and adequately powered central equipment rooms for each building or for each floor or wing of large buildings. This has proved to be a major impediment to rewiring our older buildings.

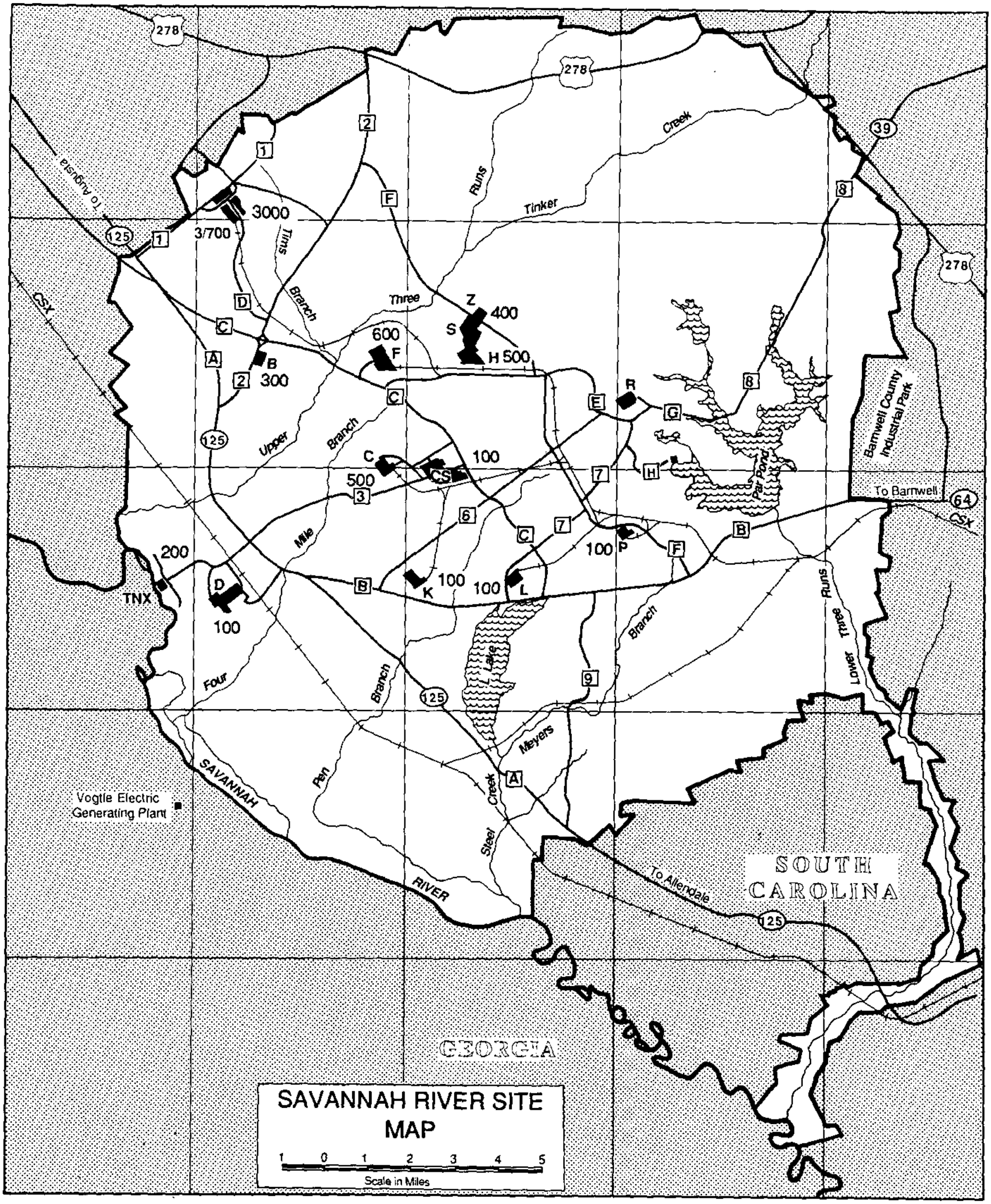

Figure 1. The Savannah River Site–Network Users

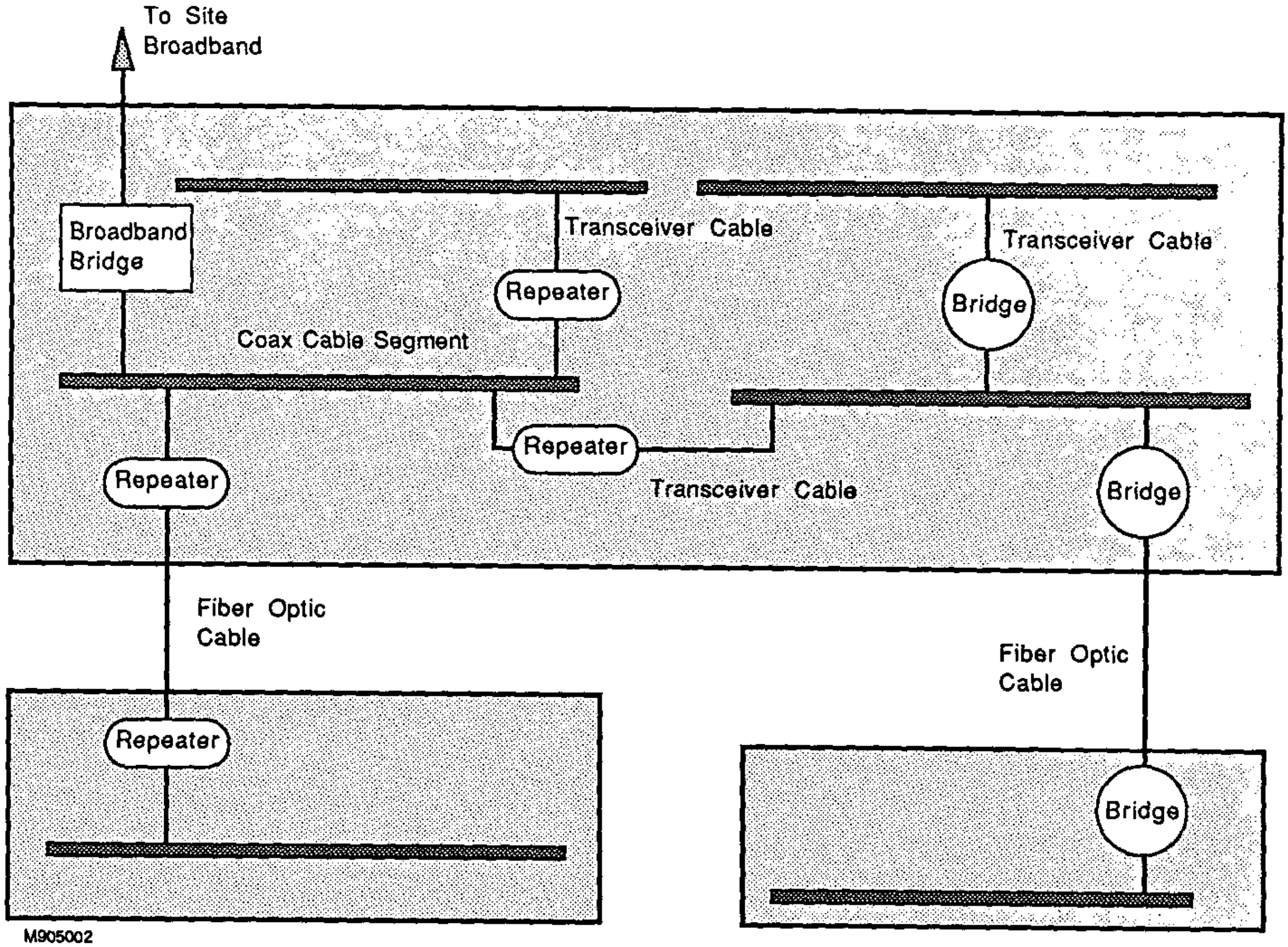

Figure 2. Typical Ethernet LAN

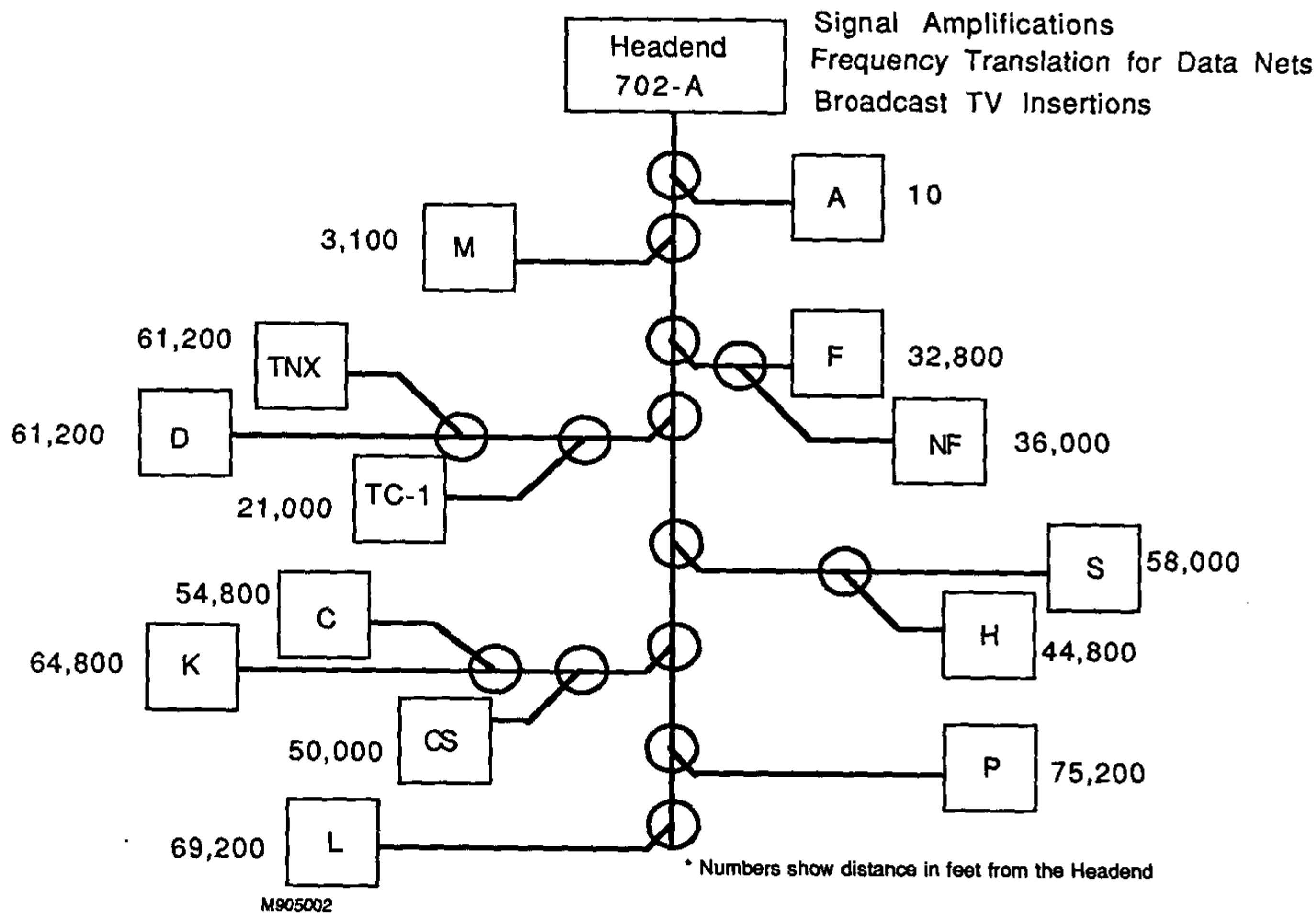

Figure 3. SRS Broadband Network*

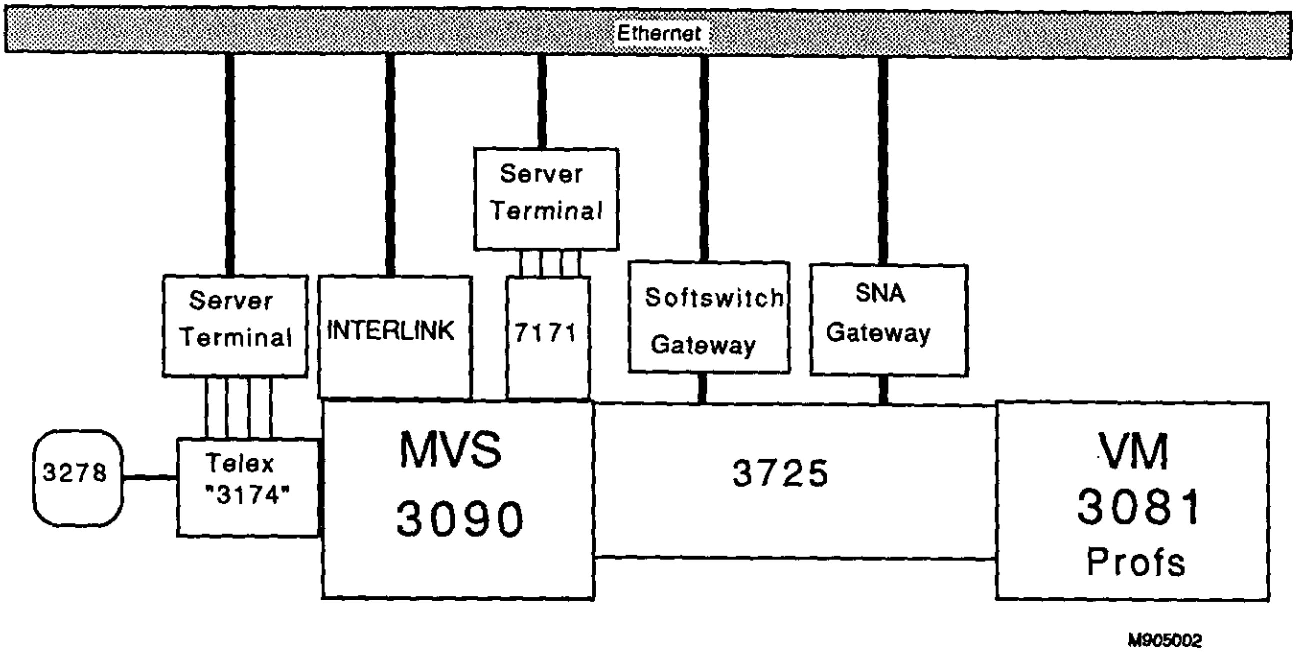

Figure 4. IBM Connections

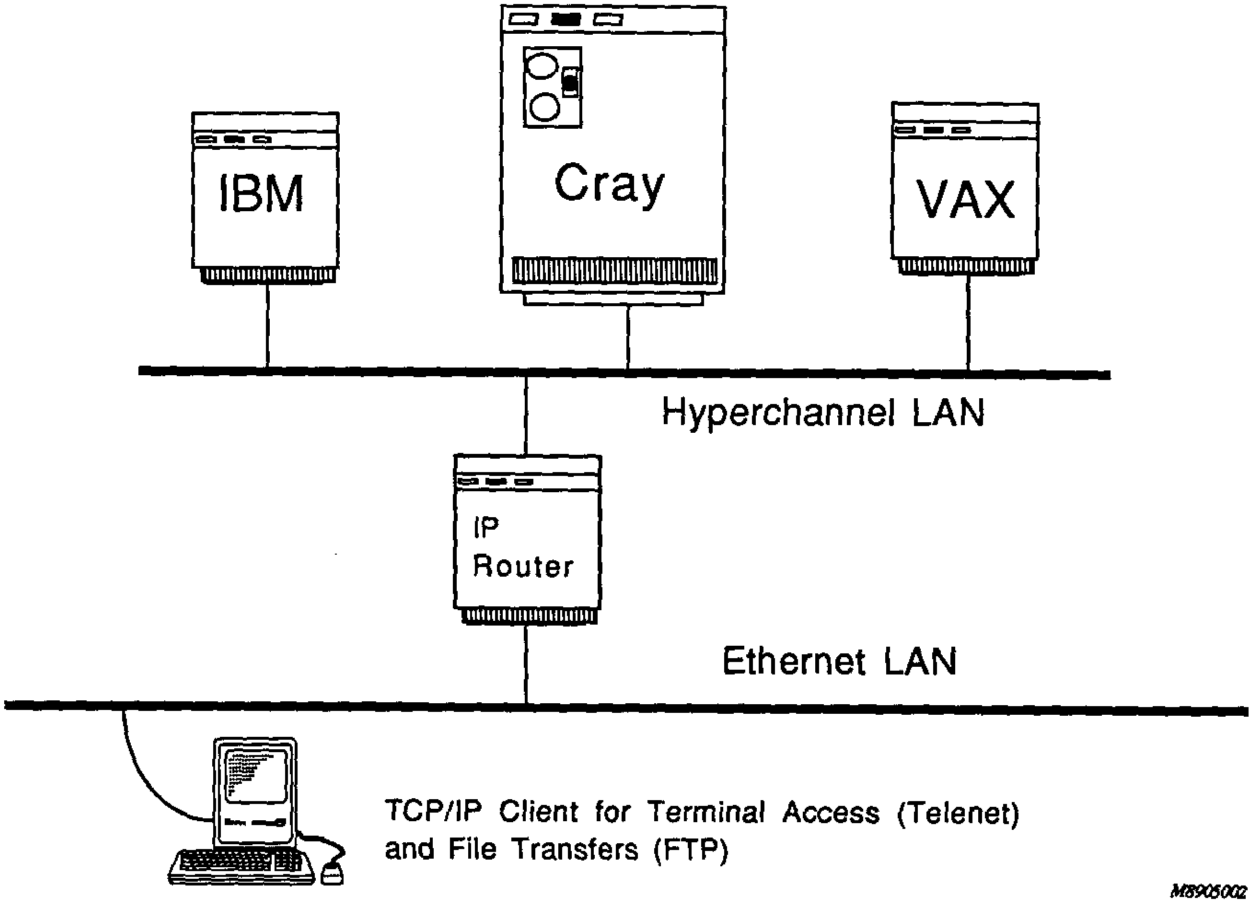

Figure 5. Cray Access

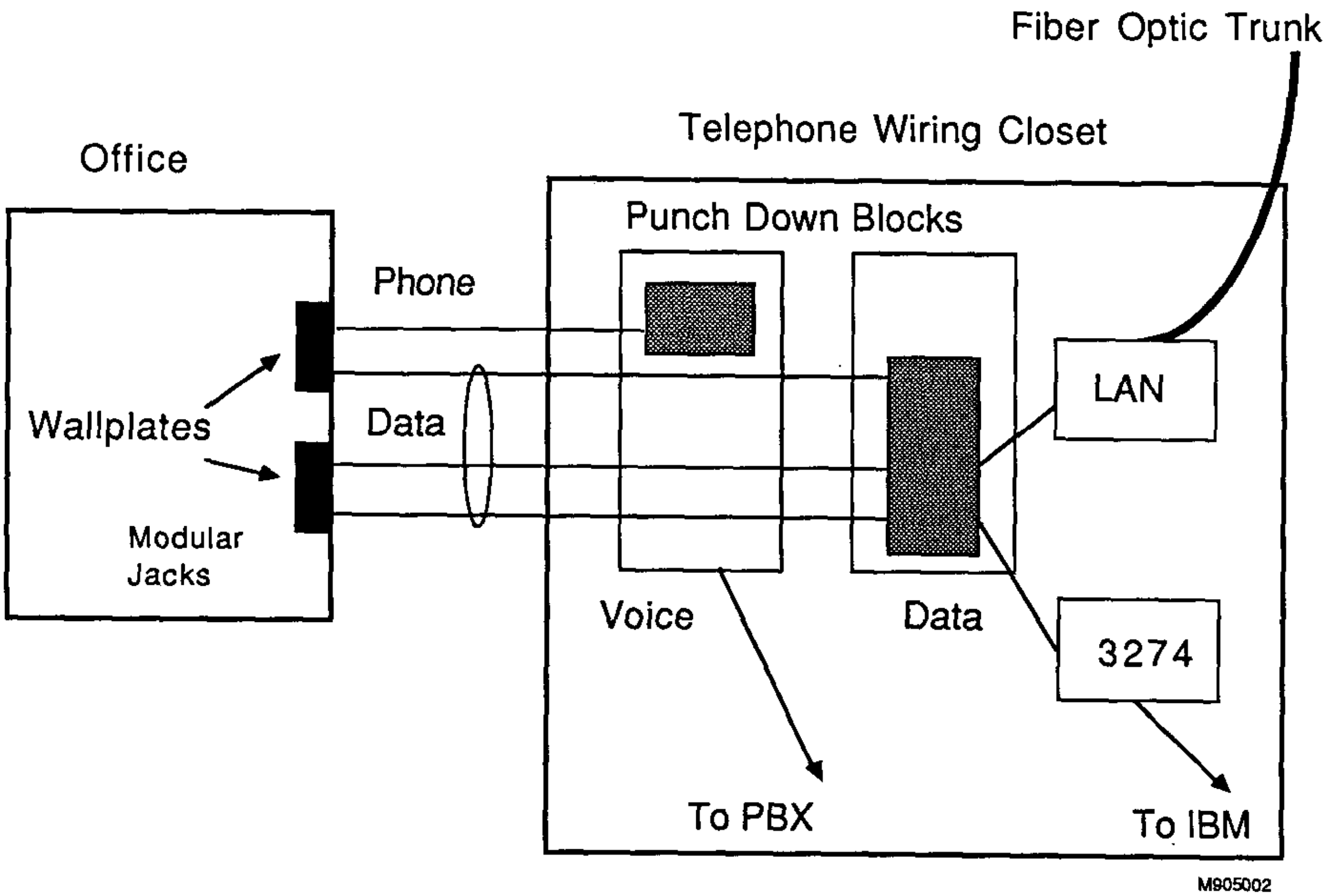

Figure 6. Universal Wiring