THE MFECC ELECTRONICS GROUP HAS PLAYED A VITAL ROLE IN THE CREATION OF THE NATIONAL MFE COMPUTER NETWORK

Shortly after its inception in late 1973, the MFE computer center at LLL began providing the computing power of a large digital computer to magnetic-fusion-energy researchers throughout the nation. The system has grown rapidly from the use of rented time on a dial-up CDC 6600 computer to a full network of PDP-10 based user service centers that communicate directly over dedicated telephone circuits with the computer center's CDC 7600/6400 central computer and central storage system. A group of engineers and technicians from the EE Department, assigned to the computer center from the beginning of the project, has made important contributions to the design and development of the network at every step in its growth.

Introduction

Our usable reserves of natural gas, oil, and coal are rapidly being depleted. Alternative sources of energy must be found quickly if we are to avert a serious national energy shortage. For years researchers at laboratories and universities throughout the country have been working on the development of a very promising source, magnetic fusion energy (MFE). With growing national awareness of the energy problem, greater emphasis has recently been placed on MFE research, including a decision to support the widespread MFE researchers with a powerful centralized computer system.

When LLL was selected as the site for the national MFE computer center on October 9, 1973, engineering support from the EE Department was requested to assist the Computations Department in designing and implementing the timeshared computer network. Since then, EE Department engineers and technicians have worked closely with MFECC management and computer scientists, and with commercial hardware manufacturers to provide MFE researchers with a reliable, powerful computer network in a very short time.

Major Hardware

Specifications were drawn up for the central computer complex, the user service centers (medium-scale DEC PDP-10 computers at the major MFE research centers), and the data communications network. These became the basis for a request for proposal, which was sent to 52 vendors on June 28, 1974. Proposals from the vendors were opened on September 4, 1974, and from September through early December three evaluation committees, each composed of computer scientists and electronics engineers, performed technical evaluations of the proposals.

The configuration selected for the network was a central computer complex at LLL consisting of a CDC 7600 large-scale scientific computer combined with a CDC 6400 file-management computer, and DEC PDP-10 computers with KI-10 CPU's at each of the user service centers (USC). The USC's are tied to the central computer through communications links and communications-control minicomputers. The locations of the six initial USC's are shown in Fig. 7. Two are located at LLL (one for M-Division and one for the MFECC). A seventh USC was added for Science Applications Inc. at La Jolla, California in December 1976.

Each USC is a PDP-10 with disk storage, tape drives, printers, and keyboard terminals. In use, a researcher may log onto his local PDP-10 at a keyboard terminal and either run programs on the PDP-10 or request that he be connected to the 7600. If he chooses the latter, he may then log onto the 7600 and run programs on it as if he were connected to it directly. While running on the 7600, he may have his files sent from the 7600 to his PDP-10 to be printed or stored on disk. Or, without ever logging onto the 7600, the researcher may develop a batch input job on his PDP-10, transmit it to the 7600 for execution, and have the output sent back to the PDP-10.

Hardware installation began in July 1975, and MFE researchers first gained access to the CDC 7600 in October 1975.

While the major hardware was being ordered and installed, EE personnel prepared specifications for expanded PDP-10 memory and for standardized highspeed keyboard terminals for all the USC's. The subsequent purchase of this hardware in large lots enabled all the research centers to save a substantial amount of money.

Interim Computer Service

While the permanent computer facility was being selected and installed, the MFECC provided distant

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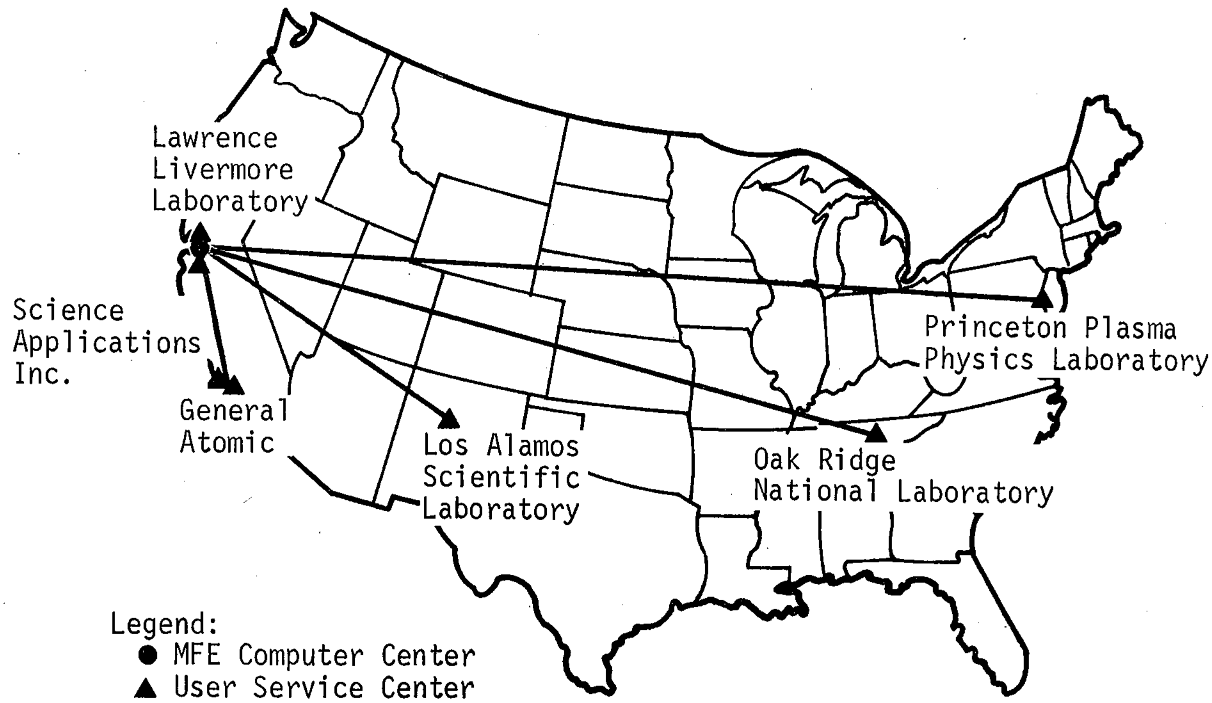

Fig. 7. **The initial configuration of the MFE computer network. The MFE computer center at LLL includes a CDC 7600/6400 central computer and its own user service center (USC) for systems development work. Six other USC's for MFE researchers are located at LLL, General Atomic, Los Alamos, Oak Ridge, Princeton, and Science Applications Inc.**

researchers with a substitute computer. The Computations Department agreed to provide MFE users with time on its CDC 6600 (the G-machine), which is an unclassified system that can be run by remote users over voice-grade telephone circuits.

In the Fall of 1974 the Princeton Plasma Physics Laboratory made an urgent request for expanded service on the G-machine so that it might prepare for use of the new computer complex. An evaluation of the alternatives led to the decision to provide Princeton with an LLL RJET (remote job-entry terminal).

A study of the bi-sync protocol used with the RJET showed that a more modern protocol would be needed to allow full-duplex operation (simultaneous transmission and reception) and improved error recovery. A new protocol was selected, flow-charted, and then programmed. At the same time, the RJET interface was redesigned to allow the 4800-bit/s Bell 208A modem to be used in the data link.

Finally, a keyboard-terminal multiplexer was designed, and software was developed to permit the interleaving of terminal traffic and RJET traffic. The entire job — including fabrication, checkout, programming, and installation — was completed in February 1975, just 3-1/2 months after the initial planning.

Keyboard Terminal Concentrators

During the initial period of service to MFE researchers, remote computer users had access to the G-machine through a DEC PDP-8 concentrator with 16 dial-up ports. When the new CDC 7600 was installed, it too was accessed via the same PDP-8, but it was clear that an improved concentraor would be required to allow access to larger numbers of users and to permit higher transmission rates.

Most of the equipment was already available to construct a PDP-11-based terminal concentrator that could handle 256 terminals at transmission speeds from 10 to 960 characters. Unfortunately, the PDP-11/CDC 7600 interface was not available, and there would be a 5-to-7-month delay to provide it. A PDP-8/CDC 7600 interface was available, so a temporary solution was provided by using a PDP-8A and its interface as a channel between the PDP-11 and the CDC 7600. The PDP-8A and PDP-11 were connected with a serial line 'souped up' to 9600 bit/s. The decision to use this configuration was made in mid-November 1975, and first user access was provided in late January 1976. Service was available on four CDC 7600 operator terminals at 10 character/s, twenty dial-in ports at 30 character/s, and eight 120-character/s ports (later converted to dial-in).

The terminal access provided by this concentrator proved to be the major facility for interactive use of the CDC 7600 until September 1976, when the 50-kbit/s network was sufficiently developed to handle terminal traffic.

The Communications Network

The communications network (see Figs. 8 and 9) consists of four wideband 50-kbit/s links, each radiating from the center at LLL to one of the remote USC's. (The new USC at Science Applications Inc. uses the General Atomic link.) The communications processors at LLL consist of a pair of DEC PDP-11/50 minicomputers connected to the Bell 303 modems of the data links through DEC DQ-11 communications interfaces. Each link terminates at the USC in a Bell 303 modem through a DQ-11 to a DEC PDP-11/40. The PDP-11/40 is connected to the USC's PDP-10 through a DEC DA28 channel interface.

Our earlier experience with the Princeton RJET convinced us of the need to be able to restart a communications processor remotely. Consequently, EE personnel designed a watch-dog circuit that has been installed in each PDP-11/40. Each circuit monitors its PDP-11/40; if the PDP-11/40 does not maintain proper activity with the timer, the PDP-11/40 will be restarted and forced to execute a program from read-only memory (ROM) that will reload and restart the communications processor program. The addition of this circuit contributed significantly to the reliability of the network while the communications software was still in the early stages of its development.

Interface Channels

Interfacing has presented a special challenge during the design and implementation of the network. Several interfacing problems had to be solved before the CDC 7600 could begin to provide service to its users. Special interfaces had to be constructed, including a channel from the PDP11/50 network procesor to the CDC 7600, a PDP-8 channel to allow a connection between the 7600 and the G-machine terminal concentrator, and a new design to allow the M-division PDP-10 to be connected to the network. The hardware needed for the operation of the 7600 was fabricated, tested, and available by the time the 7600 arrived in October 1975.

It was realized early in the design of the network that a standardized highspeed (10-to-40-Mbit/s) channel would be needed for interprocessor communication. Such a large computer network requires interconnections between computers built by a variety of manufacturers. While channels are sometimes available for interfacing different computers from the same manufacturer, they are rarely available for interfacing computers of different manufacturers. In our network, then, we might have had a large number of unique and incompatible interconnecting channels, and many would have required special design. The development of a standard channel allows total freedom of choice in interconnecting computer pairs, and it minimizes the need for custom hardware and software design.

The EE group began defining the design of such a channel in mid-1975 and arrived at the following characteristics:

- All channels consist of nearly identical hardware.
- Channels are interfaced to each computer type with a relatively simple interface.
- Channels are full duplex.
- Any standard channel can connect to any other standard channel.
- Channels can carry at least 40 Mbit/s over a distance of at least 100 m.
- There are a minimum number of wires for interconnections.
- There is automatic filling (and subsequent stripping) to any word boundary.
- Software interfaces are similar regardless of computer type.

The EE group has produced a design that exceeds the design criteria listed above. Currently, interfaces are almost ready for hardware checkout and software debugging for a CDC 7600, CDC 6400, DEC PDP-10, PDP-11, and HP 2100. The channels will allow any of these machines to connect to any other.

In a related project, a standard channel will be used to interface an electrostatic printer/plotter with a PDP-10 using a microprocessor-based interface. This provides a very cost-effective method for producing a printer/PDP-10 interface, and it significantly reduces the processor overhead in driving the printer. An interesting by-product of this standard approach is that printer interfaces are simultaneously produced for a CDC 7600, CDC 6400, PDP-11, and HP 2100 (and any other machine for which a standard interface is produced in the future).

The File Storage System

A centralized computer complex like the MFE network must provide a facility for storing data files and programs. The computer center has provided users with a two-level file-management and storage

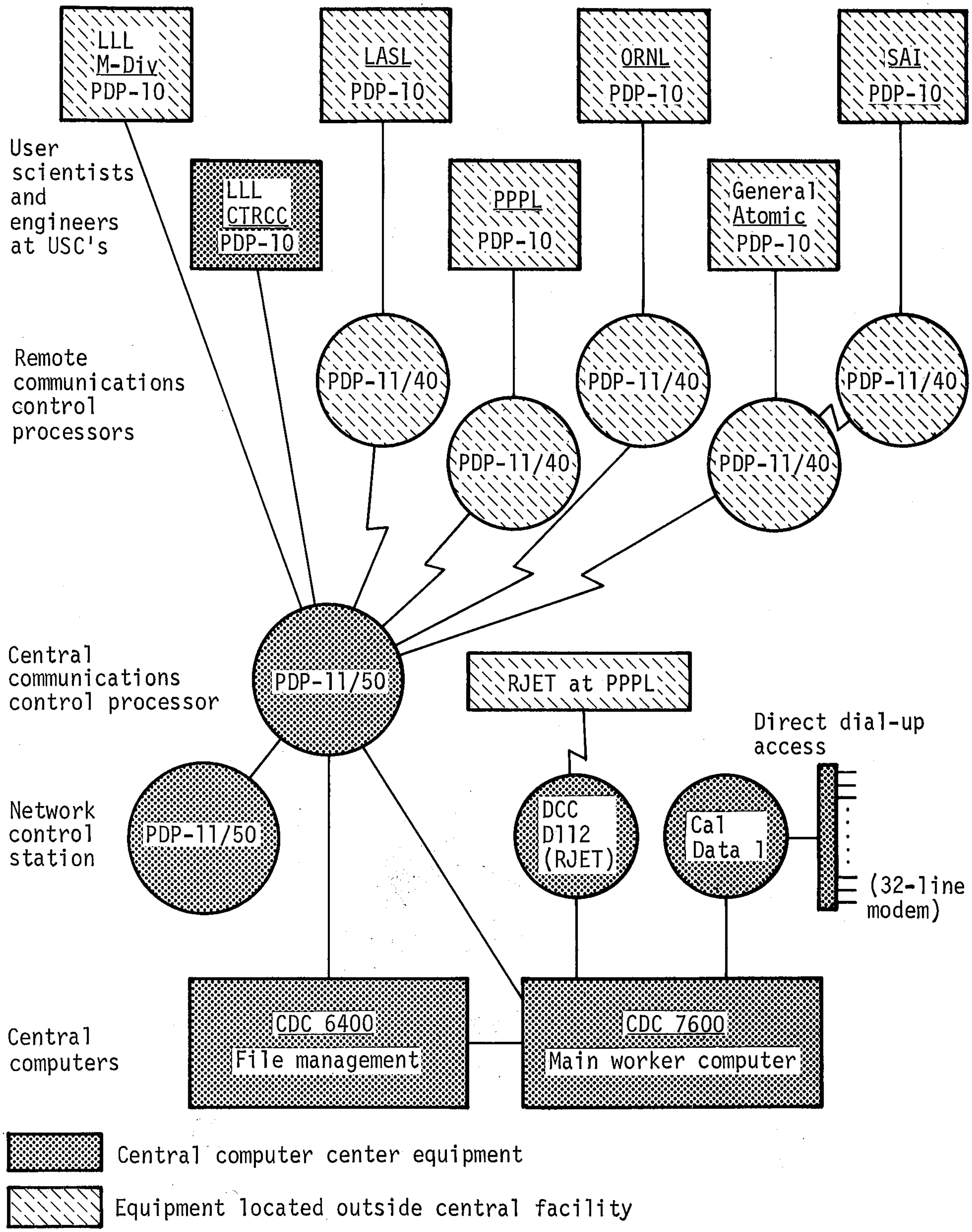

Fig. 8. **Communications links in the MFE network. The PDP-10's at the USC's are connected to the CDC 7600/6400 via a pair of PDP-11/50 communications processors.**

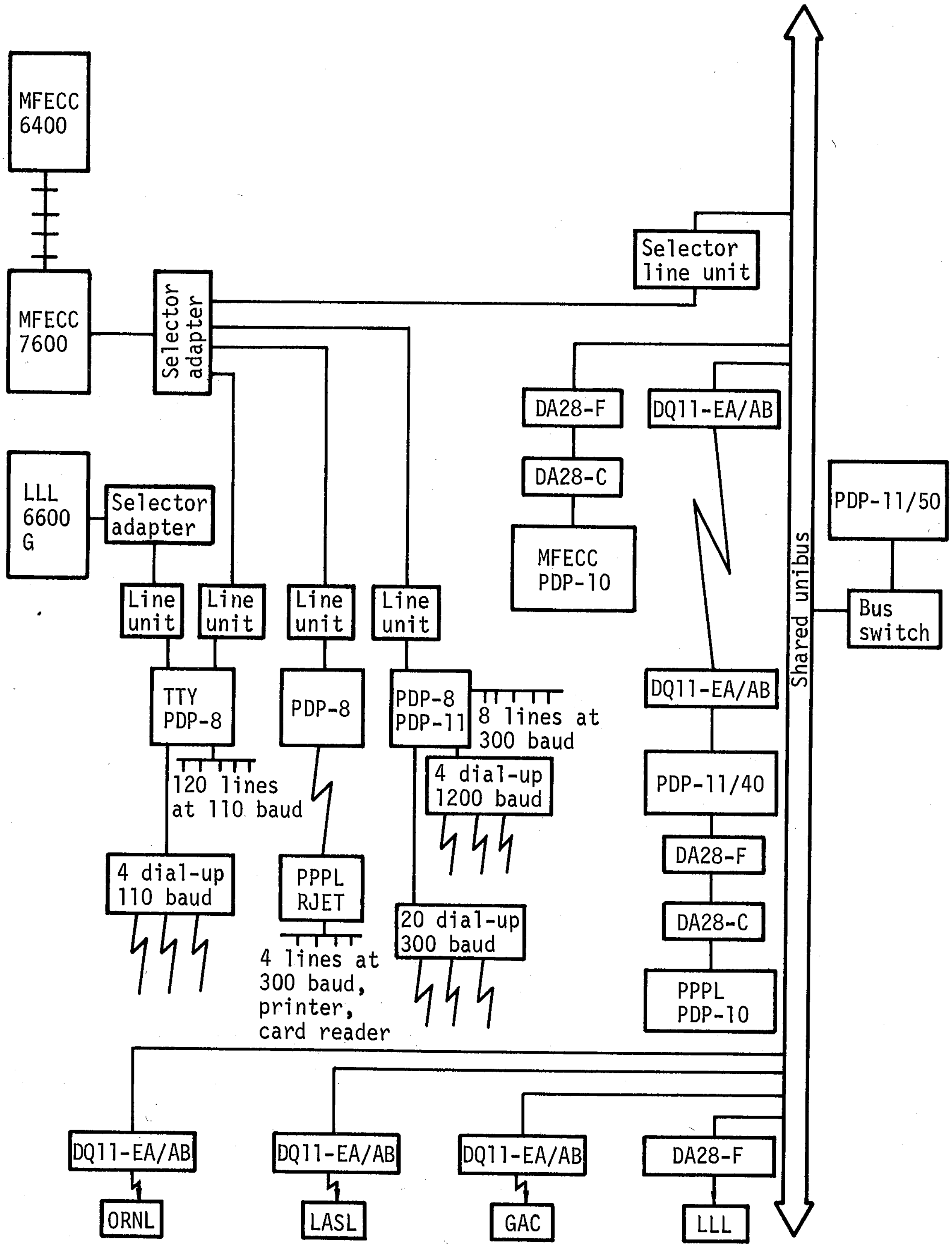

Fig. 9. **The central complex for the network. The four wideband communications links are connected to the central complex via the PDP-11/50.**

system. First-level (short-term) storage is on disk, and second-level (long-term) storage is on manually retrieved magnetic tape. The heavy volume of file traffic demands that the second-level storage and retrieval system be automated.

EE support personnel were principally responsible for a technical specification that described a 1/2-trillion-bit random-access (11 s, maximum) storage system. The evaluation of hardware and the resulting evaluation document were singled out by ERDA as models of excellence. The system selected was a CDC 38500 mass store. The system architecture will provide complete redundancy for all but one of the major components. In operation, the system will store and fetch cartridges of highdensity (6250 bits/in.) magnetic tape (see Fig. 10).

Conclusion

The MFE computer center's EE support team has contributed to the unusually rapid implementation of the MFE central computer complex and communications network. A close working relationship with MFECC personnel has allowed many quick-response solutions to be conceived and executed by using available hardware and modifying it when necesary. A permanent system is being developed now that incorporates standardized hardware interfacing and includes carefully planned maintenance for all LLL-designed equipment.

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