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ABSTRACT

The Project C-BE plan for a data communications system is designed to support a dedicated minicomputer time-shared system for undergraduate use. The system is flexible and accepts a wide variety of terminal devices for a broad range of course materials. Provision is made for expansion and updating of equipment and data, and a commonly supported transmission code (ASCII) will be compatible now and in the future. Extended BASIC is the programing language used by undergraduates throughout the system. (CH)

PLANNING A DATA COMMUNICATIONS SYSTEM FOR USE IN UNDERGRADUATE COMPUTER-BASED EDUCATION

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Computer-based education (C-BE) is a general term for one type of a number of teaching techniques designed to enhance learning through the use of a computer which interacts directly with a student. At this moment within The University of Texas at Austin, "PROJECT C-BE,"[1] funded partially by the National Science Foundation has been organized for the purpose of developing a broad spectrum of curriculum matter in the Colleges of Natural Science, Engineering, Social and Behavioral Sciences, and Humanities. The project research plan provides for an orderly and well-defined systems approach for course development using acceptable instructional design techniques. An incisive analysis of the present state of the art for the integration of computer technology into the educational learning environment must take into account a trend toward the utilization of time-sharing minicomputers and the requirements for economical and efficient data communications. This paper then is a summary and chronology of the factors used in the planning, installation, operation, and maintenance of a small scale (20 terminal) time-shared network serving a diverse group of users.

Rationale:

In establishing the requirements for a minicomputer data communications network there were major project constraints which had to be observed. These were as follows:

a. The system was to be designed for use by undergraduates at scheduled times for scheduled courses for each semester (called the production mode).

b. The undergraduate would be guaranteed access to the system if scheduled for time on a terminal.

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[1]Allan, J. J., Lagowski, J. J., and Muller, Mark T.; University of Texas "Planning for an Undergraduate Level Computer-Based Science Education System that Will be Responsive to the Needs in the 1970's" AFIPS Conference Proceedings, 1970, Volume 39, pp. 257-267, Fall Joint Computer Conference, AFIPS Press, Montvalle, N. J.

c. The initial number of terminals on the time-sharing system to be limited to 20; and these could be accessed simultaneously using commonly supported vendor software. (Extended BASIC)

d. The system reliability (mean time between failure) had to be 92 percent or better during the semester.

e. The average response time for each terminal had to be three seconds or less (using as a calculation the time that the data is transmitted from the keyboard to the time the information is received back at the display or printer portion of the unit).

f. An error rate of data transmitted of not more than one character in 10^6 characters transmitted either on "hard-wired" private lines or dial up lines via data sets (MODEMS).

g. The system had to be capable of being expanded in both storage capacity and number of data communications (multiplexer) channels.

h. The system had to operate continuously (except for scheduled down time for preventive maintenance) 24 hours a day, 7 days a week.

i. The system would be totally dedicated to interactive terminal use with no batch processing required.

j. The majority of the communications lines to be located on campus and use commercially leased private lines with provision for several data access arrangements (DAA) commercial dial-up lines.

k. That user system access security be fairly high and employ procedures that could be instantly changed to prevent unauthorized usage of the computer system.

l. That a data management system be integral to the system for recordkeeping of undergraduate data files and retrieval of information by authorized personnel.

m. That ordinary unconditioned 4KHz bandwidth voice grade leased lines be used within the network.

Discussion:

In designing the data communications configurations that would meet the requirements outlined above, an analysis was made of the types of undergraduate C-BE applications that were to be used on the system. A sample summary of the types of applications are shown in Table 1. From analyzing the applications, it was determined what types of terminal hardware were required and what data (BAUD) rate the hardware would transmit data to and from the multiplexer and central processor. The

COURSE	APPLICATION	SPECIAL FUNCTIONS REQUIRED	AVERAGE # OF WORDS IN FILE	BAUD RATE	TERMINAL CONFIGURATION	MODEM
Mechanical Engineering 366L	Use of graphic techniques for Mech. Eng. Design	Vector generation Light pen tracking Cursor control Binary storage of picture frames	5,000 (16 bit words	1200 Asynchr.	IMLAC-PDS-1 8K core with light pen	General Data Comm. Model 202-2 (E.I.A.)
Chemical Engineering 471	Simulation of on-line process control experiment (continuously stirred tank reactor)	Record copy of x-y plotted outputs, printed copy of tables of numerical data	2,000 (60 bit words)	110 Asynchr.	ASR-33 teletype Model TSP-212 timesharing x-y plotter	Omnitec 701 Acoustic Coupler (E.I.A.)
Psychology 317	Self-paced introductory Psychology course	Use of optically scanned forms for interactive on line grading & scoring of student exams	5,000 (60 bit words)	110 Asynchr.	ASR-33 teletype Decision Model OMP-650 optical mark/sense reader	Omnitec 701 Acoustic Coupler (E.I.A.)
Theoretical Chemistry 302	Computer augmented lectures using interactive CRT and Theatre Videoprojector for group display	Display of real-time interactions: computing and tutorial instructructional matter	4,000 (60 bit words)	300 Asynchr.	Beehive Model 1 CRT, Amphicon Model 260A Videoprojector	Anderson Jacobson Model 260 Acoustic Coupler (E.I.A.)

SAMPLES OF TYPES OF INSTRUCTIONAL APPLICATIONS

Table 1

final choice made was "that the data transmission rates of 110 BPS, 300 BPS, and 1200 BPS (asynchronous) should be the standard rates for all terminal devices operating in the network."[2] All terminals selected (other than teletypewriters) had to have a built-in internally switchable data rate capability. Each terminal purchased was also "wired for a standard E.I.A. RS232/C data set interface."[2] The reason for this became very obvious when certain exotic peripheral devices had to be accomodated, i.e., an optical scanner, x-y plotters, etc. Since such devices had to operate in conjunction with a terminal, the simplest method we found was the adoption of data sets (acoustic couplers and MODEMS) which contained at least one or more standard E.I.A. data receptables (the standard 25 pin connector) already built in. The E.I.A. standard data interface was selected for all terminals, and for the NOVA 820 multiplexer; the latter containing provision for up to thirty-two (32) channels. Since only 20 data ports were to be used, it was decided that each terminal would have the same priority for system access with no preemption allowed users. The operating system provided by the vendor did in fact allow those data ports using higher data transmission rates priority processing when both low and medium speed ports were accessed at the same time.

The system possessed the capability to handle a wide variance in data transmission rates ranging from 110 BPS to 9600 BPS. Since data rates above 1200 BPS require synchronous type data sets and associated synchronous multiplexer circuit cards, only asynchronous MODEMS up to 1200 BPS were planned for use. If synchronous transmission were needed, the proper circuit boards for the NOVA 820 could be inserted rapidly to accomodate the synchronous type data sets.

The Communications Configuration

The concept of a dedicated, cluster-type minicomputer time-sharing system was adopted and implemented within PROJECT C-BE. Figure 1 shows the system configuration which is now installed and operating. Basically three types of terminals are used within the system:

a. Low speed teletypewriters with paper tape punch and reader. These provide the student with a record (hard) copy of the interactive course matter. Off-line or local use of this type terminal is employed for preparation of paper tapes where retention of data or course matter is required by personnel for future use.

b. Cathode ray tube displays (CRT's) which do not provide record copy to students. This is a replacement terminal for the teletype and has the added advantage of switch selectable data transmission rates. CRT's are quiet and sell adapted to interaction use by students.

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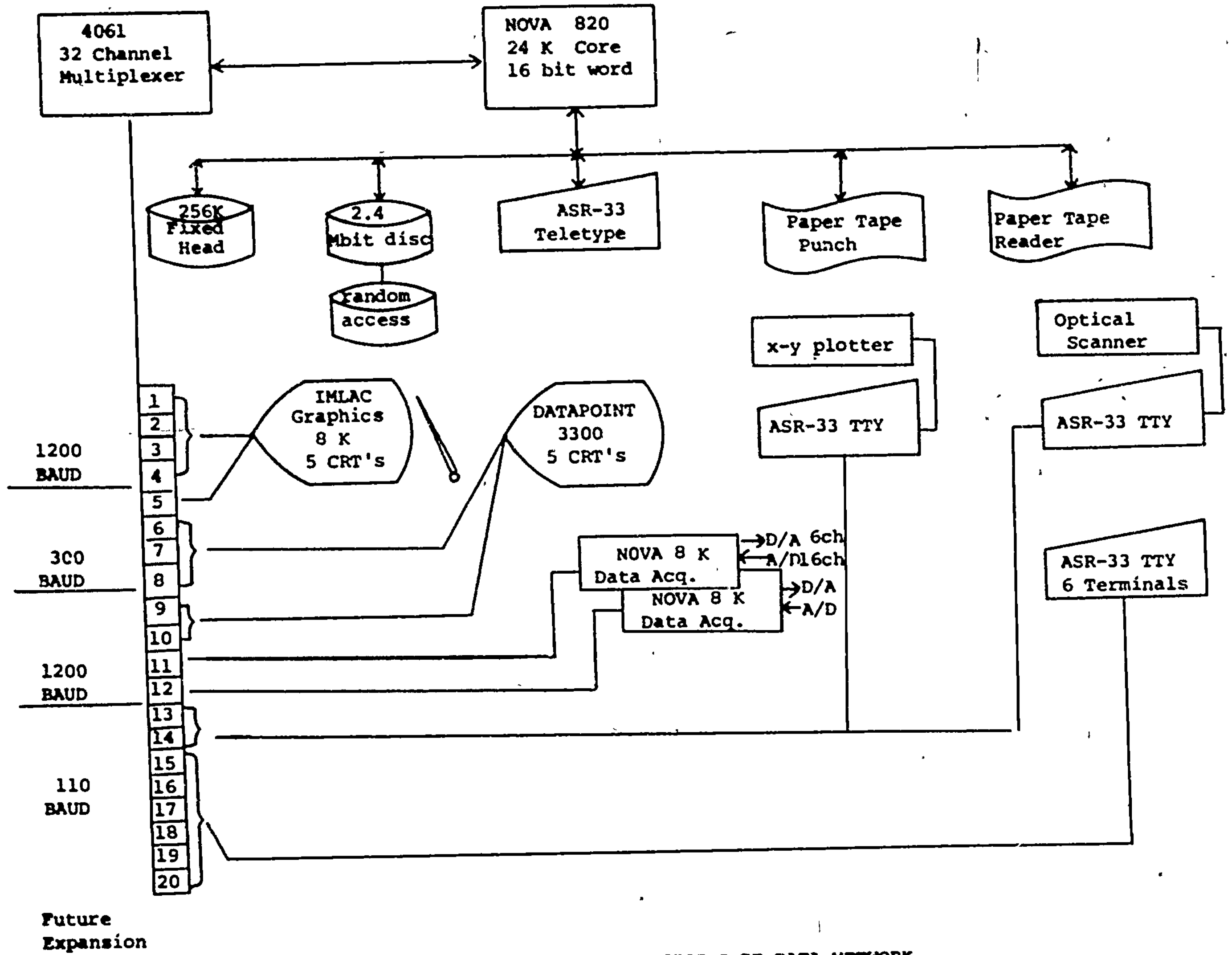
[2]Gourley, David E., "Data Communications: Initial Planning" DATAMATION, October, 1972, pp. 59-62.



SCHEMATIC OF PROJECT C-BE DATA NETWORK

Figure 1

c. Graphic terminals with stand alone capability. Included are a light pen and other types of optional accessories for special purpose interactive design applications in C-BE, i.e., graphic design, real time plotting and display, etc.

d. Special purpose terminals. These are terminals which have special interfacing plus the device attached, and are computer controlled through software commands, i.e., optical mark/sense reader, time-sharing x-y digital plotter, a random access 35mm slide projector, and a digital cassette recorder. For data acquisition experiments, specialized instrumentation and channelized transducers are linked using an analog to a digital, or digital to an analog data collection system (as NOVA 820 with 8K of core and a teletype).

In order to economize on costs and minimize the number of data sets required to operate within the system configuration--only those terminals which were external to or remotely located from the main computer room facility were provided with MODEMS for private line type service. All other terminals located in the room at the computer were "hard wired" directly to the computer communications multiplexer (without MODEMS) using an E.I.A. interface for data connections. Each user line was "wired" through a junction box using full duplex wiring. All wiring was accomplished by in-house technicians, thus requiring no monetary outlay for interior line rental other than cost of labor and materials. A standard color coding similar to the commercial telephone system wiring codes was employed on internal circuits for compatibility with external (commercial) system terminal blocks. All remote commercial lines and associated MODEMs, data plugs and receptacles were wired according to standard E.I.A. connections for rapid interchangeability of equipment in the event of trouble. Thus the repairman could diagnose trouble by an isolation of the line, data set or terminal device very rapidly simply by plug changes for trouble-shooting and diagnostics. To facilitate standardization of location identification, all terminal positions were given a permanent number, and all lines a circuit number for both internal (PROJECT C-BE installed) and commercially leased lines. A special test device found to be especially handy for use was a pocket "Data Test Set" called a "NUDATA" test set. It contains a 25 pin data set plug and jack with 25 light emitting diodes in series for use during testing to observe which pin numbers (of the data set) were transmitting signals. Thus the pins on a data plug which were required for normal data transmission and operation on common data sets could be quickly checked, i.e., Data Set Ready Signals, Data Terminal Ready, etc. It becomes very simple to check and prove whether or not the distant terminal or multiplexer is operating properly. All of the acoustic couplers (MODEMS) purchased for use with PROJECT C-BE lines and terminals were of one manufacturer's brand and designed for asynchronous low speed data from circuits 110 BPS to 300 BPS.

Parity, Error Detection and Correction System Features

Parity

All low speed terminals were wired or modified for even parity using the 64 character American Standard Code for Information Interchange (ASCII) code. This rule was not always followed as a hard and fast one because the present graphic terminals are used to access either the NOVA 820 or a larger on-campus time-sharing system, i.e., CDC-6400/6600 TSS had to be accessed using "parity disabled" because of the binary mode of transmission of information.

Error Detection and Correction

The time-sharing system employed on the NOVA 820 computer utilizes a real time disc operating system (RDOS) which provides for a very flexible interface to the asynchronous data transmission I/O rates employed within PROJECT C-BE communications lines. Input and output of all terminal data is in the form of unbuffered block transmission to and from the NOVA fixed head disc for real time operation. It also provides for a built-in error detection/correction feature.

Matching the Data Communications System to the Terminal Users Application

The PROJECT C-BE system is a very small system. It is not like the large CPU/multiplexer network now in use on campuses such as the Northern California Regional Computer Network operated by the Stafford University Computation Center, or the University of Texas Regional Network. In both of the above, the high cost of telecommunications for lines have added 20 percent to the cost of system operation. In the University of Texas TAURUS system, communications costs add on 40¢ per hour/per terminal for operations. In PROJECT C-BE, mainly leased private lines are used, and are restricted to on-campus use. The average cost of twelve private leased lines @ $1.50/month totals only $216.00 for the entire year. Assuming that two additional dial up lines with DAA were added @ $27.50 line/month, this totals $876.00 per year! It is evident that dial trunks make this type of access too costly for 20 lines! An alternate solution using two dial up lines without DAA is the purchase of "originate/answer only" type acoustic couplers which can be directly wired into the multiplexer data channel. This would require an operator for manual connection, and although the system still has the expense of two dial lines, it does allow operator control against unauthorized users.

While most of the requirements for data communications were fairly simple, some special requirements did exist as follows:

a. The use of an on-line optical scanner (mark/sense reader) for test scoring of multiple choice questions. The scanner was an auxiliary device which was attached to the teletype. We concluded that optical scanners require higher data transmission rates for rapid feedback of grades to be practical for grading student tests. As a minimum, let us say that if a 300 BPS teleprinter were used with this same scanner it would have improved the performance factor by at least 200 percent. Ideally, though, a 1200 BPS teleprinter operating at 1200 BPS setting on the present scanner would have provided the instantaneous results required.

b. The use of a time-sharing x-y-plotter connected to a teletype falls in the same category as above where at least a 30 character per second data transmission rate is required, as opposed to a 10 character per second data rate constraint with the teletypewriter. Ideally some of the newer interactive printer terminals would meet this requirement satisfactorily.

c. Multiple speed setting for data I/O requirement for graphics. Here the user requires communication with a variety of devices for input or output, and numerical print out. A modification was made to the IMLAC graphics asynchronous data channel interface which allows for a multiple asynchronous interface from either the core/buffer or the CRT. This allowed access simultaneously simply through software control as a method of handling multispeed I/O data channels.

Courseware

The C-BE curriculum matter developed to date is being used within the NOVA 820 RDOS system, and is shown in a summary contained in Table 1. As a general rule, the computer-based material augments formal lecture and laboratory instruction and does not replace either. Terminals are booked at the beginning of the semester for either one hour or half-hour time blocks by the instructor, and once this scheduling is acknowledged the priority for the user is assured. Each student is assigned to a specific terminal for a specific hour. A course proctor is present to assist or follow student performance and to cope with unforeseen contingencies, etc. The reliability of a good data communications system in a formally structured scheduled terminal facility can spell the difference between a contented student--one who can complete his on-line terminal session in a confident, happy manner--or conversely a frustrated student, due to poor data communications caused by transmission errors, noise, etc.

Conclusion

In summary, the PROJECT C-BE plan for a data communications system was designed to support a dedicated minicomputer time-shared system for undergraduate use by:

Providing a flexible general purpose (on campus) data transmission facility with a high degree of efficiency, reliability, and economy of operation.

Making provision for acceptance and use of a wide variety of terminal devices and related peripherals for a broad spectra of course materials.

Provision for future expansion and updating of equipment and data channels as the "state of the art" changes or advances.

Use of a commonly supported transmission code (ASCII) that vendors will support now and in the future with inherent features of compatibility (E.I.A.) and reliability.

Use of a commonly supported programming language (Extended BASIC) that the undergraduate can readily learn and use throughout his college career.

Provision for a utility type of facility designed to be used only where and when necessary for undergraduate enhancement of learning through the use of computers to augment formal instruction.