The NOAA/ERL COED System

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I should have included Anthony Brittain, Dan DeChatelets, Dave Lillie, Kathy Browne, Mark Emmer, Sky Stevenson, and Vernon Schryver as authors when I wrote this. All in all, they made, jointly and individually, more contributions to the COED system than I did. I'm not sure how I ended up giving this talk at VIM-26.

INTRODUCTION

Computer Services, a division of the National Oceanic and Atmospheric Administration (NOAA), Environmental Research Laboratories (ERL) in Boulder, Colorado, provides research computing services for NOAA's research labs, part of NOAA's Environmental Data Service (EDS), the Boulder-based divisions of the National Bureau of Standards, and the Institute for Telecommunication Sciences. Services are provided by a CDC 6600 running the KRONOS operating system and an XDS 940 dedicated to interactive computing.

The NOAA/ERL COED (communications and editing) system is a front-end network designed to provide flexible synchronous and asynchronous communications to all host computers, file sharing between hosts, a central text editor, a central repository for all permanent files, and insulation to the users from changes in the host computers. A custom operating system and redundant hardware provide "fail-soft" operation. The network is currently composed of four MODCOMP minicomputers.

Although the project is not yet complete, COED currently provides full-duplex asynchronous communication for about 50 TELEX terminals at speeds from 110 to 9600 bps (bits per second), and synchronous communication for EXPORT at speeds up to 19.2 Kbps for the CDC 6600. One hundred Mbytes of COED file storage are being used by the XDS-940 computer. Asynchronous communication through COED for the XDS 940 is very close to being installed.

This paper describes the part of the NOAA/ERL COED system in use as a front end system handling remote job entry (RJE) and interactive (EXPORT and TELEX) terminals. Section 1 summarizes the history and design goals of the COED system. Section 2 describes COED's current usage, advantages, and disadvantages. Sections 3, 4, 5, and 6 describe and explain the implementation hardware, software, protocol for RJE terminals, and protocol for interactive terminals. In section 7 future plans and some measurements are discussed.

1. HISTORY AND DESIGN GOALS

Several years ago Computer Services recognized that the growth of interactive terminals and RJE terminals would exceed the capacity of its XDS 940 and CDC 3800. There were other problems such as the necessity of using magnetic tapes to transfer files between computers, an unreliable and obsolete disk storage system on the XDS 940, and the lack of a permanent file system on the CDC 3800. The COED system was invented as a solution to the problems. It would store permanent files accessible to the host computers (the 940 and the 3800), handle as many terminals as necessary at high data rates, and provide an editor.

During the design phase of the COED project the XDS 940 provided the only permanent file storage available from Computer Services. At that time the 940 would regularly go down for a period of days because of disk hardware failure, with the usual consequences to all of the 940 users but also to a great many CDC 3800 users who used the 940's permanent files and very convenient text editor for program maintenance. The inability to run programs during the crashes was distressing but the inability to access and edit files was devastating. Experiences led to the design of a "fail soft" system in which a single hardware failure would not crash the entire system but would allow the unaffected part of the system to continue running, providing degraded (and possibly limited) service. The "fail soft" capability was to be implemented by redundant hardware and software that would dynamically reconfigure the system when a hardware failure occurred.

Further design goals were to provide a system which would have a fixed set of protocols for connection to host computers so that the COED system could be connected to a "big X"[1] computer when it arrived to replace the CDC 3800 without changing the protocols.

The COED system was also designed to be independent of its hardware so that if it becomes necessary to replace the hardware, the users would not have to even know of the replacement.

2. COED STATUS

COED has been operational for about 18 months serving as a front-end system controlling up to eight RJE terminals using the CDC 200 User Terminal protocol. In addition, for the last 9 months all access to TELEX for a maximum of 56 asynchronous Teletype-compatible terminals has been through COED.

One of the RJE terminals runs at 19.2 Kbps, three at 9600 bps, one at 7200 bps, one at 2000 bps (over hardwired or leased lines), and one terminal at 2000 bps on a dial up line. The printer and card reader on these terminals will run at full speed (1000 LPM and 600 CPM on the 19.2 Kbps terminal, 600 LPM and 400 CPM on the 9600 bps terminals).

COED can handle a wide variety of interactive terminals at speeds from 110 to 9600 bps. Terminal variations and dial-up bandwidth limitations result in most terminals running at 300 bps. There are eight dedicated lines with modems that will run up to 9600 bps, 11 hardwired lines that can run to 9600 bps, three high-speed (up to 1200 bps) and 28 low-speed (up to 300 bps) dial-up lines. Thirty more low-speed dial up lines will be added when the XDS 940 is using COED for asynchronous communications.

There are at least seven Tektronix storage-tube interactive graphics terminals on high-speed (over 1200 bps) lines. These terminals are heavily used. Also at least three terminals are being used for high-speed data entry, with one terminal (actually a minicomputer) sending data at 9600 bps.

The advantages of the COED front-end system for TELEX users are that it supports high-speed terminals, allows true full-duplex operation, and provides for more convenient usage. For example, one convenient feature allows a user to stop and later restart data transmission to the terminal by typing one or two character commands. This allows the user to transmit data to a CRT at high-speed but read it at his leisure. A user could also stop a noisy mechanical printer while he receives a phone call without losing any data.

Full-duplex operation and a 64 character input buffer allow users to "type ahead" several commands even

[1] The "big X," in the form of a CDC 6600, replaced two CDC 3800s before anything was connected to the COED system.

if TELEX is not ready to accept any of them. Another very convenient feature is that COED determines the transmission speed of the terminal from the first character typed, and the second character specifies the terminal type. Thus any dial-up phone number will work for any speed terminal (within constraints of the modem), and from the terminal type COED computes the number of timing characters required for the Carriage Return and Line Feed operations. COED provides much more convenient paper or cassette tape operation by automatically turning off the tape reader when buffers are nearly full and turning the reader back on when the buffers empty.

There is one slight disadvantage: the COED system is not exactly the same as the standard TELEX system because of slightly different dial in, program interrupt, output interrupt, and paper or cassette tape procedures. Thus the KRONOS reference manuals are not completely correct. Some potential problems are: decreased reliability due to another computer system and lack of support for correspondence code terminals. The COED hardware and software has proven to be quite reliable, however, and correspondence code terminal support is scheduled to be available starting September 1977.

3. HARDWARE CONFIGURATION

Figure 3.1 shows the hardware configuration of the CDC 66ØØ. The main item of interest is the (modified) MODCOMP-CDC Satellite Coupler, model 1941. This computer link is the pathway for all messages between TELEX and EXPORT and their associated processes in COED.

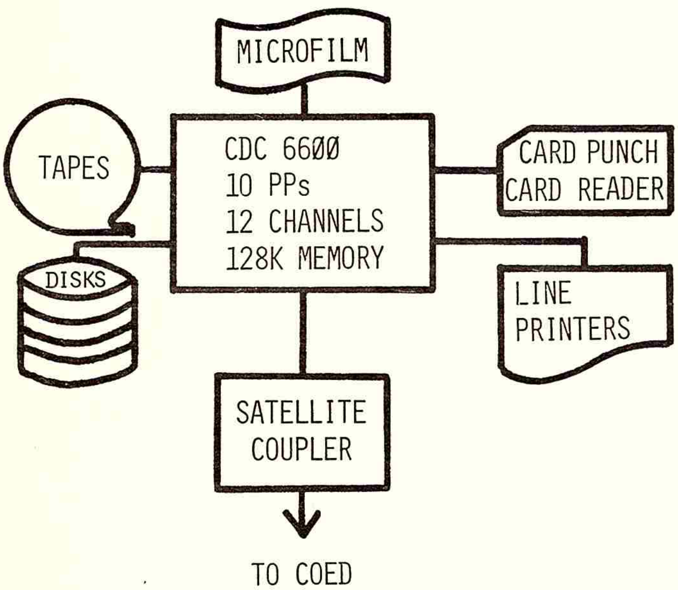

Figure 3.1 CDC 66ØØ Configuration

Figure 3.2 shows the hardware configuration of part of the COED system. The main items of interest are the (modified) Model 1941 Satellite Coupler (CPU link), the Model 19Ø7 Communications Subsystem, Model 2 (mux), and the Communications Processor Macro Plane (CP). The 1941 coupler, or CPU link, is modified so that it will do all the repacking necessary to copy three 16-bit MODCOMP words to four 12-bit PP words, or vice versa. The mux is the synchronous and asynchronous communications interface, and the CP option allows high-speed core-to-core data moves with optional translation or editing.

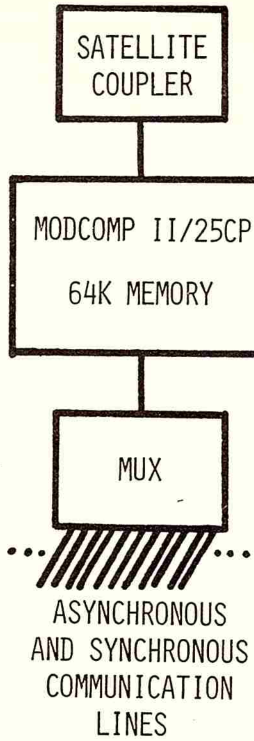

Figure 3.2 COED CPU Ø Configuration

4. COED OPERATING SYSTEM

The COED system runs under the CORTEX (COED real-time executive) operating system, which provides a variety of utility and I/O executive services and allocates CPU time to jobs on a priority basis. Certain jobs in the COED system are symbionts. They have all the privileges of ordinary jobs (e.g. making executive service requests) but also have the responsibility of emulating I/O devices. Thus certain I/O requests are handled by jobs (symbionts) while others are processed by the device drivers at interrupt level. Another feature of CORTEX is that a job may establish an I/O path to another job, rather than only to peripheral devices. In particular, a job called COIN (COED interface) establishes an I/O path to TELEX and a job called RJB (remote job entry terminal boss) establishes a path to EXPORT.

There are two separate full-duplex I/O paths between the 66ØØ and COED (one between COIN and TELEX and the other between RJB and EXPORT), but the 1941 CPU link is only a half-duplex device, and there is only one link. Two levels of protocol result in the emulation of multiple full-duplex data paths. First, the CPU link drivers on both the 66ØØ and COED CPUs are programmed to emulate a single full-duplex path. Second, a link symbiont program multiplexes the link among all of the paths through it, thus making the solitary half-duplex link appear to be an arbitrarily large set of full-duplex links.

The link symbiont in the 66ØØ runs in a resident PP along with a (modified) EXPORT driver (1ED), a process (we call it 1TX) that communicates with the (modified) TELEX driver (1TD), and an executive to allocate PP time to 1ED, 1TX, or the link symbiont on a round robin basis.

Figure 4.1 summarizes the various jobs, processes and I/O paths.

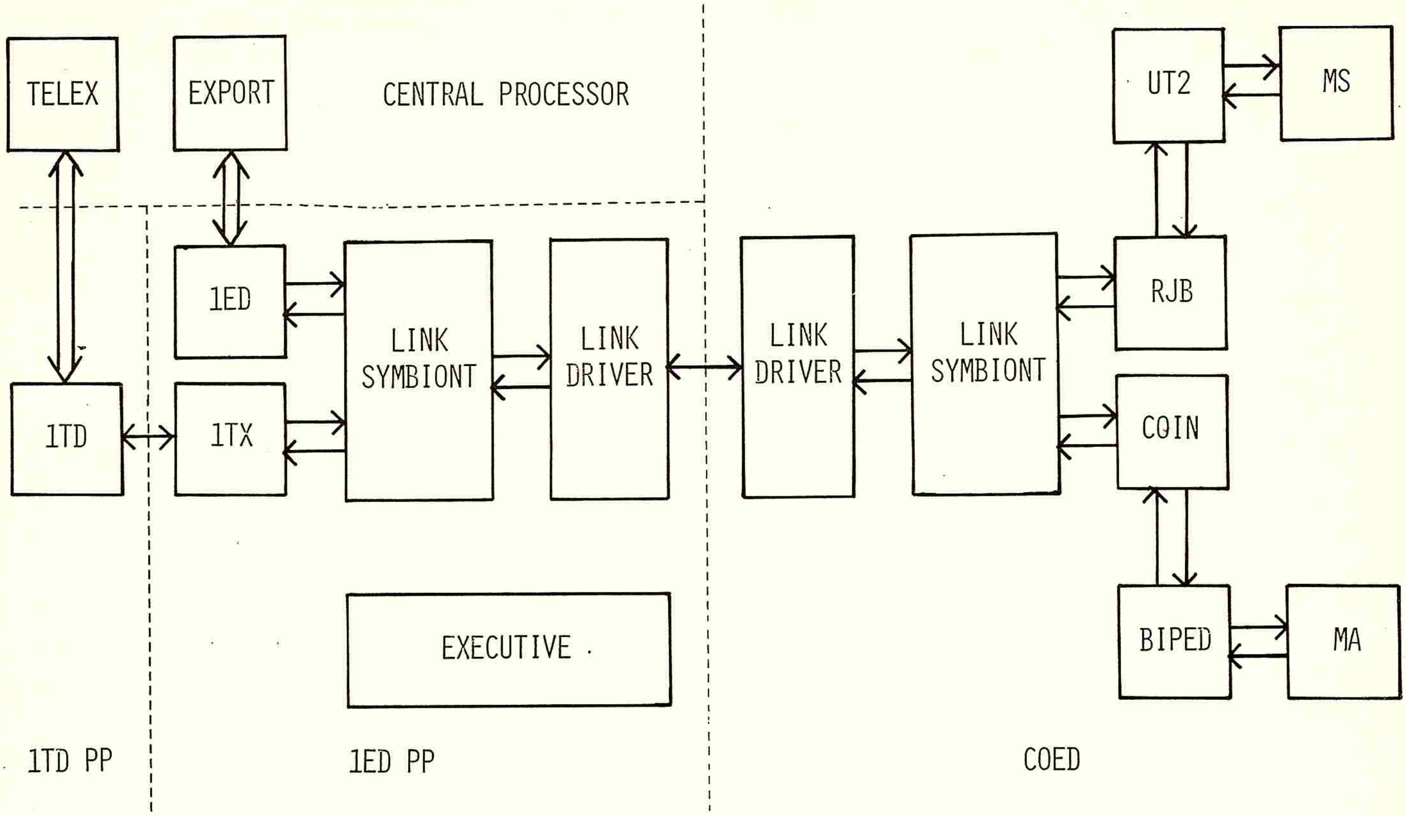

Figure 4.1 Process Configuration

5. RJB PROTOCOL

EXPORT and RJB communicate via a simple protocol in which each message is one function. EXPORT sends control functions to RJB which indicate that EXPORT is up or going down and data functions which indicate the terminal number, the destination for the data (console screen or line printer), other control and status information, and the data. The data always corresponds to a line on either the printer or the console display screen. RJB sends functions which always indicate the terminal number and the terminal and printer output buffer status. The input data function also indicates the source of the data (console keyboard or card reader), the data (again a line from the keyboard or a card from the reader), and some further status for end-of-record or end-of-information from the card reader.

The protocol is such that reading cards requires one message per card to be sent from RJB to EXPORT. It is assumed that EXPORT can handle incoming cards faster than all the terminals can send them and there are no interlocks on data sent to EXPORT. If EXPORT can't handle incoming data for some reason, however, no data is lost. Rather, all terminals are slowed down to whatever average rate EXPORT can handle. EXPORT can generate print lines faster than the terminals (and COED) can handle them, and the RJB protocol has an interlock for each terminal which requires RJB to send an output buffer status update message to EXPORT periodically (currently at most every two lines). Thus at most three messages are required for every two lines printed on a terminal. Output buffer status updates for more than one terminal may be combined into one message if the timing is right, resulting in lower overhead when more terminals are busy.

The changes to the EXPORT system are primarily localized in the central program E2ØØCP and the driver 1ED. The executive and special function processors, 1LS and XSP, remain substantially unchanged. The driver, 1ED, was changed extensively and shortened to support the RJB protocol. 1ED gets a whole line from the line buffer and sends it to RJB or gets a card image from RJB and puts it into the line buffer. The way in which E2ØØCP packs and unpacks lines and card images between the mass storage (CIO) buffers and the driver's line buffers was changed slightly. The driver (including buffers) occupies about 1.3K words. It shares the PP with the link symbiont which occupies about 1.8K words and 1TX which occupies about Ø.8K words (with buffers).

RJB gets functions and data from 1ED, but does not convert them to 2ØØ UT protocol itself. Rather, it translates the RJB protocol to a protocol based on a COED virtual synchronous terminal (CVST). The CVST was invented to provide a method of operating on an RJE terminal independently of the terminal's actual protocol. The COED system will include a different symbiont to emulate a CVST for each different actual terminal protocol to be used. This will allow EXPORT to use terminals that don't use the 2ØØ UT protocol. The only symbiont so far implemented, UT2, emulates a CVST given a terminal which uses the 2ØØ UT protocol. MS (the mux synchronous driver) actually does the input from and output to the terminal for UT2 and all other symbionts that use synchronous terminals.

6. COIN PROTOCOL

TELEX and COIN communicate via a rather complicated protocol, due to the great flexibility of interactive terminals. A wide variety of functions allows TELEX to: specify terminal modes and codes (such as binary, half-duplex, or the number of timing characters to be used between lines), output data, request input, set input wake up conditions (COIN should send characters immediately or wait until a character in the wake up set

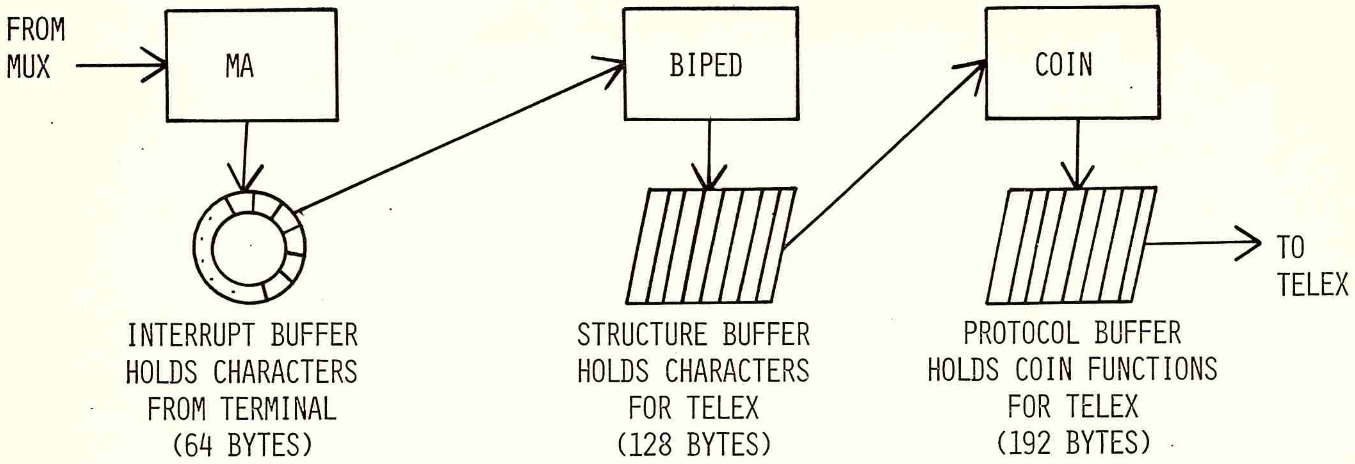

Figure 6.1 Input Data Flow

has been typed), et cetera. Likewise, COIN can: signal TELEX that it is ready for more output data, send input data, inform TELEX when the BREAK key on the terminal is depressed, inform TELEX of current terminal status, et cetera. Interlocks prevent either TELEX or COIN from overflowing each other's buffers. As many functions as possible (or necessary) are packed in each fixed length message, with different functions requiring different amounts of room.

Data sent in the COIN protocol input and output data functions is either 8-bit binary characters which will be sent to the terminal uninterpreted and untranslated or ASCII characters packed in 8-bit bytes. COED will translate ASCII characters into whatever character set is used by the terminal. As with the RJB protocol, the COIN protocol allows a substantial amount of data per terminal to be sent in a message. This allows TELEX to send about 128 characters of output data at a time. TELEX requires that COIN send input data on a line-by-line basis, but the use in TELEX of the ESC (escape) character to delete a line and the BS (backspace) to delete a character result in TELEX setting an input wake up condition of "wake up on control characters". COED then buffers input characters until either the byte count in TELEX's read request is satisfied, the buffer is full, or a character in the wake up set is typed.

COIN processes all of the functions from TELEX, but it doesn't actually do the terminal I/O. Functions from TELEX are passed on to a program called BIPED (bi-directional partial editor) which processes requests based on a COED virtual asynchronous terminal (CVAT). BIPED uses MA (the mux asynchronous driver) to do the actual I/O on the terminal. MA puts input characters into the input interrupt buffer, where they sit until TELEX sends a read request function. If the interrupt buffer is nearly full, MA attempts to turn off the terminal's paper or cassette tape reader. If the interrupt buffer is full and another character is typed, the character is lost and MA sends a BEL character to the terminal immediately to let the user know that the character was lost. When the interrupt buffer empties the terminal's tape reader is turned back on. When BIPED is processing the read request function, it moves the characters to another buffer (the structure buffer) where they sit until a character in the wake up set is typed, the structure buffer is full, or the byte count from TELEX's read request is satisfied at which time BIPED causes COIN to send the input data to TELEX. Figure 6.1 shows how characters are routed through the interrupt, structure, and protocol buffers.

Full-duplex terminals have independent printers and keyboards, thus requiring input characters to be echoed (sent back to the terminal) if they are to appear on the printer. Half-duplex terminals require that line feeds be echoed for carriage returns and vice versa. BIPED does echoing as the characters are moved into the structure buffer, thus keeping typed-ahead commands and data in proper order on the printout or CRT screen at the terminal. COIN protocol functions are available to specify that certain classes of characters should or shouldn't be echoed, with echoing to start and stop on specific characters. This is useful in keeping passwords from printing on the terminal.

Output from TELEX proceeds in a similar fashion, with COIN transferring data from the output data function to the output structure buffer and requesting BIPED to send the data. BIPED converts the characters as necessary and fills the output interrupt buffer, requesting that MA actually output the characters. MA empties the output interrupt buffer, but allows the user at the terminal to stop and then restart output by sending control characters DC3 (control S) and DC1 (control Q) respectively. Figure 6.2 shows how output characters are routed through the protocol, structure and interrupt buffers.

The major change to the TELEX system was in its driver, 1TD, which was modified for the COIN protocol. 1TD now sends as much output data at one time as possible, sends read request functions, and then stores the incoming data. Communication between TELEX and 1TD, and the programs TELEX, TELEX2, 1TA, and 1TO all remained basically unchanged except for cosmetic work and a few changes required by the slight incompatibilities of the COED system.

7. SYSTEM DESIGN

The preceeding sections describe the part of the COED system and its design in current use as a front-end system for a CDC 6600. Many of the capabilities and design features not used for the 6600 front-end system were ignored. This section describes future plans and gives some performance measurements for the COED system.

Figure 7.1 shows the ultimate configuration of the COED system and host computers (such as the CDC 6600 and the XDS 940). The bilateral symmetry is to allow "fail soft" operation whereby failure of a single component allows the unaffected part of the system to continue running with degraded performance. The MODCOMP IIs are dedicated to communications processing while the

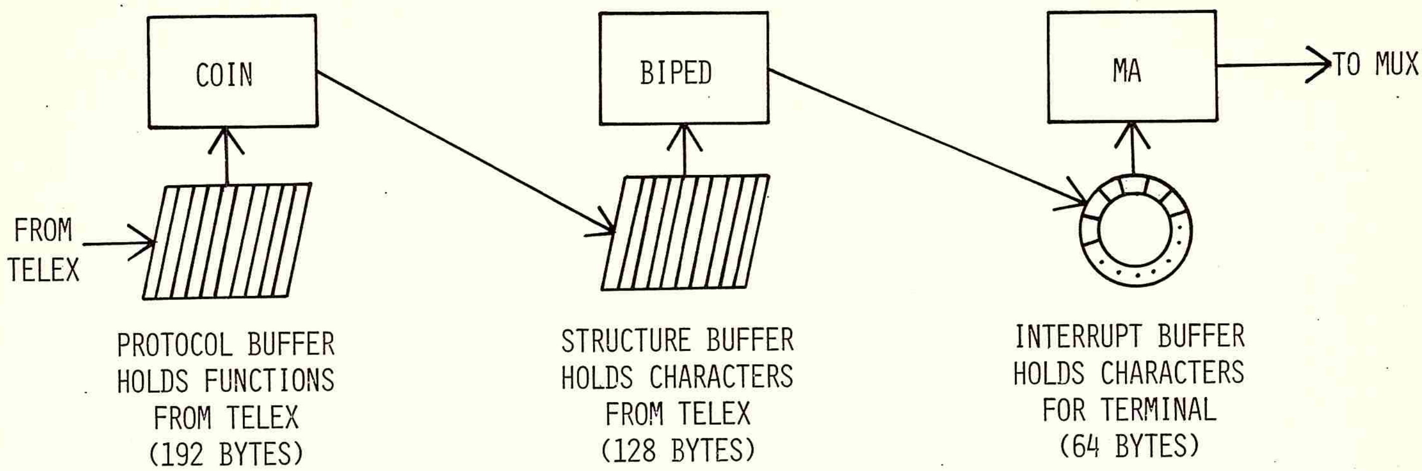

Figure 6.2 Output Data Flow

faster IVs handle the heavier computation and I/O loads of text editing and permanent file management.

The links to the host computers (and within the COED system) require a sophisticated network management system. The management is distributed among all CPUs that are intermediate nodes on a path between any two CPUs. Thus all COED CPUs have network management software as part of the link symbiont. All host CPUs are dynamically informed of the network configuration and status. The link symbiont protocol allows messages to be routed through intermediate CPUs, allowing processes in a host to communicate with processes in any other CPU.

The COIN job that interfaces with BIPED is called a head COIN, and TELEX's driver, 1TD, is actually a tail COIN. Other tail COINs will exist in the XDS 940, other host CPUs, and the MODCOMP IV CPUs, where a time-sharing executive program and an editor will provide file and file directory maintenance and editing. Special executive commands will connect a terminal to any host. Other processes, called COIN edges, will allow implementation of command files and command programs (somewhat like KRONOS procedure files) whereby input from a file is supplied as though it came from a terminal and output is intercepted to be analyzed, saved on a permanent file, or perhaps sent out to the terminal.

BIPED will be upgraded to handle line editing functions (thus reducing link traffic and overhead in CPUs with tail COINs), handle correspondence code terminals, and use a fixed-head disk for buffering. Symbionts for RJE terminals of different protocols will be added as necessary.

A file management system for COED is currently being designed and implemented to allow COED to store permanent files for hosts. Sequential or indexed-sequential text files will be stored using the ASCII character set and will be converted as necessary for the file system of any host requesting the file. Files of other access methods will be stored as bit strings and will be meaningful to the host that created them.

Thus the different hosts can share text files and the user can edit text files using the COED editor. By putting the communications, editing, and file storage processes in the COED system, users can be somewhat insulated from changes in host computers since a command language, the file and file directory formats, and an editor will remain constant across changes in host computers.

The COED system performance has been good. Reliability is now high, with system restarts necessary only rarely (at most every few days), certainly less often than deadstarts on the 6600. Line printers and card readers on RJE terminals run full speed (300-600 CPM and 400-1000 LPM). Average output rates on interactive terminals at 9600 bps are 600-800 characters per second on a loaded system. Although the rates are 15%-40% below the maximum of 960 characters/second, they are adequate. Most terminals run at 300 bps, at which speed there is no degradation. Even during busy periods, the COED CPU is idle about 60% of the time.

CONCLUSIONS

The COED system is built on a solid basis of layered protocols (link symbiont, RJB, and COIN) and virtual devices (CVST and CVAT). This approach has been very effective in allowing us to bring up the system in a reasonable time. TELEX was modified, the COIN protocol designed and implemented as COIN, and MA and BIPED written by three people working mostly (but not exclusively) on the project for about 6 months. The modifications to EXPORT and writing RJB, UT2, MS, and the 6600's link symbiont required about 12 man-months of three peoples' time, spread out over a 9 month period. The tail COIN for the XDS 940 is currently being debugged and has so far required about 2 man-months of labor.

The design goal of providing high-speed terminal access to host computers has nearly been met. The goal of providing "fail soft" operation is partially implemented in the network management routines of the link symbiont and in coding conventions for jobs like RJB, COIN, and UT2. The permanent file system and time-sharing executive are currently being implemented, and the final editor design and implementation is awaiting completion of the file system. The design goals for COED have proven realistic and implementable.

The NOAA/ERL COED system is a reliable, convenient front-end system which greatly enhances the KRONOS TELEX and EXPORT subsystems, allowing the use of high-speed terminals for remote job entry, time-sharing, and interactive graphics applications.

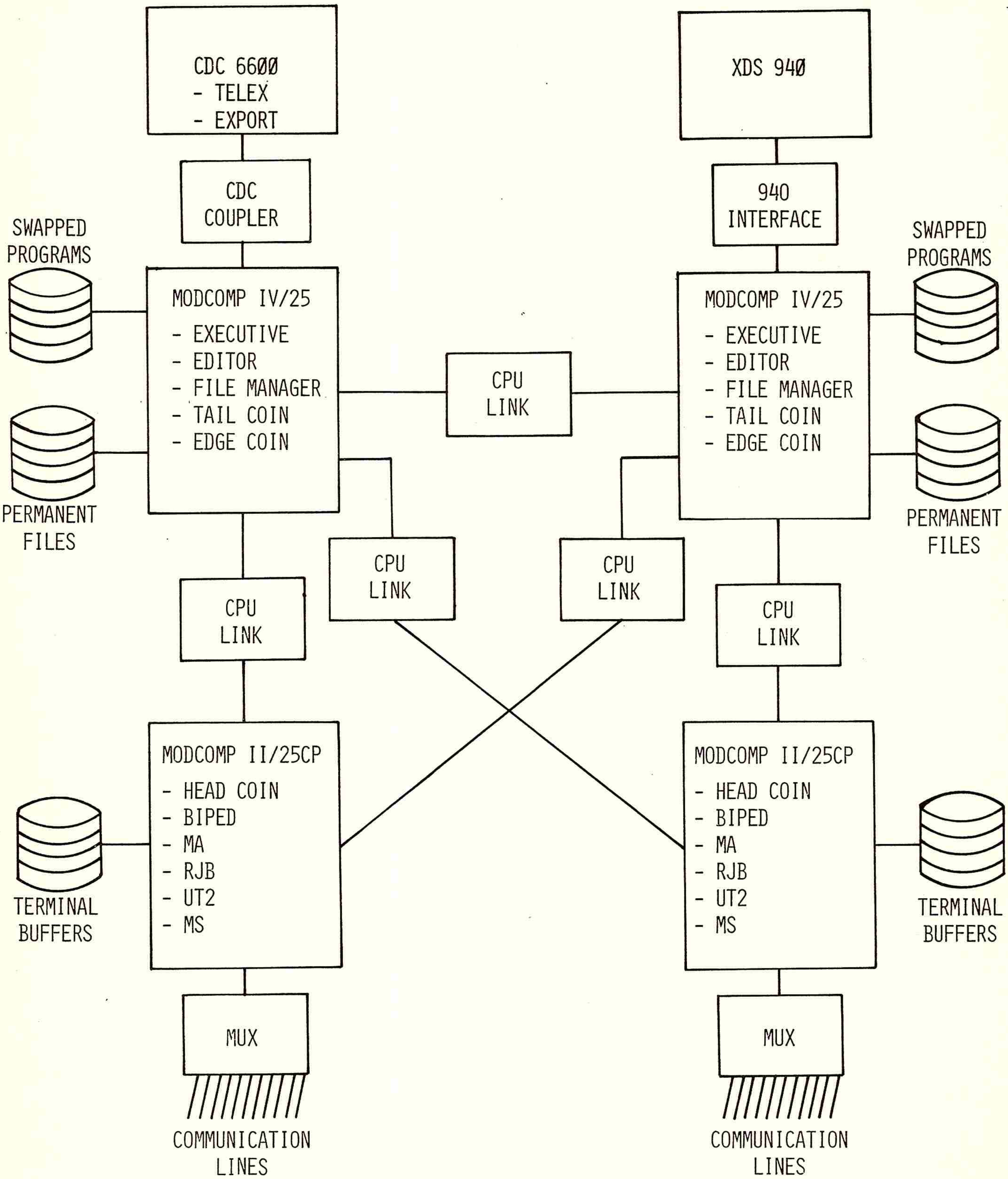

Figure 7.1 Full COED System Configuration