THE ANATOMY OF AN X.25 BASED EMS APPLICATION (AND HOW WE PRINT THE MAIL)

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Summary

This presentation describes the architecture of a multi-vendor electronic mail system (MCI Mail), concentrating on the innovative Hardcopy Distribution System supported by HP1000s and HP3000s with 2680A Laser Printers. The basic system consists of six Digital Equipment Corporation (DEC) VAX clusters and three HP1000s located in a central facility, and a number of HP3000 based print sites located across the United States and Europe. The components of this system are connected by a private Bolt Beranek and Newman (BBN) X.25 packet switching network which uses a combination of 9.6 and 56 kbps lines, largely derived from the MCI Telecommunications Transmission System. There are three operational centers, one of which monitors and controls the hardcopy system exclusively.

This paper will include an overview of the network components and system architecture, but will focus on the transmission and processing of hardcopy bound mail. It will also describe our implementation of a Graphics Design Center which supports the use of letterhead and signature graphics, and will touch on our plans to provide a communications path to support print sites located on foreign public data networks. The scope of this paper does not provide for a detailed description of each and every feature or capability of the electronic mail system.

This paper is divided into four sections covering the Packet Network, the Electronic Mail System, the Hardcopy Distribution System, and the support of "Off-Net" Print Sites. To facilitate the presentation, a "simple" network configuration diagram is presented in Figure 1.

The Packet Network

The packet switching network is made up of five major components: Packet Switch Nodes, PADs, the Network Authentication Server, the Server Maintenance System, and the Network Operations Center. The switching subsystem is made up of packet switch nodes (PSNs) which are interconnected via MCI long-haul microwave or optical fiber trunks operating at 9.6 or 56 kilobits per second.

Packet Switch Nodes

There are over 50 packet switches in our network, each of which can support up to 30 host connections and 14 trunk lines, the total of which is constrained to 44 or less. Each PSN can support a throughput rate of approximately 300 packets per second, counting one for a packet which enters and leaves the PSN. The network interfaces to service hosts and PADs by way of the CCITT X.25 protocol, and utilizes the balanced Link Access Protocol (LAPB) version of CCITT standard High Data Level Link Control protocol (HDLC). Data rates up to 56 kilobits per second are supported for host and PAD access to the PSN.

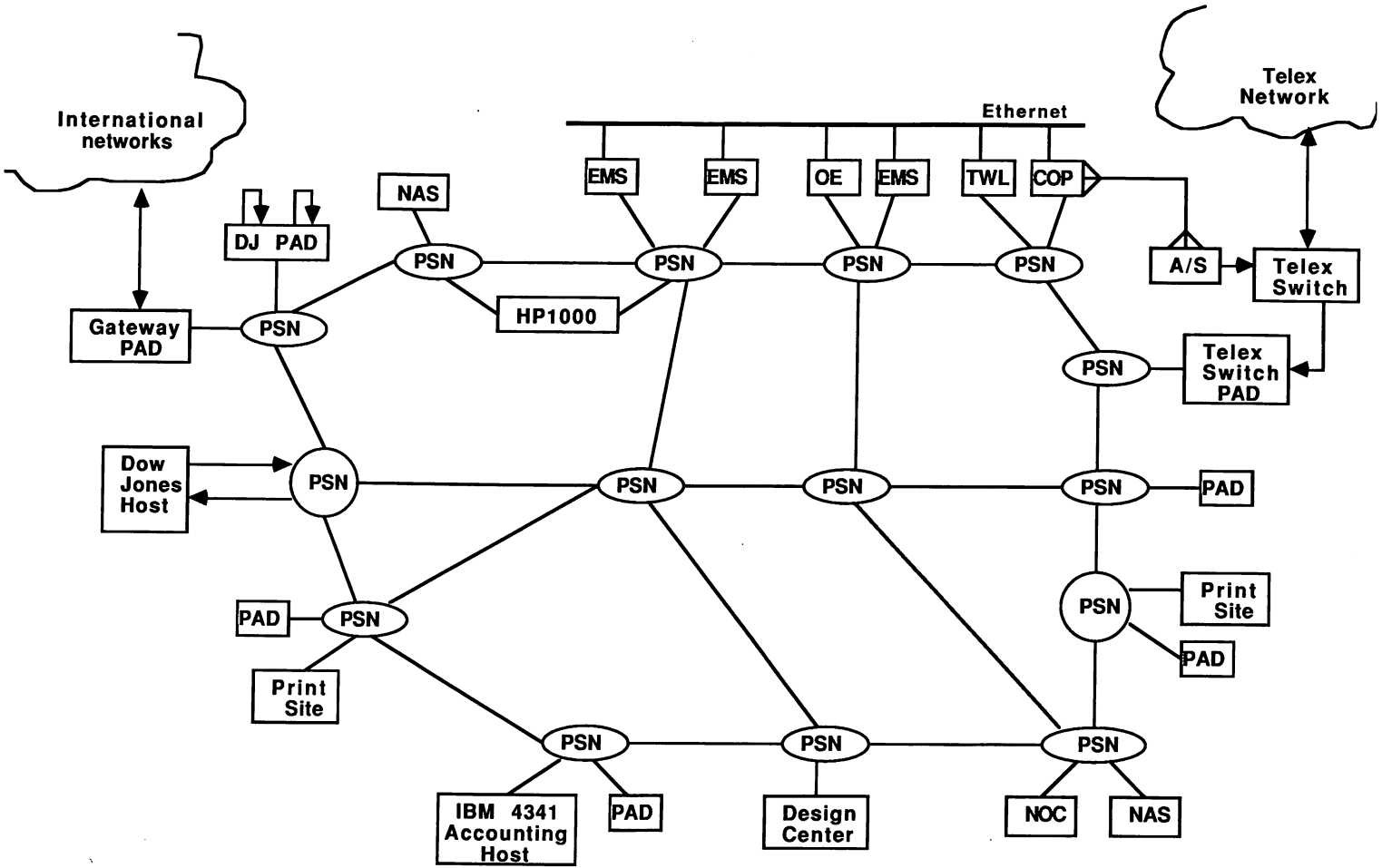

Figure 1: "Simple" Network Diagram

In addition to the link level reliability provided between hosts and PSNs, the inter-PSN protocols in the network permit adaptive alternate routing in the event of network congestion, line or node failure. These features preserve end-to-end virtual circuits even when intermediate nodes or lines fail.

Packet Assembler/Disassembler (PAD)

The next component of the packet network is the PAD. This device supports external access to the electronic mail system from dial-up and hard-wired terminals, Personal Computers, Word Processors with asynchronous dial-up support, Telex devices which use Direct Distance Dialing, and other asynchronous access devices. There are approximately 60 PADs in the network, each of which support up to 64 devices operating at speeds up to 19.2 kbps. Our system currently supports 110-1200 baud asynchronous dial-up, and special hard-wired services at 4800 baud. For our Document Processing service, special provision for the support of word processors operating bisynchronously at 2400 baud is also provided.

Two special PAD variants, the Gateway PAD and Telex Switch PAD, provide special purpose interfacing to domestic and international public packet switch users, the Dow Jones News/Retrieval Service, and the Telex user community.

Network Authentication Server

Access to the electronic mail system is controlled by a special processor called the Network Authentication Server (NAS). There are three NASes in our network to support both load sharing and reliability. Each NAS has a database that contains information for all registered users of the system, and PADS are able to access any NAS for purposes of user authentication. The database contains login names, a one-way encrypted password, the corresponding mailbox identifier, the network address of the host serving the mailbox, and a table of user service privileges.

All users accessing the mail system begin by establishing a connection from their device to a local access PAD. The access PAD prompts the user for username and password. This information is sent, in an encrypted form, to any one of the NAS servers, where the information is checked against the database. Once a user is validated, the NAS provides the access PAD with the network address of the user's mail host. The access PAD then establishes a virtual circuit to that host, and the mail session begins.

The NAS databases are updated daily by means of a Server Maintenance System which runs as an adjunct to the Order Entry System. On a daily basis, changes to the registered user database which must be reflected in the NAS, such as password changes, addition of new users, movement of mailboxes among service hosts, removal of users, and changes in user service privileges are communicated to each NAS using a private application protocol between the host running the Server Maintenance System and each NAS.

Network Operations Center

The monitoring of the network is accomplished by another special processor called the Network Operations Center (NOC) which uses a special interface to the network to access internal processes operating in each PSN. Each PSN reports periodically to the NOC the status of all attached hosts and trunks, throughput, alarms, and abnormal conditions. The NOC is also capable of monitoring the status of all network PADs. Statistics on the use of PAD ports can be collected for analysis.

The NOC is capable of remotely controlling the reloading of operational software into any of the packet switches. Consequently, the propagation of new software or recovery from a node failure is readily accomplished. The NOC can also distribute new releases of the PAD software by downline loading the operational programs through the network.

The Electronic Mail System

A multi-cluster system, situated in a central facility, acts as the focal point for the electronic mail system. Physically, the system is made up of DEC VAX 11/780s and 11/785s which are organized into six clusters of four processors each. Each cluster supports twenty four large (404 mbyte) disks which are sharable among all processors in the cluster. The system supports disk shadowing so that the 24 disks in one cluster are organized as 12 shadow pairs. Any data written to one of a shadow pair is also written to the other. A disk failure does not cause any loss of service and a new disk can be installed without interruption of service.

Each processor is connected to a 10 mbps Ethernet to support high speed transfers both within and between VAX clusters. Each VAX is also connected to a packet switch and it is this connection that permits PAD users to access the mail system and to accommodate communication between these VAXen and with hosts not connected to the Ethernet.

The Mail System

Users may use the electronic mail system either interactively or in batch mode. Interactively, there are two classes of service: basic and advanced. The basic service is menu driven and supports the basic creation, editing, reading and sending of electronic mail to other electronic mailboxes, Telex users, or to one of the print sites for postal or courier delivery. The advanced service is command driven and provides users with more capabilities. All users, basic and advanced, have access to the Dow Jones News/Retrieval service and may exchange messages with the Telex community.

Each mail host has access to a copy of a relational database containing all registered subscribers of the mail system. During message creation when users enter addressee names, they are looked up in the database and any ambiguities or failures to find matches are instantly reported. The service permits a correspondent to be addressed by his formal name, user name, or the unique mailbox identifier.

The batch electronic mail service is requested by the user when initially connecting to the mail system. This service gives access to a subset of the interactive services and is oriented around the requirement to support computer based interfaces to the mail system. The batch service provides an exchange protocol permitting the caller's PC or mainframe to stay in synchrony with the mail service, handshaking at each major step to assure completion and to report any problems in a machine understandable fashion.

Each VAX-mail host also has an administrative subsystem that includes an accounting facility which logs information about user sessions and message deliveries (including hardcopy and telex). On a daily basis, every VAX sends this accounting file over the network to an IBM 4341 which functions as the accounting host. The administrative subsystem also maintains logs of system activity, error messages including any user encountered problems that may be detected by either the application software or the operating system. It also accepts daily updates to the user databases produced by the Order Entry system which is described in the next section of this paper.

Order Entry and the COP

There are two "special purpose" VAXen in our central facility. One is the Order Entry (OE) machine. The Order Entry system is the means by which the registered user databases are maintained and it is through this system that user information is added, deleted, or modified. The system provides customer service personnel with full interactive access to the user database permitting the entry and editing of user records. The system also supports interactive access via the network to the accounting and invoicing database maintained on the IBM 4341. The Order Entry system is the originator of all database transactions to the EMS database and, through the Service Maintenance System, to the NAS databases.

The second special purpose VAX is called the COP (which doesn't mean anything...it functions as a traffic COP) whose purpose is to interface the electronic mail system with the Telex community. Every registered user of our mail system has a unique Telex number which is simply the mailbox identifier preceded by the characters 650. A telex sent to one of these 650 numbers comes through the Telex switch which has a connection to the Telex switch PAD mentioned earlier. This PAD is linked to the COP through the packet network and a special process turns the incoming telex message into an electronic mail message and delivers that message to the user's INBOX. In addition to sending messages to other registered users and to the hardcopy system, mail users may also send messages to domestic or international telex machines. In this case, the system reformats the message for injection into the MCI International Telex Store and Forward AUTOSAFE system, which automatically transfers the call to the Telex switch.

The Hardcopy Distribution System

One of the innovative features of the mail system is the ability to send hardcopy or "paper" mail to specific message recipients. The Hardcopy Distribution System is made up of four components: the Hardcopy Relay Agent which runs on the VAX, the HP1000 which serves as an interface and router, the HP3000 based print sites (called Digital Post Offices or DPOs), and the Graphics Design Center which maintains the master graphics database.

If a user wishes to send a hardcopy letter to another registered user, the mail system will look up that recipient's registered address from the EMS database which becomes the mailing address. If the recipient is not a registered user of the service, or the registered recipient is not at the "home" address, the originator has the ability to supply a postal address for the recipient. The registered address of the message originator is used as the return address.

Another special service offered by the mail system is the Telex World Letter (TWL). This service permits Telex users to address and send telex messages from their devices that are to be printed at one of our HP3000 based print sites and delivered by the postal service. This service allows telex users to take advantage of our hardcopy system without being registered as mail users.

Though the message is created on a VAX which serves the user as a mail host, copies need to be transmitted over the packet network to the appropriate print sites, based on the postal code of each recipient, where the copies will be printed on a 2680A Laser printer. This requirement caused some problems initially as HP3000s insist on using DSN/DS as the [OSI model] transport layer protocol and DS was not (and is not) available on VAX equipment. The "normal" methods of transferring data files between VAXen and HP3000s were not acceptable: tape transfers were obviously not appropriate due to time constraints and geographic separation of the DPOs and VAX facility, and RJE sessions did not support the overall design concept of the electronic mail system, and would have been both expensive and inefficient.

The solution was to introduce HP1000s between the VAX and the HP3000. The HP1000 has two modem cards installed, each of which is connected to a PSN. One modem card is used to communicate with the VAX using the the DSN/X.25 communication package and a simple file transfer protocol (SFTP) transport layer developed internally to facilitate file transfers among multi-vendor host computers. The other modem card uses DS/1000-IV to communicate with the various print site based HP3000s, using DSN/DS as the Transport Layer protocol.

The hardcopy system provides the user with the ability to specify that a letterhead is to be printed on the first page of the message, and whether or not a signature graphic is to be printed. Of course, this requires that the user register the letterheads and signatures with the mail system. The mail system will not permit a user to reference a letterhead or signature graphic that is not associated with that user's mail account.

Hardcopy messages can be delivered by one of three methods: the postal service, courier for next day delivery, and courier for Four Hour, same day delivery in some locations. When a user has created the message and posts it, the mail system checks the country code, postal code, and priority for each recipient. If the user has requested a delivery option not available in the recipient's area, the system will not post the message but will warn the user and permit the editing of the envelope.

Hardcopy Relay Agent

After the message has been posted by the user, a copy is delivered to a special mailbox which is serviced by the Hardcopy Relay Agent (HCRA). The HCRA processes only those recipients that are to receive the message in hardcopy form. As a message may contain any number of recipients, because there may be different delivery options specified for the hardcopy recipients, and because the monitoring, tracking, and accounting must be done for each copy, each postal recipient is handled as a separate unit. Based on the combination of a recipient's postal code, country code, and delivery option, the HCRA determines which print site is to receive and print the message.

All hardcopy traffic is transmitted from the Hardcopy Relay Agent to the one of the Hardcopy Distribution System Interfaces (HP1000s), which in turn transmit the print files to the appropriate remote print site. Each print site has a primary HP1000 associated with it, and the VAX will attempt to send all hardcopy messages to the primary HP1000. If the HP1000 is unable to accept the print files, the Hardcopy Relay Agent will send the print files to an alternate HP1000. Each VAX may send hardcopy traffic to any of the HP1000s, and each HP1000 can communicate with any HP3000 print site. Interestingly enough, each HP1000 believes it is the only HP1000 in the network, but what it doesn't know won't hurt it. While the hardcopy environment is capable of being supported by a single HP1000, three are used for backup and load leveling purposes.

The HCRA knows the node names of each of the print sites, but not the network addresses. Instead, each print site is initially associated with one of the HP1000s and the DTE addresses of these HP1000s are known to the VAX. An output queue process exists for each HP1000 in the network. The HCRA takes each message and places it into one of the output queues. Within each output queue, the messages are maintained in priority order.

After the message has been sent from the VAX, acknowledgments are returned from the remote print sites, permitting the HCRA to keep track of successful processing of each hardcopy message. These acknowledgments are used by the HCRA to generate accounting transactions, monitor the status of individual messages, generate return receipt notifications (if requested by the originator) and to maintain the status database of the hardcopy system.

The Hardcopy Distribution System Interface

The Hardcopy Distribution System Interface (HP1000) serves as the "router" of hardcopy traffic and provides operational personnel with an overview of the state of the hardcopy environment.

When the connection to the HP1000 is opened by the VAX, all print files are transmitted in one session over an X.25 virtual circuit using SFTP. The HP1000 is responsible for examining each print file to determine the target remote print site and the priority of the message. The HP1000 is capable of receiving print files from every VAX simultaneously, and places these print files in the appropriate queues, based on the target print site, and the priority of the message. These queues are maintained internally in the memory of the HP1000, and the queues may be viewed or manipulated by authorized operations personnel. It is possible to move the contents of one print site's queue to another, and it is possible to instruct the HP1000 to always send a particular queue to an alternate print site. Manipulating queues only effects the eventual print site that will process and print the letter. The priority of the message is never changed.

When the HP1000 has print files in its queue for a particular print site, a connection to that print site is made, using DS over an X.25 virtual circuit. The HP1000 starts up the receiving process on the remote HP3000 and transfers the contents of the queues in priority order, receiving confirmation of successful transmission from the remote print site for each print file transmitted. When the transmission of all print files in every queue for the print site has been completed, the transfer process is closed down and the connection is cleared.

The processing of acknowledgments from the remote print sites are handled in a similar way. The print site will open a connection, via DS, and transmit all the acknowledgments to the HP1000. The HP1000 places the acknowledgments in the appropriate queues, also maintained in memory, for each VAX. Regardless of the print site that processed the print file, acknowledgments are always returned to the VAX that originally sent it, for monitoring and accounting purposes.

The HP1000 permits the operations staff to monitor the state of the hardcopy environment and provides mechanisms to react to potential problems or operational decisions, such as the rerouting or moving of print files to alternate print sites. Monitors are also used by operations to show the progress of file transmissions between the HP1000 and the EMS hosts and the remote print sites. The monitors notify the operations staff when problems are encountered in transmitting files to either the VAXen or the remote print sites.

Laser Print Sites

The printing of hardcopy messages is performed at the remote print sites. The application software runs on an HP3000 series 40 to which the HP2680A Laser Printer is attached. Print site equipment also includes disk and tape drives and operator terminals. The HP3000 and the Laser Printer are configured with two mbytes of memory each.

The application which runs on the HP3000 has been designed in such a way as to stream line much of the processing and printing activities, minimizing the amount of operator intervention required, providing a real time display of activity and status, and providing the capability to control the flow of messages through the system. There are five major processing modules that handle the messages to be printed, from receipt of the message from the HP1000 through the actual printing and sending of an acknowledgment back to the originating VAX. The design of the print site software is illustrated in Figure 2.

Receipt of Print Files

When the HP1000 has messages in its queues for a particular print site, the HP1000 logs on to that HP3000 and initiates a process to accept the print files. During the transfer, all print files are transmitted in queued priority to the HP3000. The receipt process on the HP3000 notifies the preprocessing module of incoming print files, and sends acknowledgments back to the HP1000 for each print file received. This acknowledgment is not sent until the entire print file has been received and stored on the HP3000.

If additional print files for the HP3000 are received at the HP1000 during the transmission, these files are injected into the queues and transferred during the same session. When the entire transfer is completed, the receipt process is closed down by the HP1000. The application is designed to permit up to eight simultaneous transfers from the HP1000s. The print site operator has the capability to disable any or all of the HP3000 receipt processes to prevent any transfer from the HP1000.

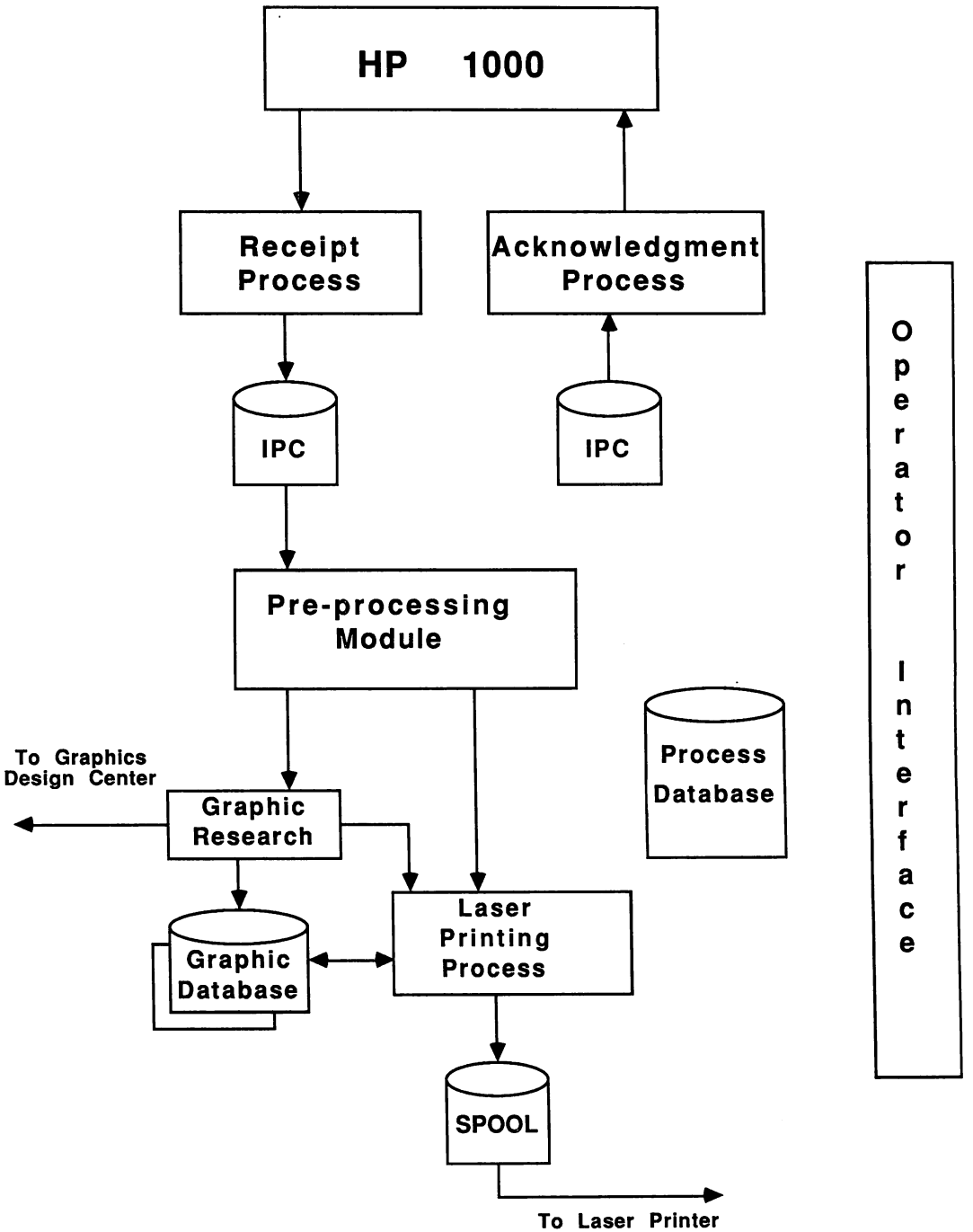

Figure 2: Remote Print Site Design

Pre-processing of Print Files

The pre-processing module of the application examines the print file contents for errors and graphic requirements, reformats the print file for later processing and printing, and places the print file into a prespool file. A prespool file is a collection of print files of the same priority. Prespool files are used to optimize the efficiency and throughput of the laser printer, and also to provide more controls to the remote print site operations personnel.

The pre-processing module will continue to add print files to a particular prespool file until the maximum number of print files has been entered or until the configurable spool timer expires. When the prespool file has been created, the pre-processor notifies the printing module, which takes over the processing responsibility of the prespool file. If necessary, the pre-processor immediately creates a new prespool file and continues processing print files that have been received by the HP3000. The pre-processing module dynamically allocates disk space to store the prespool files. This process prevents the allocation of more storage than is necessary to store the file, and also provides for the storage of very large messages.

Another function of the pre-processing module is to examine the graphic requirements for a given message to determine if the required graphics are in the remote print site's local graphics database. If the graphics are in the local database, processing continues. If the graphics are not in the local database, a message is sent to the graphics retrieval process.

Graphics Retrieval

When the pre-processing module encounters a print file requiring a graphic not stored locally at the print site, the print file is placed in a separate prespool file and the graphics retrieval module is notified that a particular prespool file contains one or more print files requiring a specific graphic. The graphics retrieval module establishes a virtual circuit through the packet switching network to the Graphics Design Center. The print site HP3000 logs onto the Graphic Design Center and performs a remote database access against the master graphics database. When the requested graphic record is located and extracted, it is stored in the local database. The graphic retrieval module then informs the printing module directly that the prespool file is ready for printing. If for any reason the requested graphic is not available, the printing module is notified to print a reject page for that particular prespool file.

The local graphics database is actually two files. The first file contains the unique identifier, margin settings and other data, including pointers to a position in the second file. The second file contains the actual partitioned raster files of all graphics stored at the local site. The local graphic database also contains the date the graphic was last referenced and print site operators have the ability to delete entries from the local database.

Laser Printing of the Print files

The Laser Printing module accesses the prespool files, creates the print spool files and submits them to the HP2680A laser printer. The prespool files are processed and submitted to the laser in priority order. In addition to the printing of text and either letterhead or signature graphics, the laser printing module supports bolding, underscoring, superscripting and subscripting, and the use of headers and footers within the text of the message.

A spool file, containing the information needed to drive the laser printer, is created for every prespool file submitted to the laser printing module. The laser printing module prints a header and trailer page before and after the letters in a prespool file. These pages contain the name of the prespool file, the total number of letters within the prespool file, and the unique identifier assigned to each recipient letter by the HCRA.

Between the prespool header and trailer pages are the letters themselves. Each printed letter is preceded by an address page, which contains the mailing address of the recipient and the originator's return address. Following the last page of each letter is a print control page which contains information about the message just printed. These control pages are maintained at the remote print site for tracing and monitoring purposes, and as required by law.

To facilitate the handling and monitoring of priority mail, and to meet the requirements of the courier company, each priority message is assigned a bill of lading number as it is received at the HP3000. Each remote print site has a unique location code (three characters), and this location code becomes the first three characters of the bill of lading number. The bill of lading number appears beneath the recipient mailing address on the address page. For overnight or courier mail, a destination airport code is appended to the bill of lading number.

This module will also print REJECT header and trailer pages if it is not able to print a letter. Between the reject header and trailer pages will be a control page stating the reason for the reject (for example, if no graphic was found by the graphic retrieval process). Any "problem" messages will result in a REJECT header page followed by a control sheet indicating the problem, followed by the trailer page.

Acknowledgments

Throughout the processing of a print file, entries are made to a process database, including the status returned from the Laser Printing module. This information is included in the acknowledgment sent from the HP3000, through the HP1000, and back to the originating EMS host VAX. The acknowledgments require remote print site personnel to assert an accounting code and cause the acknowledgments to be transmitted. The accounting code is used to indicate whether the letter is billable or not. Acknowledgments are generated for a given prespool file. The operator may set a global accounting code for each print file within the prespool file, though they do have the ability to modify the accounting codes for particular print files.

Receipt of a successful printing and billable acknowledgment by the EMS host VAX causes the accounting transaction record to be generated and, if requested by the message originator, will cause a return receipt notification to be generated and posted.

Remote site personnel also have the option of sending back an acknowledgment that essentially requests the VAX to retransmit the print file to an alternate print site. This capability facilitates the processing of user mis-addressed mail which resulted in the print file being transmitted to the default printer.

Acknowledgments are sent back to a primary HP1000, as configured at each remote print site. If the network connection cannot be made to the primary HP1000, or the HP1000 cannot accept the acknowledgments, this module will attempt to send the acknowledgments to an alternate HP1000. Should the module determine that is is unable to send the acknowledgments to any of the HP1000s, a warning message is printed and displayed on the HP3000 status screen. In any event, these acknowledgments are maintained in a queue until successfully transmitted.

Operator Interface

The operator interface module controls the hardcopy application software on the HP3000 and continually displays the "state of the world" when not being used by remote site personnel. The operator interface module consists of four separate screens (Command, Status, Acknowledgment Processing, and Report Generation) which are used by the site personnel to monitor the application and hardcopy processing activities, or to process operator commands and requests.

The command screen is used by the remote print site operators to control the application and perform operational tasks. This screen is used to start and stop the entire application, pause or resume certain processes, check and delete graphics from the local database, reprint letters received, and to provide control over the acceptance of new print units and the transmission of acknowledgments.

The Command Screen will also display information on the screen, either by prespool file or print file, and permits detailed examination of the displayed information. The command screen also simplifies such tasks as performing maintenance dumps (system backups), the ability to change the information or status of an acknowledgment and the ability to retransmit an acknowledgment.

As many of the command screen options are very powerful, some capabilities require the operators to enter their personal operator code before the requested process is begun. Some of the capabilities require the password of the remote print site supervisor.

The Status Screen is a real time display which is continually updated as it receives status information from the various modules. The status screen will display which connections to the HP1000s are open, which are currently active, which pre-processing components are active. If active, the name of the prespool files are displayed with the number of letters currently contained by the prespool file. The Status Screen also displays which prespool files are being processed by the laser printing process, along with the total number of pages that have been printed.

A table in the corner of the status screen displays, by priority, a historical record of the number of letters that have been received, printed, rejected, and acknowledged. The table also shows how many graphic retrieval requests have been made and completed. These counters are maintained over time, even if the application is stopped and restarted. Through the Command Screen, the supervisor has the ability to reset all or some of the counters.

The Acknowledgment Processing Screen is the interface used by the operators in generating and transmitting the acknowledgments. The operator is required to enter the prespool file name, enter the global accounting code, change the status for any number of print units within a prespool file, and request that the acknowledgments be transmitted. To facilitate the process, this screen displays all valid accounting codes and validates the operator's entry.

The Report Generation Screen, as its name implies, is used to generate reports which are printed on the laser printer. The operator may request a report and specify how the information to be displayed is to be sorted and the time period the report is to cover. The report generation screen is also used to generate the courier manifests which include the bill of lading numbers. This manifest accompanies the letters to be delivered by the courier.

The Graphics Design Center

The Graphic Design Center, an HP3000 series 64, is the central repository for all graphic information which may be used at the remote laser print sites. This includes both letterhead and signature graphics. An HP26096A Digital Camera System is used to optically convert these letterheads and signatures into a digital dot-bit format for electronic transmission and reproduction. Storage, retrieval, maintenance, and transmission facilities are included within the Design Center to allow access to the registered graphics from all laser print sites.

Each graphic is stored in the graphics database at the Design Center and associated with a unique graphic identifier. This identifier is assigned by a module of the Order Entry system. Once the graphics have been created and entered into the master graphic database, the graphic identifiers are added to the user's EMS database record. At this point, these graphics may be referenced by the user when creating a message to be printed at a remote laser print site.

Each mail account has a default letterhead. If only one letterhead is registered, it is the default. If more than one letterhead is registered, the user specifies which letterhead is to be the default. An account may also have more than one signature registered, but it is not necessary to designate one as the default signature. The user assigns a name to each letterhead and signature and references them by their assigned names. The mail system will substitute the actual graphic identifier associated with the named graphic when the message is posted by the user.

When creating a message, the user specifies which graphic is to be used by providing the name of the graphic in the handling field of the message. If no specific reference is entered, the defaults are used. If a letterhead has not been registered, there exists a system default letterhead which appears on the laser printed message. There is no system default signature. If no letterhead is desired, the user may request a "BLANK" letterhead.

All graphic information is stored in an IMAGE database. In addition to the graphic identification number, the database contains internal information such as the submission date, the creation date, margin defaults, and the last access date.

Inter-Network Hardcopy Support

As system usage increased, it was noted that more and more users were sending hardcopy messages to recipients in foreign countries. As this percentage grew, we were soon faced with the demand for print sites located outside of the United States, specifically in Europe, to support time critical processing and delivery of hardcopy messages. A print site was established in Belgium, connected by a private leased line to one of our domestic switches, and plans were developed to establish additional print sites in other foreign locations. The use of dedicated international circuits to link foreign print sites to the domestic U.S. system is expensive, however, and we were strongly motivated to make use of sharable public packet net systems as an alternative means of supporting these remote facilities.

These "off-net" print sites must still function as Digital Post Offices, receiving hardcopy traffic, initiating graphic research requests to the Graphics Design Center, and sending acknowledgments back to the originating EMS host VAX located on the private network. In essence, a link had to be established between our private network and a public network.

Fortunately, our organization had just introduced a public packet switching network (MCI DataTransport) and had established an X.75 Gateway connection to our international packet switching network (MCII IMPACS) which already had connections to a number of other public data networks. All that remained was to link our private network and our public packet networks.

X.75 only supports connections between public data networks, not private networks, so X.25 links had to be established between the our network and the public data network. This was accomplished by adding a physical connection from the Graphics Design Center and from one of the HP1000s to the public network switch (See Figure 3). From the public network, traffic (print files) will pass through X.75 gateways to other public networks, and from there to the final "destination" network. Once a print file reaches the destination network, it will be delivered by the network to the print site host at the destination DTE address.

An off-net print site must be connected to our public packet switching network or to a network that can be reached by the public network through a series of X.75 connections between consenting networks. All hardcopy traffic destined for one of the off-net print sites is sent by the Hardcopy Relay Agent to the inter-network HP1000 whose network print site link (to HP3000s) is connected to the public network. The inter-network HP1000 maintains a table of all off-net print sites, their Data Network Identification Code (DNIC), which identifies the destination network, and the DTE address.

The VAX-based Hardcopy Relay Agent still refers to the print site by its node name only and does not need to know on which network the print site is located or its DTE address. The destination print site is determined by the country code and postal code of the recipient's mailing address, though in the case of the off-net print site it will only key off of the country code. If the destination print site is off-net, the Hardcopy Relay Agent will transmit the print file to the inter-network HP1000.

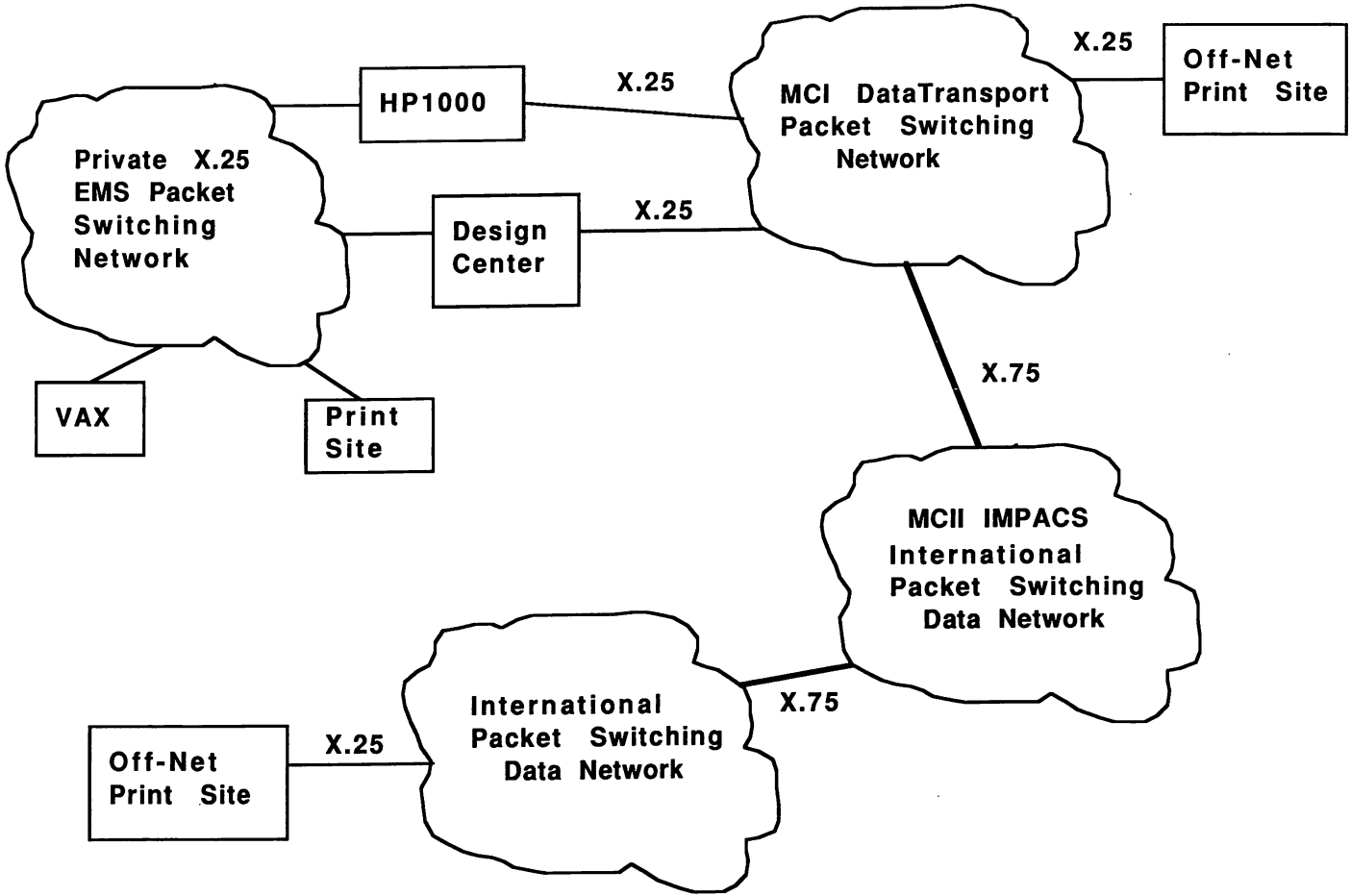

Figure 3 : Off-Net Print Site Architecture

From the inter-network HP1000, a virtual circuit is established through our public data network, out the X.75 gateway(s) to the public DTE address of the off-net print site. Once the connection is established, the print files are transferred to the off-net print site for processing and printing. When the print site processing is completed, acknowledgments from the off-net print site follow the same path back through the X.75 gateway(s) to the inter-network HP1000. The HP1000 then establishes a connection to the appropriate VAX and transmits the acknowledgments.

If an off-net print site receives a hardcopy message requiring a graphic not available in the print site's graphic database, a Graphic Research Request is initiated by the print site. This results in a connection being established from the off-net print site on the "destination" network through the X.75 gateways(s) to the Graphics Design Center which is now connected to the public data network as well as our private network. Once the connection is established, the off-net print site performs a remote database access against the master database on the Graphic Design Center, retrieves the necessary graphic information, and closes down the connection. The graphic information is then placed into the off-net print site's local graphic database for future use.

Mail Control

There are three operational centers supporting the mail application and the network. Once of these, the Mail Control Center, is responsible for monitoring and controlling the Hardcopy Distribution System. A central facility is organized around a set of data terminals which are used to access special software running on the VAX EMS hosts and on the HP1000s. Mail Control personnel have special privileges that permit them to access these programs through the network from the data terminals connected to PADs.

When connected to the VAX Master Node (where the software is located), Mail Control personnel are able to start or stop the Hardcopy Relay Agent process on all or individual VAX hosts. They are also capable of viewing the hardcopy process log files (and any error messages about problems in processing hardcopy mail) and maintaining the postal code routing databases. The software includes report and query options to display all pending messages (those sent out but awaiting acknowledgments from the print sites) and all queued messages, on a host by host basis.

When connected to an HP1000, Mail Control personnel can monitor and control the various VAX and HP3000 queues maintained in memory. This includes the moving of print files from one print site's queues to another, entering instructions that will automatically reroute traffic from one print site to an alternate print site, and stopping the flow of traffic to individual HP3000s or VAXen. The software on the HP1000 permits the addition or deletion of hardcopy hosts, changing node names or DTE addresses, and closing down all packet network links.

A data terminal is connected (again via a PAD) to each HP1000 and functions as a monitor, tracking the progress of file transmissions to and from the HP1000. The software running this monitor displays inverse video error messages and "beeps" whenever a problem is encountered establishing a virtual circuit to either a VAX or HP3000.

Conclusion

This paper has explored the basic architecture of most of the components of our mail system in general, and the hardcopy system in particular. It focused more on WHAT is done rather than HOW it is done. There are a number of features and capabilities that were not mentioned at all, such as our Custom Mail product and Response Plus services to support large volume mailings of hardcopy messages. Even though some of the tools were described, there was no mentioned of the operational aspects of supporting the hardcopy system, how and why these tools are needed and used, or what is involved in digitizing customer letterheads and signatures. Unfortunately, time and size limitations prohibit a more detailed explanation.

The MCI Mail system integrates a broad range of technologies and vendor products into a coherent collection of practical and innovative services. The system described in this paper has been in operation since 1983. A number of implementation details have changed since them as we learned from experience about operating the system and supporting new and "unique" client requirements, but the basic architecture has remained stable.

Biography

Steve Coya has been with MCI Digital Information Services for the past three years. He is the Senior Project Manager for MCI Mail Hardcopy Systems Development, and is also responsible for the overall planning and scheduling of system integration tests and for managing and coordinating the implementation of new software releases into the operational environment.