Department of Veterans Affairs

Symposium on High-Speed Telecommunications and Integrated Hospital Image Systems

September 25-26, 1989
Washington, D.C.

Sponsored by
DHCP Integrated Imaging Project
Department of Veterans Affairs
Washington Information Systems Center
50 Irving Street, N.W.
Washington, D.C. 20422
(202) 745-8305

High-Speed Telecommunications and Integrated Hospital Image Systems: Issues and Options

Sponsored by the DHCP Integrated Imaging Project
Washington DC Information Systems Center, Dept. of Veterans Affairs

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Introduction/Summary

The Dept. of Veterans Affairs (VA) is constantly examining opportunities for effective development in hospital information systems and evaluating new technologies for use in its 172 medical centers. Medical imaging systems are emerging as essential components of hospital information systems of the 1990's. The Dept. of Veterans Affairs Washington Information Systems Center recently sponsored a Symposium on High-speed Telecommunications and Integrated Hospital Image Systems. The purpose of this meeting was to bring together experts in the fields of telecommunications, hospital information systems, image systems, and standards in order to share their ideas and to discuss the state-of-the-art in these important areas. Speakers from a number of institutions participated, and attendees came from five countries.

Background on the VA DHCP Imaging Project

An important part of a patient's medical data is represented in image form, but to date, images have not been included in the computer-based medical record. The Department of Veterans Affairs has recently implemented a prototype distributed information system to demonstrate the feasibility of integrating medical images with the alphanumeric data in the current VA hospital information system (DHCP). A primary goal of this effort was to demonstrate the capability for sharing both images and text data located on remote servers in a network environment. The initial portion of this project has been successfully completed, and the next phase is about to begin.

A demonstration imaging network will be set up at the Washington DC VA Medical Center. This new system will enable physicians and other health care providers to access all available patient information from a computerized medical record. This medical data includes a wide variety of medical images such as photographs of the patient, X-rays, CT and nuclear medicine scans, lesions of the respiratory passages, stomach, and intestines as seen through fiber-optic endoscopes, and microscopic views of surgical specimens and body fluids. Clinical information from the patient's automated record will also be available to consulting physicians at workstations in other hospital areas. The new system is based on the VA's existing hospital information system which has been produced in-house by VA developers and is presently being used nationwide in 169 VA medical centers. It is currently the most fully integrated hospital information system in operation in a nation-wide healthcare system and is being adapted for use in many other hospitals in the U.S. and abroad.

The VA's new image system is unique for a number of reasons. It is an integral part of an operating hospital information system. It is implemented on low cost, industry-standard personal computer workstations rather than specialized medical devices. It will take advantage of the inherent network attributes of the VA hospital information system, making images available anywhere in the hospital -- including the wards, emergency room, and intensive care units. It can handle images produced by the full range of medical specialties, providing a powerful tool to aid clinically relevant communication between physicians as well as among other health care providers. This integration of medical text and images may herald a new era in hospital information systems and will allow dramatic changes in the way all health care providers team up to deliver effective patient care.

Summary of Symposium Proceedings

The Symposium on High-speed Telecommunications and Integrated Hospital Image Systems covered a number of important issues including the importance of integrating images with hospital information systems, the need for patient-oriented data retrieval, the need for a general system model including object-oriented database facilities and image processing functions, the need for a carefully designed user interface, experiences gained in implementing radiology picture archiving and communications systems (PACS), the importance of high speed telecommunications, and the central role which standards will play in this work. A number of areas were identified as critically important in planning for the next generation of hospital information systems. These included the use of developing standards, the emergence of parallel and distributed processing, and issues related to the user interface with multimedia data systems.

Following the formal symposium presentations, a number of distinguished attendees participated in an open workshop discussion. A summary of the principal issues discussed is included in this book. The speakers and participants provided valuable information about the state-of-the-art and the results that are actually being obtained today. It was generally felt that the direct incorporation of images as objects in a database system would be effective. The fact that the Dept. of Veterans Affairs has one of the few integrated hospital information systems installed in multiple facilities makes the task of incorporating images into an integrated HIS environment simpler than in the multi-vendor environments that typically exist in many private hospitals today. This also presents an important opportunity and unusual challenge to the Department to take the lead in developing and implementing this new capability. This "workbench" for development together with the VA's current open, standards-oriented development strategy should provide valuable experience to others in the government and as well as the private sector. A modular development approach is most important and provides the benefits of continuing compatibility of state-of-the-art technology with emerging standards. The importance of careful evaluation of the benefits of such a system became increasingly clear throughout the discussions. The VA hopes that this symposium sets the stage for further discussions on these important issues.

Acknowledgements: The Washington Information Systems Center would like to thank the MIRMO Information Technology Management Program for providing conference facilities for the symposium.

Ruth E. Dayhoff, M.D.
Daniel L. Maloney, M.S.E.E
Barclay M. Shepard, M.D.
Washington Information Systems Center
Department of Veterans Affairs

High-Speed Telecommunications and Integrated Hospital Image Systems: Issues and Options

Potomac Ballroom, Sheraton Carlton Hotel
923 16th Street, Washington DC

September 25-26, 1989

Sponsored by the
DHCP Integrated Imaging Project
Washington DC Information Systems Center
Department of Veterans Affairs

September 25

8:30 am — Opening Remarks
Timothy Williams, Hospital Director, VAMC Washington DC
David Van Hooser, Director of Medical Information Resources Management Office
Daniel Maloney, Director Washington DC Information Systems Center

Integrated Hospital Image Networks: Identifying the Issues

8:45 am — Integrating Images with the V.A.'s DHCP Hospital System: Goals, Issues, and Perspectives
Daniel Maloney MSEE, Ruth Dayhoff MD, Barclay Shepard MD, Ross Fletcher, MD
Dept. of Veterans Affairs Washington DC Information Systems Center

9:30 am — Image Management and Communication: Integration of Information
Roger Shannon, MD, Director Radiology Service, Dept. of Veterans Affairs

10:00 am — Integration of Images with NIH's Hospital Information System
Thomas Lewis, MD & John Foy, MD, PhD, Clinical Center Information Systems, NIH

10:45 am — Break

Radiology Image Communications: Experience

11:00 am — Filmless Digital Imaging System
Lt. Col. Fred Goeringer, US Army Medical Materiel Development Activity

11:30 am — High Speed Radiology Image Communications to Medical Services
H.K. Huang, DSc, Dept of Radiological Sciences, UCLA

12:30 pm — Discussion and Lunch

1:45 pm — Georgetown University's Radiology PACS Experience: Architecture and Communications Issues
Seong K. Mun, PhD, Dept. of Radiology, Georgetown University

2:15 pm — The ACR-NEMA Standard: HIS to PACS Interface Issues
Steve Horii, MD, Dept. of Radiology, Georgetown University

2:45 pm — Break

High-Speed Telecommunications and Integrated Hospital Image Systems
September 25-26, 1989

Architectural Options Analysis: State-of-the-Art and Future Prospects

September 25

3:00 pm	High Speed Communications and X-Windows for Image Processing: Present and Future Henry Dardy, PhD, Naval Research Laboratory
3:45 pm	ISDN for Image Communication Tom DeWitt, National Institute for Standards and Technology (NIST)
4:15 pm	High Throughput Communications Protocols Sharon Heatley, National Institute for Standards and Technology (NIST)
4:45 pm	Discussion

Architectural Options Analysis: State-of-the-Art and Future Prospects (continued)

September 26

9:00 am	Opening Remarks Daniel Maloney, Director Washington DC Information Systems Center
9:15 am	FDDI: Present Status and Future Developments William Burr, National Institute for Standards and Technology (NIST)
10:00 am	Biomedical Image Processing Shell Ronald Levin, ScD, Biomedical Engineering and Instrumentation Branch Etienne Lamoreaux, MS, National Cancer Institute National Institutes of Health
10:45 am	The Quality of Images: Issues and Examples Melvyn Greberman, MD, MPH and Loren Zaremba, PhD, US Food and Drug Administration, Rockville MD
11:15 am	Break
11:30 am	The VA File Manager in a Distributed Workstation Environment Dr. Gunther Schuller, University Wurzburg, West Germany
12:00	Software Standards and Imaging: The NIST Software Backplace Project Wayne McCoy, National Institute for Standards and Technology (NIST)
12:30 pm	Discussion
1:00 pm	Lunch Break
2:00 pm	Workshop Sessions

The symposium will be held at the Sheraton Carlton Hotel, 923 16th Street in the Potomac Ballroom (near McFearson Square or Farragut North Metro Stops). Please RSVP to Dr. Ruth Dayhoff or Dr. Barclay Shepard at 202-745-8305 (FAX 202-745-8511).

Integrated Hospital Image Networks:

Identifying the Issues

Integration of Images with the Veterans Affairs Hospital Information System in a Distributed Environment

Ruth Dayhoff MD, Daniel Maloney, MSEE,
Barclay Shepard MD, Ross Fletcher, MD

Dept. of Veterans Affairs
Washington DC Information Systems Center

Integration of Images with the Veterans Affairs Hospital Information System in a Distributed Environment

Ruth E. Dayhoff, M.D., Daniel L. Maloney, M.S.E.E., Barclay M. Shepard, M.D.

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Abstract

The effective delivery of health care has become increasingly dependent on a wide range of medical data much of which consists of a variety of images. Ordinarily manual as well as computer-based medical records do not contain image data, leaving the physician to deal with a fragmented patient record widely scattered throughout the hospital. The Dept. of Veterans Affairs (VA) has recently implemented a prototype hospital information system (HIS) workstation network to demonstrate the feasibility of an integrated medical image and text information system. This prototype demonstrates the capability for sharing both images and text data located on remote file servers in a networked hospital environment.

Introduction

Current manual storage methods for patient data typically fragment the medical record, placing text data in the patient's chart, pathology slides in the pathology storage cabinets, x-rays in the radiology department's library, nuclear medicine images in the nuclear medicine department, and so forth. Manual retrieval of the image data for use by clinicians is typically cumbersome and inefficient. The image data usually exists in only one copy and must be shared among a number of physicians, leading to absent or missing data. Too often the clinician responsible for a patient's care has trouble gaining access to the image data when it is needed most, i.e. during diagnosis and treatment.

Currently available computer-based medical record systems have not adequately addressed this problem. Text data (consisting of multiple strings of alphanumeric characters as short data fields and longer word processing fields) is stored in the automated record, while image data storage remains fragmented. A number of projects are underway to develop Picture Archiving and Communications Systems (PACS) for radiology applications [1,2,3]. These and other related projects [4,5] have produced very useful data regarding medical image resolution, interfacing and transmission requirements. However, attempts to integrate image management systems with hospital information systems have been extremely limited. Currently this problem is the subject of considerable interest [6].

The VA has recently developed a prototype distributed system capable of displaying both image and text data, fully integrated with the VA's existing DHCP hospital information system software [7,8]. This automated system that stores and conveniently retrieves both text and associated image data will provide a tool to facilitate the physician's integrated thought process as well as enhance communication among physicians. The prototype workstation provides a 'panoramic view' of the patient [9] to the clinician, including a variety of types of multimedia data such as text and true color, pseudo-color, and black and white images originating from a wide range of specialties. The extension of this prototype work to an interspecialty network is planned for the near future, with hospital-wide workstations to follow soon thereafter.

Prototype Distributed System

In a clinical setting, patient images as well as patient text data must be shared among a number of users at different locations. The prototype distributed system consists of a high resolution true color imaging workstation connected across a network to an image file server and an integrated patient data server (see Figure 1).

Several criteria were considered when establishing this workstation network architecture. The system has a modular design so that, as technology advances in a particular area, individual components can be upgraded without affecting the rest of the system. Text and image data must be accessed over a high speed network from a variety of operating systems

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running on equipment from a number of different manufacturers. The data server(s) for patient text data and digital image files may or may not be located on the same computer system depending upon the system architecture. Communications must share network devices, such as ethernet cards and cables. The workstation should have local disk drives to temporarily store or cache image files and software during a work session in order to minimize network traffic. In general, the VA's DHCP development goals include the production of vendor-independent, transportable systems through adherence to standards.

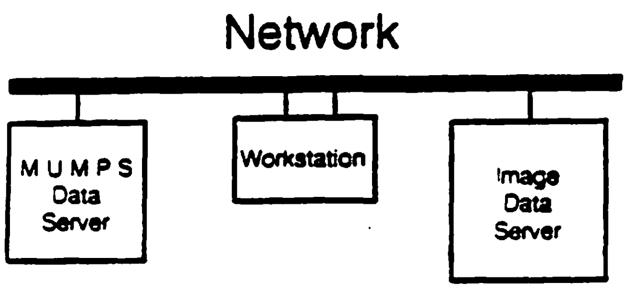

Figure 1: Configuration of the prototype distributed system

Workstation: The imaging workstations are based on off-the-shelf hardware and are relatively inexpensive. They are based on an 80386 microcomputer (COMPAQ 386/20). A Truevision VISTA imaging circuit board allows true color image digitization, capture, storage and display on an analog RGB monitor. Image resolution is software controlled and displays vary up to 1024 by 768 pixels with 32 bits/pixel. The hardware is capable of holding images up to 2048 x 2048 x 8 bits/pixel for scolled display. Images can be obtained from a video camera, directly from medical instruments as video signals, directly through digital file transfer, or from scanners. The workstation contains an ethernet interface card for data communication (see Figure 2).

Communications Network: Workstation communications of both text and images are currently based on ethernet. The prototype network consists of bus topology thin wire ethernet between workstations and servers. This allows up to 10 mbit/sec communications. To maximize throughput, the network to be used in the hospital wide system will consist of a fiber optic 100 mbit/sec backbone with dedicated ethernet interfaces to the workstations.

Data Servers and Network Software: The network software co-resides in the workstation as two concurrent protocol stacks for text and image communication. Patient text data from the MUMPS-based DHCP system can be shared directly within the MUMPS environment. Using the workstation, individual data items can be accessed transparently on remote data servers using facilities provided by various MUMPS implementations.

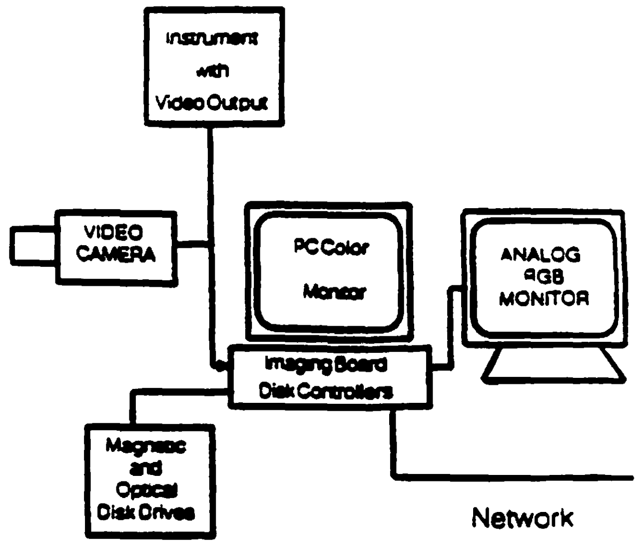

Figure 2: Diagram of the imaging workstation

The workstation contains networking software that allows digital image files (individual files directly under the operating system) located on remote disks to appear as files on disks locally connected to the workstation. Therefore, any program which can access a file on a local disk can access that file located on the workstation's virtual disks without any software changes. The prototype system uses Novell Netware 2.15 network software, although other software is available to serve this purpose. This transparency of software provides modularity that will allow flexibility for future modifications.

The prototype network utilizes magnetic disks as data servers. The hospital-wide network will be equipped with optical disk mass storage units capable of storing gigabytes of data on removeable media, as well as magnetic mass storage devices for rapid data access.

Applications Software: The VA's Decentralized Hospital Computer Program (DHCP) is the most integrated medical information system available; and it most closely meets the needs of the agency's health care system. The system and its derivatives are currently in use in virtually all 172 VA Medical Centers, as well as the Department of Defense, the Indian Health Service, other federal and state agencies, and private hospitals in the US and worldwide. The current VA DHCP software includes core modules for admission-discharge transfer, scheduling, pharmacy, clinical laboratory, radiology, dietetics, records tracking and a hospital wide ordering/purchasing/fiscal package. In addition, applications have been added for medical specialty use. The system's modular design and emphasis on adherence to standards allows easy addition of new applications, and adaptation to new hardware developments.

The prototype workstation software currently includes an abbreviated clinical record and full integration of images with the VA's existing cardiology [10] and nuclear medicine [11] packages. Images are fully integrated with the existing application packages in a manner appropriate to the context of the application. Images are automatically retrieved and displayed as the corresponding text data appears on the screen without user intervention. These application packages acquire echocardiograph or nuclear medicine images directly from the video output of the instruments. Angiography images are currently acquired via video camera. A wide variety of types of images have been included in the abbreviated clinical record database.

A major design goal of our prototype was to interface different hardware and software systems to achieve the best possible overall environment. In keeping with this goal, the ANSI standard MUMPS computer language was used for the medical text database, an application for which it is well-suited. Assembly and C language programs are called for the image handling functions. Vendor-independent network protocols were used whenever possible.

Databases: In the prototype design, the patient record is central to the system and manages the images which reside within the network system. Network connections mean that the locations of image storage are not critical, but performance depends on network speed. The sharing of image and text data files means that information need only be stored once and in one location for all hospital users. A local workstation in a distributed environment is best suited for image display, sparing the centralized system the resources required for manipulation and display functions.

A variety of types of medical images are stored in the system. The database software used by the system to handle both image and text data is the VA File Manager and related DHCP software written in ANSI standard MUMPS. Shared medical data stored in MUMPS global nodes is accessed directly from remote file servers. Images are stored as multimedia data objects in the database system similarly to any other field type (such as numeric data, dates, word processing fields, etc.) [12].

The image database structure is fully integrated with the application. To the programmer, it would include the image directory which allows image access by image number or descriptive image name. The image directory resides in the MUMPS environment which controls image handling routines written in other languages. Image files are stored as underlying operating system files, and consist of header information including image dimensions, plus image pixel data.

User Interface: The interface between user and image data has some differences from the interfaces that are typical for text data. "Image abstracts," small low resolution versions of the images, are used to aid the user in image selection and to decrease demands on the network. These provide a panoramic patient view that serves as an instantaneous summary of the patient's record.

Conclusions

The fundamental objective of the VA integrated imaging workstation prototype is to provide a new and important dimension to the VA's existing DHCP software, which is believed by many to be the best fully integrated hospital information system available today. Our prototype system demonstrates the feasibility of integrating images with the DHCP software and provides a unique opportunity for image capture by the full range of clinical specialties, image storage in a shared database, and rapid retrieval by any clinician responsible for delivering timely and effective health care. This integration of medical text and images may herald a new era in hospital information systems and a consequent revolution in the practice of medicine.

Acknowledgements

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Dr. Ross Fletcher, Dr. Felipe Robinson, and Dr. Roger Shannon of the Dept. of Veterans Affairs for their advice and encouragement in this development effort.

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Principles of DHCP

- Integrated Information System
- Standards Based
  - ANSI Standard MUMPS
- Vendor Independent
- Database Management System (VA File Manager)
- Common User Interface
- Public Domain

Pre-DHCP Automation

Automation Prior to 1982:

- Clinical Laboratory System in 9 VAMC's
- Pharmacy System in 10 VAMC's
- Automated Hospital Information System in 1 VAMC
- Locally Procured MUMPS Pilot Sites

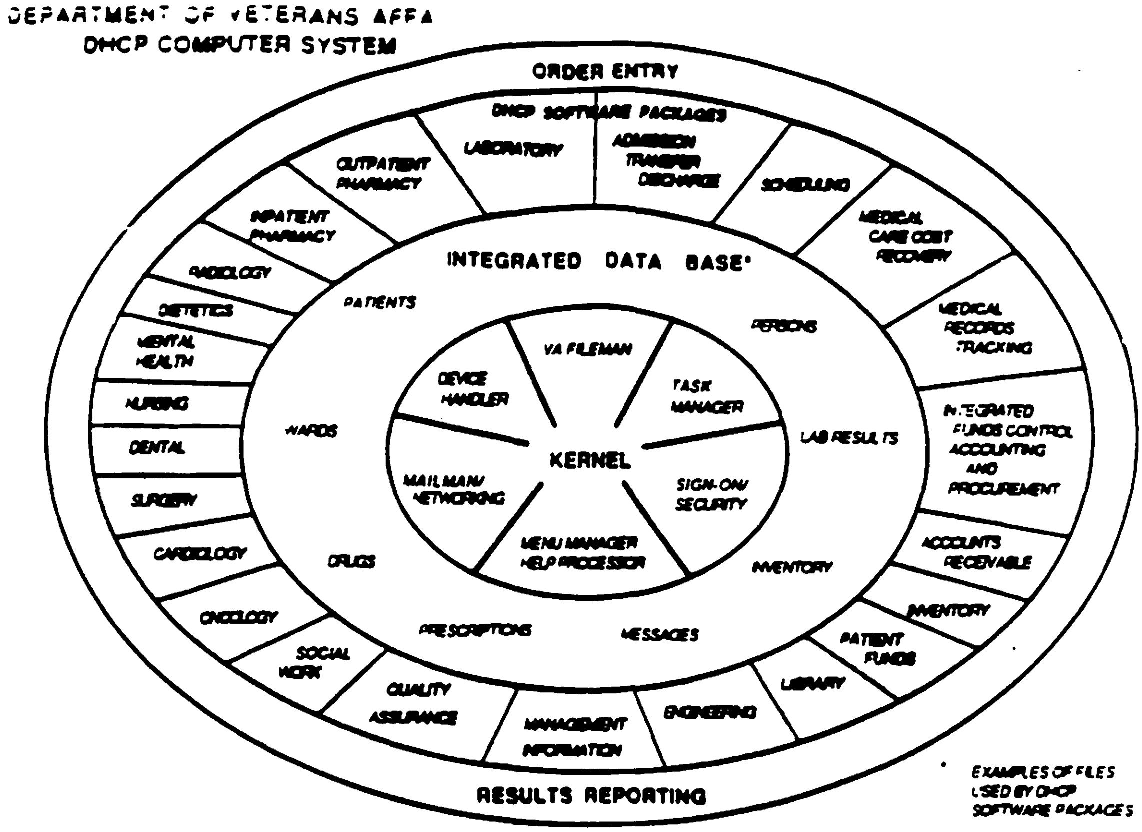
Current Operational DHCP Systems:

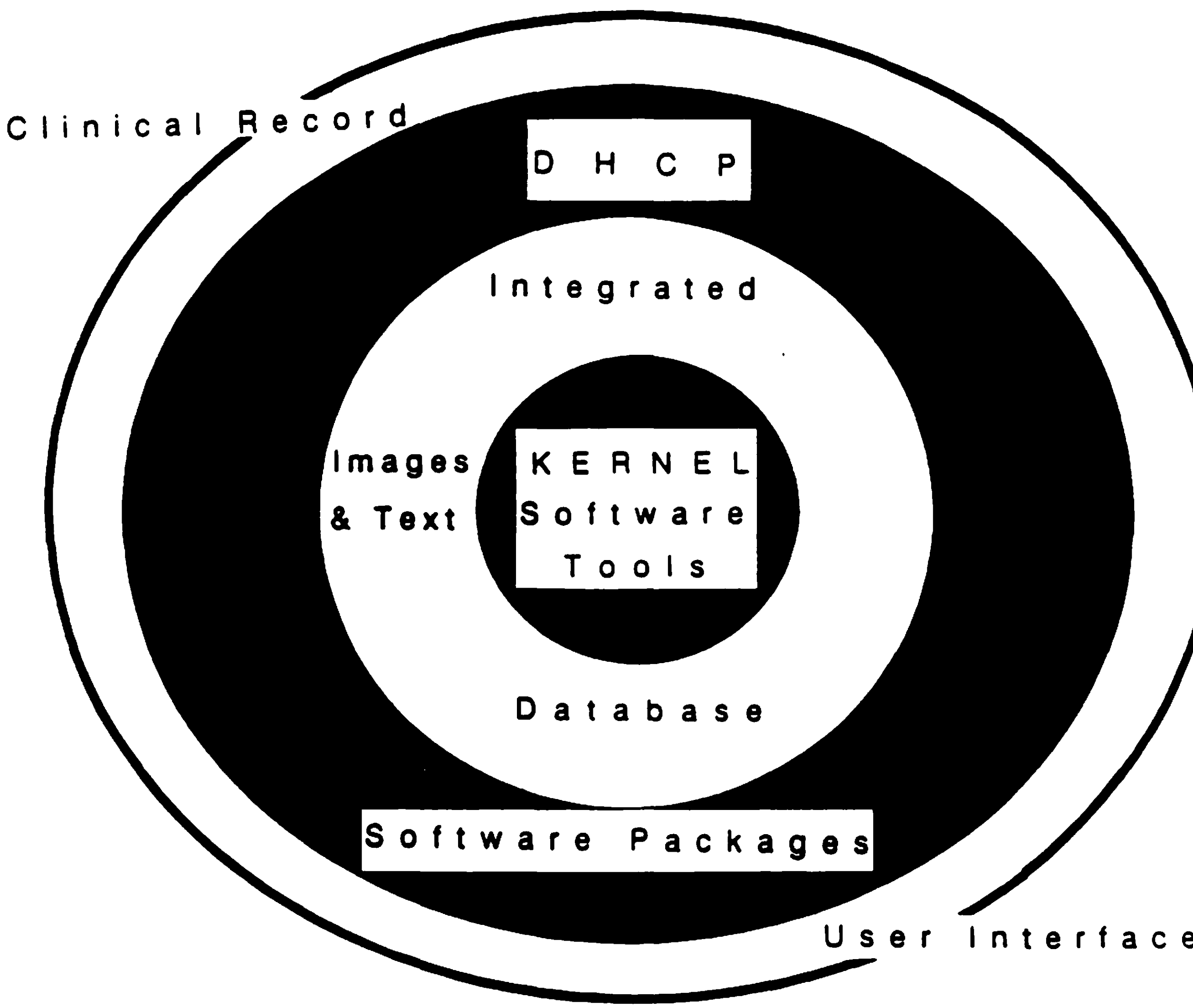
- 169 VA Medical Centers
- 1 Independent Domiciliary
- 7 Independent Outpatient Clinics
- 55 Satellite Outpatient Clinics

Decentralized Hospital Computer Program

(DHCP)

- Initial Core: Medical Administration Services
Outpatient Pharmacy
- Full Core: Clinical Laboratory
Inpatient Pharmacy
- Enhanced DHCP: Radiology
Dietetics
Records Tracking
Ordering/Purchasing/Fiscal
Surgery
Mental Health
Nursing
Medical Management


DEPARTMENT OF VETERANS AFFA
DHCP COMPUTER SYSTEM
ORDER ENTRY
DHCP SOFTWARE PACKAGES
LABORATORY
ADMISSION TRANSFER DISCHARGE
SCHEDULING
MEDICAL CARE COST RECOVERY
MEDICAL RECORDS TRACKING
INTEGRATED FUNDS CONTROL ACCOUNTING AND PROCUREMENT
ACCOUNTS RECEIVABLE
INVENTORY
PATIENT FUNDS
LIBRARY
ENGINEERING
MANAGEMENT INFORMATION
QUALITY ASSURANCE
SOCIAL WORK
ONCOLOGY
CARDIOLOGY
SURGERY
DENTAL
NURSING
MENTAL HEALTH
DIETETICS
RADIOLOGY
INPATIENT PHARMACY
OUTPATIENT PHARMACY
INTEGRATED DATA BASE*
PATIENTS
PERSONS
WARDS
LAB RESULTS
DRUGS
INVENTORY
PRESCRIPTIONS
MESSAGES
VA FILEMAN
TASK MANAGER
SIGN-ON/ SECURITY
MENU MANAGER HELP PROCESSOR
MAILMAN/ NETWORKING
DEVICE HANDLER
KERNEL
RESULTS REPORTING
* EXAMPLES OF FILES USED BY DHCP SOFTWARE PACKAGES


Clinical Record
DHCP
Integrated
Images & Text
KERNEL Software Tools
Database
Software Packages
User Interface

Why Images?

- Part of Patient's Clinical Data
- Information Content Large
- Difficult to Translate into Words without Loss
- Currently stored throughout the Hospital
- Often Missing When Physicians Need It Most
- Clinician Often Lacks Integrated Patient Information
- Technology Advances

Technology Advances

- True Color Digitizing Technology
- Mass Storage Devices
- Image Display Technology
- Network Software

File Manager Database System

Image Integration

Text Field Types	Multi-media Field Types
Dates	Images
Numbers	Audio data
Free Text	Cineloops
Coded Sets	EKG data
Pointers	3-d data
Word Processing	

Project Goals

Phase I: Feasibility Study 1989

Phase II: Hospital wide working prototype 1990

Phase III: Phased Nationwide Implementation

Phase I

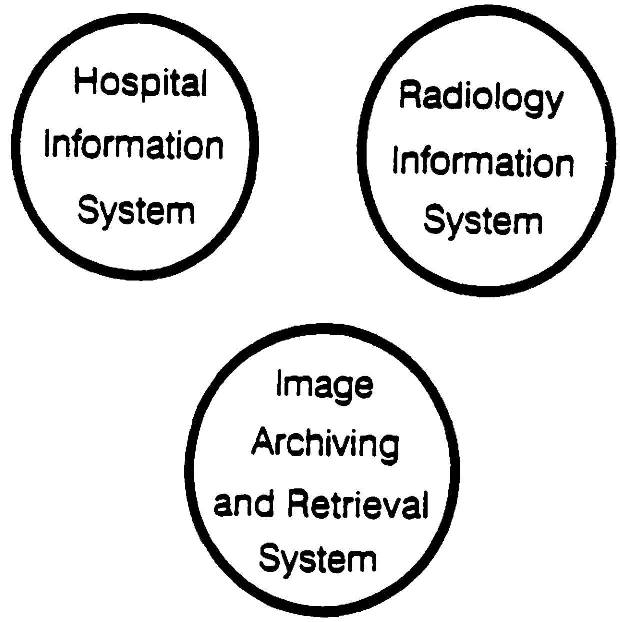
Feasibility Study

- Integration of Images with existing DHCP systems
- Sharing Access to Images in Network Environment
- Handling High Resolution Images Suitable for Medical Use

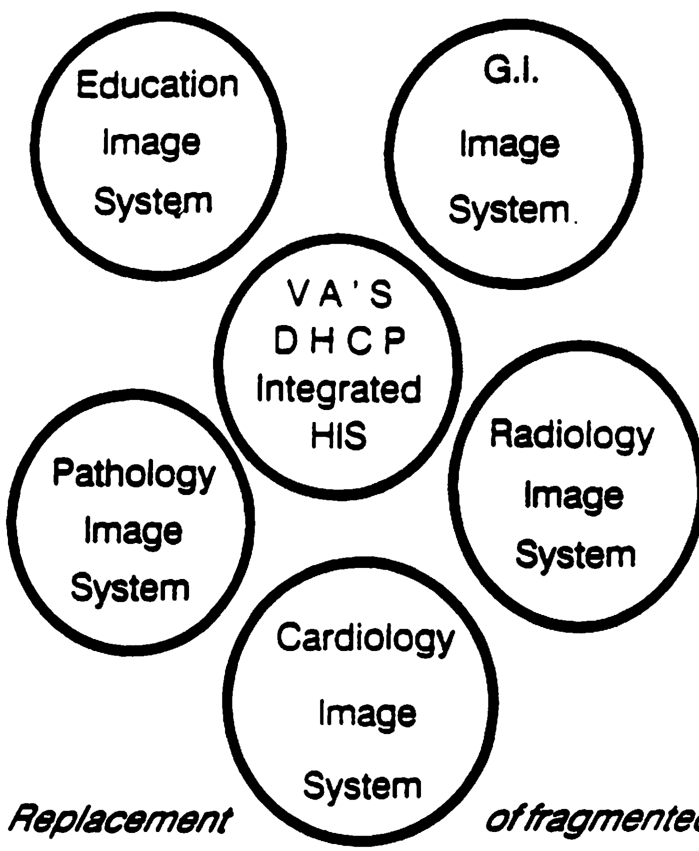
Phase II

Hospital-wide Working Prototype Integrated DHCP Image Network

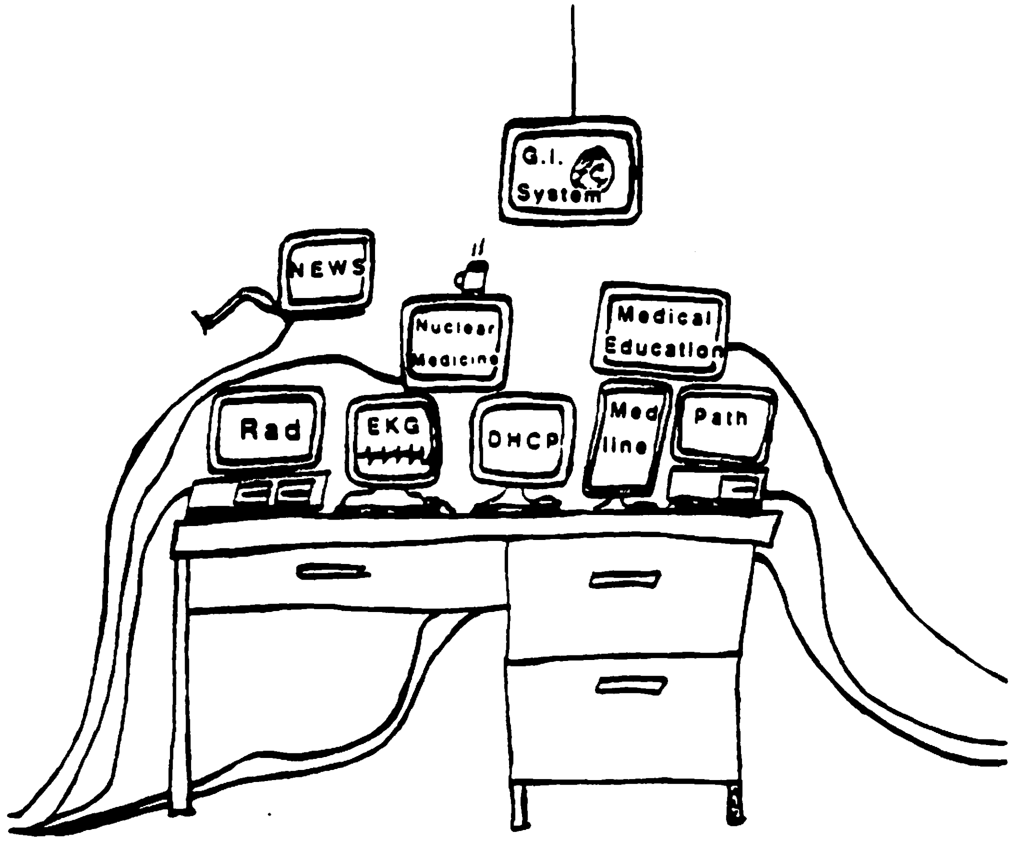
- Evaluation of Delivery of Integrated Data to Clinicians
- Evaluation of Technology in Hospital Environment
- Hands-on experience with imaging system requirements for system component specifications



What's happening now in Radiology



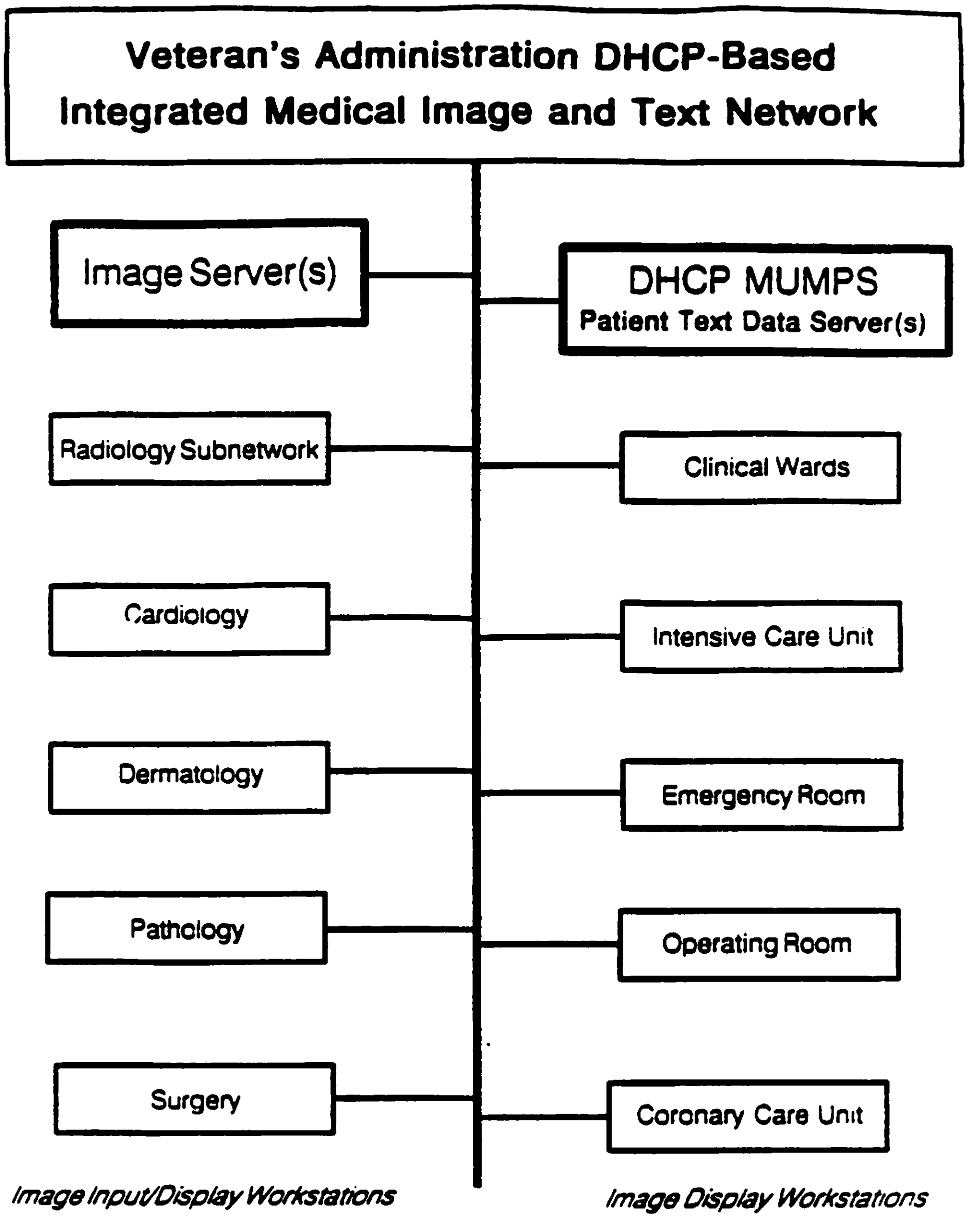
Replacement of fragmented paper and film clinical record with fragmented automated clinical record



Is This the Physician's Desk of the Future ?

VA's Unique Image System Components

- Integrated DHCP Hospital Information System in Place
- Ability to Access Shared Hospital DHCP Patient Data
- Compatible Prototype Image Workstation
- Ability to Access Shared Image Data
- Working Prototype System Shows Components Work Together


Veteran's Administration DHCP-Based
Integrated Medical Image and Text Network
Image Server(s)
DHCP MUMPS
Patient Text Data Server(s)
Radiology Subnetwork
Clinical Wards
Cardiology
Intensive Care Unit
Dermatology
Emergency Room
Pathology
Operating Room
Surgery
Coronary Care Unit
Image Input/Display Workstations
Image Display Workstations

Network

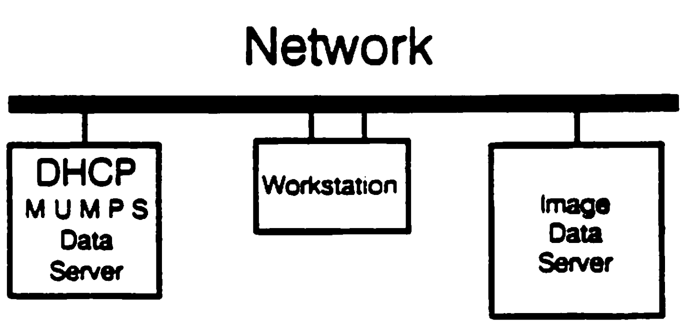
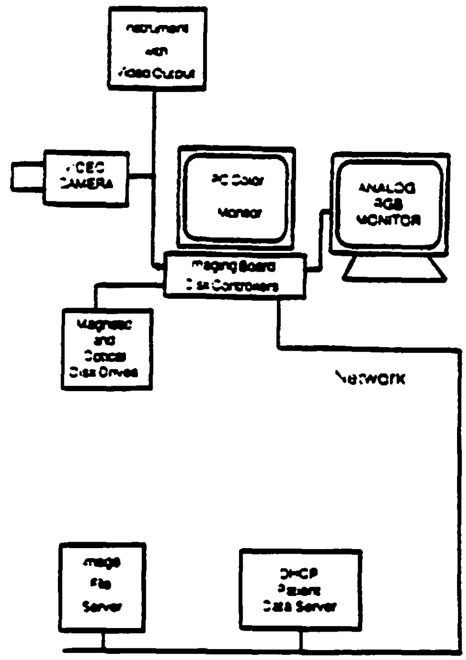

Network
DHCP
MUMPS
Data
Server
Workstation
Image
Data
Server

Image Input Workstation



Functional Elements of the Prototype Workstation

Hardware:

- Microcomputer - PC/AT compatible or 80386-based
- TrueVision Color Image Board for Image Capture, Manipulation, and Display
- High Resolution Color Display Monitor
- Video signal input connection or High Resolution Video Camera
- Optical and magnetic disks for Local Storage
- Network Interface Cards for MUMPS and Non-MUMPS Data Communication

Software:

- Network Operating System
- TrueVision Image Handling Module
- Networking Version of MUMPS with drivers
- Image Function Extension Module for DHCP
- VA File Manager and DHCP Applications

Benefits of Integrated DHCP Image System

- Rapid access to comprehensive patient data
- Enhance communications about patients between specialists for consultation
- Education
- Research

Technical Results of this Project

- VA File Manager software well-suited to image database management
- Workstations integrate well into the Distributed DHCP Environment due to MUMPS networking facilities
- MUMPS Adapts Well to New Technologies
- Transparent Access to Image Files Possible with Available Off-the-Shelf Network Software
- Transparent Access to Optical Disk Drives Possible from MUMPS Environment

Future Directions

- Image Display Options
- User Interface
- Input Interfaces for Additional Data Types
- Emerging Data Storage Technology
- Continued Emphasis on Standards

Workstation

	Today	Short Term	Long Term
Hardware	80386	80386	?
Operating System	MS-DOS	MS-DOS	POSIX/Unix
User Interface	Text/Image	Text/Image	X-Windows
4th GL Tools	VA File Manager / VA Kernel ——————>		
Application	DHCP ——————————————>		

Image Handling

	Today	Short Term	Long Term
Hardware	Truevision TI 34010 graphics processor		X-Workstation with 24 bit color
Software	Assembly / C	C	C
Image Storage Format	Truevision	Truevision ACR-NEMA ?	?
Image Processing	display, zoom	enhancement	
Image Compression	evaluation	compress when moving off-line	compress going to optical media
Image Acquisition	Video capture File transfer	Video capture ——————> File transfer ——————>	 Gateways

Network Issues

	Today	Short Term	Long Term
Physical Layer	Coaxial cable	Fiber optic ——————>	
Network Protocol	Ethernet	Proprietary/ Ethernet	FDDI ISDN for WAN
Network Speed	10 megabits/sec	100 mb/s backbone 10 mb/s to workst	100 mb/s to workstation ISDN for WAN
Network Software	Novell Netware	NFS, RPC	OSI Software Services Backplane

File Server

	Today	Short Term	Long Term
Server Hardware	80386	POSIX/UNIX-compatible ————>	
Server Operating System	MS-DOS/Novell	POSIX/Unix ——————————>	
Storage Devices	Magnetic disks	R/W Optical with Magnetic for most often accessed	magnetic and optical with automatic magnetic caching
Jukebox	evaluation	5 1/4" R/W or WORM	?

The Next Generation of Hospital Information Systems: Systems for the 1990's

What is clear about Information Systems of the Future:

- Support Interoperability of Systems through National Standards
- Workstation Based
- Utilize Graphical User Interface
- Recognize Images as an Information Resource to be Managed
- Provide Fast Communication

What will physicians and other VA staff need?

- Integrated access to all patient data -- clinical information including all types of data objects (text, images, EKG's, audio data, etc)
- Integrated access to the VA's other information resources

What Resources Do We Need to Be Developing Now to Deliver the Next Generation of HIS?

- Commitment to Integrated Information Resources through National Standards
- In House Technical Expertise to Integrate New Technologies
- Generalized Multimedia Database System that handles all types of data objects transparently
- Adherence to Standards for Interfacing Systems purchased by the VA

Imaging, Computing, and the New Millennium

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IMAGING, COMPUTING, AND THE NEW MILLENNIUM
by Roger H. Shannon, MD, FACR, FACMI

INTRODUCTION

Imaging technology is rapidly moving toward total dependence on computers. Early in the next millennium 90 percent or more of medical images will be digital--the products of computers. These images will be managed and presented electronically on special viewing devices. Film will be a disappearing medium. Computers will help us to analyze and think, and they will be doing a few simple intelligent tasks independently. Sophisticated communications will remove spatial constraints that we now take for granted. Increasingly "realistic" images will converge on what end users see in fact or in their mind's eye. These last two developments will substantially alter the current relationships in medical specialty practice. It is likely that the imaging revolution supported by other advances in medical informatics will constitute the bridge to some new paradigm of health delivery.

The seeds of the foregoing exist. A dozen years will dramatically develop these functions. We can predict fairly well by extrapolation, as Jules Verne so ably demonstrated. But the unexpected must also be accommodated. For both, we must build open, flexible systems to accommodate both variety in the expected alternatives and the complete surprises.

ESTABLISHED TRENDS

Image acquisition is increasingly based on computer techniques. Established digital modalities include Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US), Digital Subtraction Angiography (DSA), and Nuclear Imaging. Conventional radiography, the term used to denote the bulk of work using film as the primary detector, is also yielding to digital techniques employing reusable media from which latent images are digitally collected. Chest units of this type are becoming common, and general devices are in early clinical use in a number of facilities.

As digital imaging has grown in volume and in proportion of imaging as a whole, techniques to manipulate, transmit, and store these electronic images have multiplied and dispersed. The burgeoning prospect of gathering general radiography into the digital fold makes predominantly digital facilities a viable probability in the early 2000's. Transmission of digital and digitized film images intramurally and among institutions has moved beyond the laboratory into the clinical setting. Laser discs are used for image storage, and prototype workstations separated from single specific acquisition devices are in use at a number of sites. Still, the fully digital imaging department that many have contrived on paper is not yet a reality; and the imaging network to collect, deliver, and exchange images throughout medical institutions has not yet been fully implemented.

Radiology information systems (RIS) have been developing for a quarter century. They deal with alphanumeric information that falls for the most part into 6 categories: registration, scheduling, patient tracking, image tracking, reporting, and management. Education and research functions are frequent adjuncts in academic institutions. Recently, there has reemerged a lesson largely forgotten during the fifteen year heyday of computing independence afforded by mini and micro computers. The lesson is that integration of the various special medical applications into a hospital wide medical information system creates rich team support. With integrated information system support, medical team members consolidate their services to the benefit of the whole patient. This rediscovery of value in integrated systems has engendered new interest in language definition, code bridges, and interfaces. The last, for imagers, has focused on the RIS/HIS, RIS/PACS, and PACS/Acquisition device interfaces. Although these interfaces will be extensively developed in the next decade, the forms these will take and the market contribution to the development of multi-level large systems is very difficult to predict at this point. Nevertheless, the trend is established and will proceed by some avenue.

SUBTLE TRENDS

The most exiting trend is the increasing work on decision support. Major interface development will obviously lead to better availability of patient information. Literature access will be easily accomplished at the desk and viewing station. More questionable is how much content specific logic support will be built into clinical systems, and whether or not aggregate medical record analysis will become available as a resource to these systems. Significant, if not dramatic, advances can be expected in these latter two areas.

PARADIGM SHIFTS

Early studies support the intuitively valid notion that wide spread electronic access to images will change consulting patterns in medical imaging. Many end users will take over their own interpretive activities. Politics will strongly influence how much this will reorganize medical practices.

At the same time, images are becoming less mysterious and arcane. They are converging upon that which the end user practitioner sees in the course of practice or on what he or she would project on the basis of personal visual experience, e.g., a joint isolated from overlying tissue, functional centers of the brain, and the like.

These two trends and generally available decision support which would include visual material will, in time, probably much longer than one decade, rearrange consulting patterns among many specialties. Spatial constraints will be largely removed. The potential exists in these trends to produce a new paradigm of medical organization and practice. One decade will not complete the change, but prototypes will emerge.

THE UNEXPECTED

Always, the unexpected has arisen to frustrate the most careful and enlightened predictions. New discoveries and technological development may introduce new elements into medical practice or may alter the rates of some trends so that unpredicted interaction of trends become possible. Should a new paradigm of practice gain footing, extrapolation of new, now unseen trends, will replace those offered above. In any case, in times of rapid change, the unexpected should be expected; and it should be our plan to provide for it.

CONCLUSIONS

We have reached a watershed of medical technology and of health care delivery methodology. Much of what we predict will likely come to pass. However, the unpredictability of the rates at which interacting trends will proceed, the fickle influence of psychology on change, and the expectation that there will be some significant unexpected occurrence in the next decade promise interest for historians, crises for practitioners; and, at least, a few grand surprises for us all.

Radiology Image Communications: Experience

Digital Medical Imaging: Implementation Strategy for the Defense Medical Establishment

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Digital Medical Imaging: Implementation Strategy for the Defense Medical Establishment

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Abstract

In formulating an implementation strategy for digital medical imaging, three interrelated thrusts have emerged for the Defense Medical Establishment. These thrusts– (1) totally filmless medical imaging on the battlefield, (2) teleradiology, and (3) DIN/PACS for peacetime military health care– have significant implications in their fully developed form as resource savers and quality improvers for the unique aspects of military health care.

1.0 Introduction

Military health care can be characterized as a not-for-profit, nonreimbursable environment where two fundamental missions must be observed; (1) provision of all forms of medical care to about 1.2 million beneficiaries– a sort of health maintenance organization or HMO mission and (2) provision of health care delivery to all casualties on the modern battlefield in support of the warfighting spectrum of conflict ranging from low intensity operations to all out, full-scale nuclear war. Both missions must be planned for and carried out simultaneously under the constraint of limited resources. In both circumstances the demand for health care continuously exceeds the supply.

Because of these facts, there is a premium on initiatives that are 'resource savers'. The system is tailored to seek out and respond to initiatives that especially favor cost avoidance situations. The return on investment in digital medical imaging technology lies in the opportunity to exploit this technology in configurations that are prudent for the delivery of military health care taking into consideration some of its unique parameters– both on the battlefield and in peacetime. In the most primary sense, the reason why the Defense Medical Establishment embraces the promise of filmless medical imaging technology is the implication that it can have as a 'resource saver' and 'quality improver' for unique military medical care situations.

2.0 Digital Medical Imaging Strategy: Three Thrusts

Three clear cut thrusts have emerged as prudent implementations of digital medical imaging technology for the Defense Medical Establishment for the early 1990's. These are:

(1) Totally filmless medical imaging for the battlefield

(2) Teleradiology implementations in lieu of 'circuit rider' contracts for radiology services in remote clinic/ fixed facility settings

(3) Full scale DIN/PACS implementations in military community hospitals and tertiary care medical centers

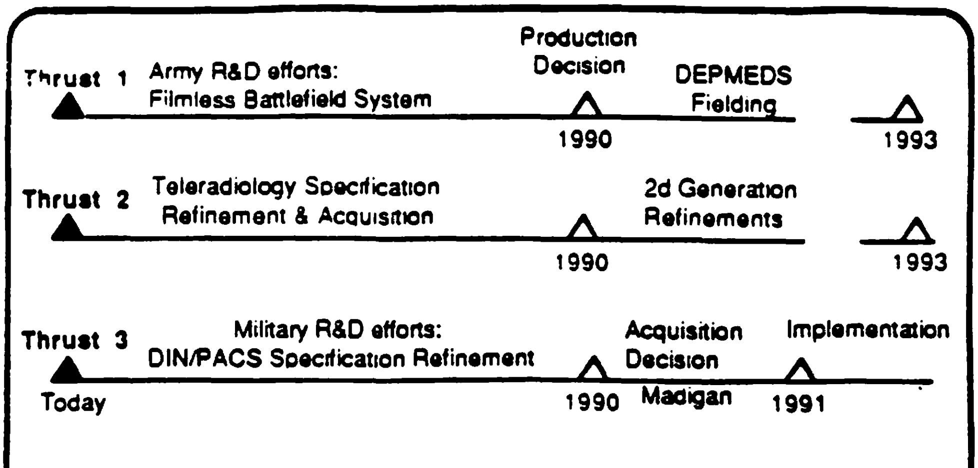


Figure 1. Digital Medical Imaging Implementation Strategy

Implementation of these three thrusts simultaneously represents the most pragmatic approach for embracing the technology; each is dependent on another and makes a contribution to the overall macro strategy. For instance, clinicians will enhance their overall understanding of medical digital imaging using teleradiology and DIN/PACS applications in the peacetime setting; this will provide confidence and a clinical training base in use of the combat medical filmless system. Additionally, digital medical images coming off the battlefield with combat casualties will be easily be integrated into fixed facility medical centers with DIN/PACS implemented in the continental United States. Teleradiology, which represents a more near-term implementation as discussed below, will serve as the 'first plateau' for the full scale follow on DIN/PACS implementations. Figure 1 depicts the overall situation.

3.0 Thrust One: Totally Filmless Medical Imaging for the Battlefield

Totally filmless medical imaging on the battlefield is a clinically and logistically superior solution to the requirement for diagnostic imaging support under combat casualty care conditions. With a filmless system, consumable resupply of film, chemicals, and fixers can be avoided in a contingency situation. Logistics and transportation resources will be available for moving other commodities which will have a more direct influence in delivering combat power. Moreover, the requirement for stockpiling war reserve stocks of potency dated film, chemicals, and fixers can be avoided. Medical logistics studies of the three most significant warfighting scenarios for the United States (NATO, Southwest Asia, and Korea) indicate that war reserve requirement stockpiles of potency dated film, chemicals, and fixers could be reduced by over 4.9 million pounds and over 128,000 cubic feet. This represents a one time program savings of $37.1 million and follow-on annual savings of $17.1 million thereafter.

Figure 2 represents a notional overview of battlefield filmless medical requirements at the combat hospital level. Medical image acquisition for combat casualty trauma will be accomplished through two modalities: (1) Computed Tomography and (2) Digital Radiography using photostimulable phosphor plates for analog to digital image conversion.

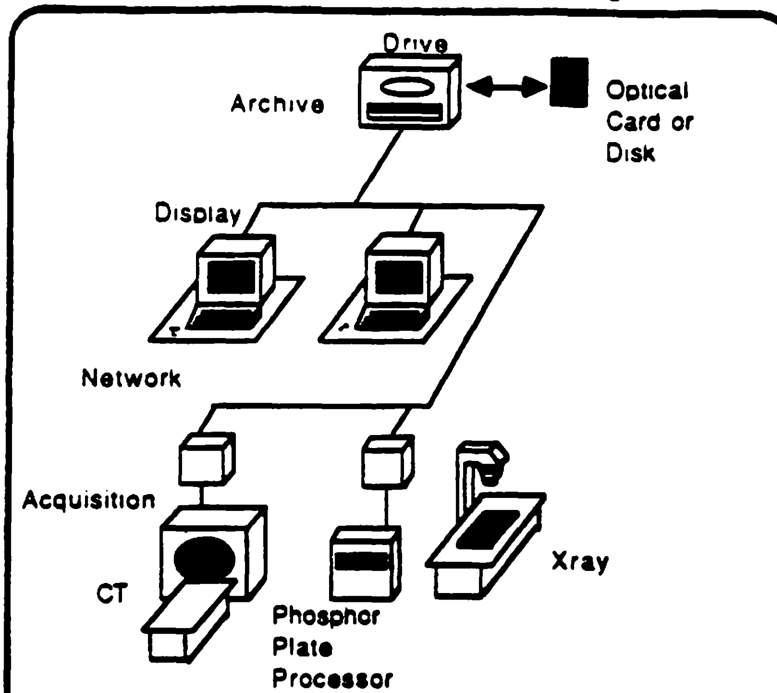


Figure 2. Notional Overview of Battlefield Filmless Imaging Requirements

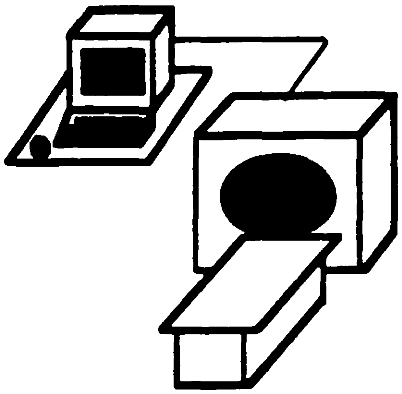
A battlefield computed tomography (CT) scanner project is underway under the sponsorship of the US Army Medical Research and Development Command. Figure 3 depicts some of the major performance parameters of the scanner. Israeli Defense Force experience in the 1982 Lebanon war indicates that CT scanning can be used very effectively for wound fragment localization, avoiding many exploratory laparotomies, and in general as a medical decision support device during mass casualty triage[1]. Lightweight, high duty cycle designs are possible using so-called "slip ring" technology which provides the ability to move digital information on and off the gantry as well as the ability to provide relatively lower line power directly to the gantry before it is stepped up via an on-gantry high frequency power supply to pulse the X-ray tube. The inherent digital nature of this device will enable it to fit readily into a filmless system.

Photostimulable phosphor plate radiography, sometimes called computed radiography, is the other primary method of image acquisition for the battlefield. The medical imaging industry has recently introduced down-sized re-engineered incarnations of this technology that can be effective for the battlefield with the appropriate level of ruggedization. These devices are presently under concept evaluation by the military to assess their overall suitability and clinical utility. Presently two phosphor plate reading devices are postulated for

[1] Eran Dolev: Computed Tomography a Valuable Tool in Triage in *Military Medicine*, Oct 87

each combat medical facility at echelon 3 and 4 of the DOD combat medical system.

The appeal of photostimulable phosphor technology is that it can be retrofit with already existing radiographic devices to provide acceptable quality digital images for combat casualty care. Other de-novo radiographic designs to acquire digital images would require replacing the entire combat imaging inventory with entirely newly designed imaging devices.



- Austere "Design to Cost" Approach
- 1600 lbs / 160 sq ft foot print
- Capable of operation in a Combat ISO Hardwall Shelter
- Up to 16 scans per minute
- 9KW Peak Power Demand
- 8 line pairs per cm / 12 bits contrast
- 512 X 512 reconstruction matrix

Figure 3. Major Performance Parameters, Battlefield Computed Tomography

Battlefield medical image display workstation and network performance is described in related papers in these proceedings by Nadel and Johnson[2]. Studies of wartime patient conditions and casualty estimates for future warfighting scenarios indicates that acceptable workstation and network performance can be achieved with configurations of systems technology that is commercially available today with ruggedization added in after-the-fact.

Unlike peacetime health care settings which require digital imaging archives that are on the order of terabytes for digital networks, battlefield health care settings have significantly less robust archiving requirements– on the order of 10's of megabytes for management of images. This is predicated on the fact that battlefield hospitals have a high throughput, transient patient population. Military medical doctrine call for not longer than a 3 to 7 day length of stay as the basic decision rule for patient evacuation from the area of conflict and not more than 30 days for evacuation back to the fixed hospital base from the combat theater.

The transient nature of the population highlights the fact that emphasis must be placed on the decentralized archiving of medical images. Rather than use teleradiology on the battlefield to move images, a more practical approach is to keep images with the patient– ideally by image archiving on optical card or some version of 3.5 or 5.25 inch high density optical technology. Related papers by Karlin and Siedband[3] in these proceedings provides

[2] L. Nadel et al: Prototype System for Digital Image Management etc. 1093-58 in these proceedings

[3] Karlin et al: 1093-59 in these proceedings. Siedband: 1093-53 in these proceedings

discussion in the use of this technology termed the SIRR or Soldier Interfacility Radiologic Record by Kerlin.

If this technology is successful, then local area networks within combat medical facilities may not be necessary; rather, unnetworked independent viewing stations located at key points in the hospital would accept the individual patient image card or disk for display wherever the patient is located. The image record would stay with patients as they move through the evacuation system. In effect, the patient would be the network. While teleradiology may be technically possible on the battlefield, it is not militarily feasible due to the demand for command and control telecommunications in combat as well as the complications that would occur with teleradiology in matching images with patients upon arrival at each new facility in the evacuation chain.

The battlefield filmless imaging initiative will be incorporated into a $2 billion DOD medical force modernization initiative called DEPMEDS or Deployable Medical Systems. From now into the mid 1990's, 250 newly equipped battlefield hospitals will be introduced into the quad service military medical force structure; 150 will be fielded for the Army with the remainder being fielded by the other services. These DEPMEDS hospitals range in size from 60 bed MASH hospitals to 1000 bed general hospitals that will operate in the combat theater. Fielding began in 1988 with about 25 hospitals being assembled and fielded each year.

4.0 Thrust Two: Teleradiology Implementations in Remote Clinic/Fixed Facility Settings

The second major thrust in the Defense Medical Establishment digital medical imaging strategy is teleradiology. Estimates indicate that about 500 military medical fixed facilities have radiographic equipment but that over 65% of these same facilities have no radiologists assigned and an additional 15% of these facilities have only one radiologist assigned[4]. Teleradiology is an ideal vehicle for redistributing image reading workload from these 'no radiologist' or 'one radiologist' sites to more adequately staffed central locations where an economy of scale can be achieved in handling workload in a timely manner. An example of this generic situation is the Fort Meade community hospital and the surrounding Army health clinics within a 250 mile radius that must be supported. Figure 4 depicts the basic situation. Weekly radiology exam workload is shown beside each clinic. In FY88 it cost $220,000 to provide circuit rider diagnostic radiologic support to the exam workload generated at the remote sites.

Rather than using this circuit rider contract coverage, Figure 5 provides highlights of the teleradiology lash up between the remote and central sites that will become a 'spoke' in the wide area network. Low volume sites will be supported by laser film digitizers for image acquisition and image will be sent to the central site through 19.2 Kbps modems over existing dedicated phone lines. High volume sites will accomplish direct digital image acquisition with re-engineered down-sized photostimulable phosphor plate readers and will be linked to the central site with with high throughput communication lines such as T1 or microwave links with an effective throughput of about 1 Mbps. With a $1 million capital investment, system

[4] Col Robert Allman et al: Potential Contribution of Teleradiology to the Management of Military
Radiologist Resources in *Military Medicine*, Dec 83

payback will be achieved in about 5 years by avoiding most circuit rider radiology contract costs.

Teleradiology will provide near-term resource payoffs to the Defense Medical Establishment today. It also lays the groundwork in the clinical community for acceptance of larger more robust implementations such as DIN/PACS within military medical facilities as well as totally filmless medical imaging on the battlefield.

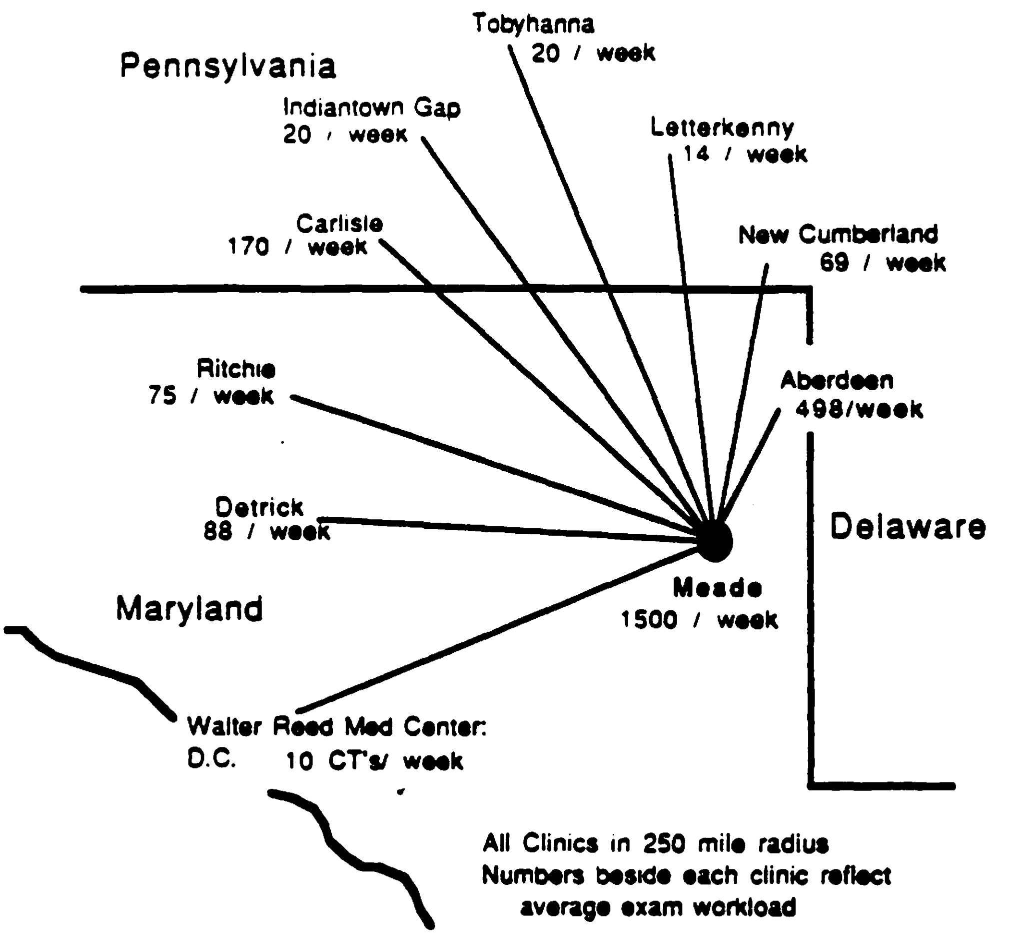


Figure 4. The Spokes of a Teleradiology Network for Ft Meade & Surrounding Military Clinics

5.0 Thrust Three: Full Scale DIN/PACS Implementations in Military Medical Facilities

The final most extensive implementation of digital medical imaging technology is the thrust for installation and use of intrafacility hospital Digital Imaging Network/Picture Archiving and Communication systems, often called DIN/PACS, for use as part of the overall, evolving medical information management system. In early 1988, the Army Surgeon General approved the planning process for the implementation of DIN/PACS as a major feature of the new military hospital construction project of the new Madigan Army Medical

Center at Fort Lewis, Washington. Figure 6 provides an overview of the new facility from a diagnostic imaging perspective which is scheduled for beneficial occupancy in early 1991. Figure 6 also illustrates the scope (but not the final topology) of the network to be installed.

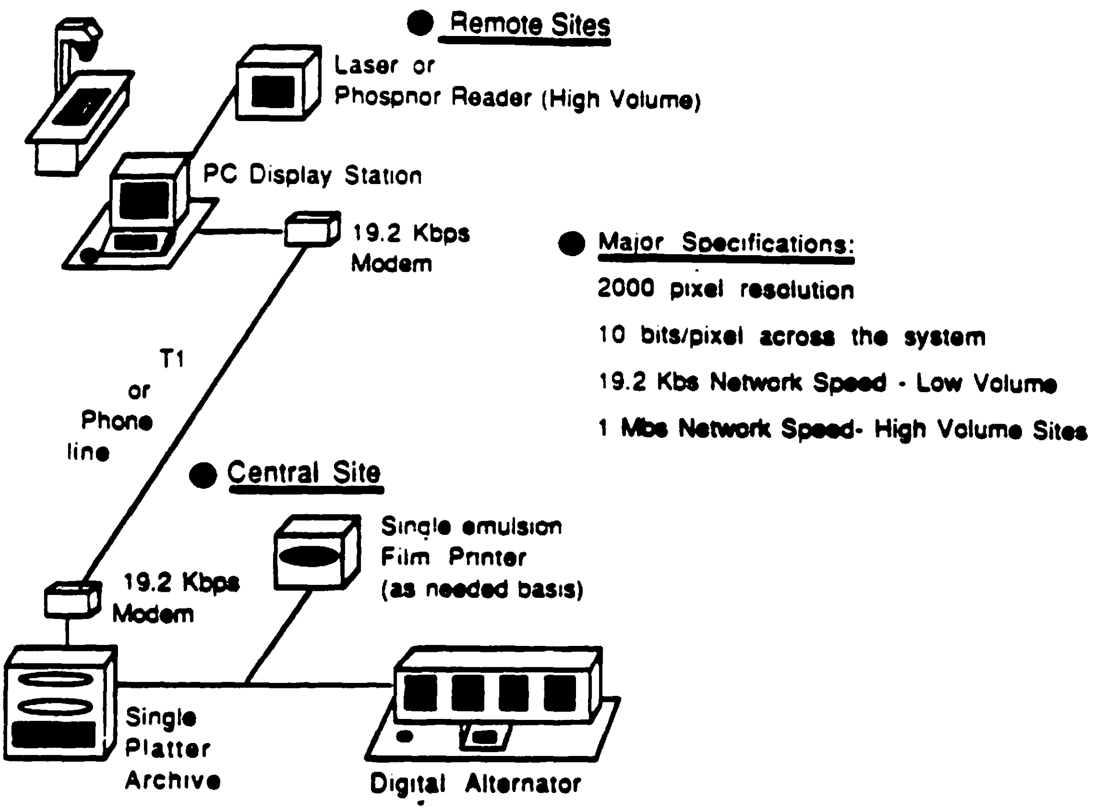


Figure 5. Composition of a Teleradiology Spoke

DIN/PACS at Madigan will support a workload of about 220,000 diagnostic imaging exams annually. All digital diagnostic modalities will be incorporated into the Madigan network as well as up to 5 individual computed radiography devices to support flat image radiography. There will be three levels of viewing station performance; 10 each high performance digital alternators will be available for diagnosis, up to 37 each mid performance clinical imaging workstations will be on the network to support locations such as the intensive care wards and the emergency room, and up to 66 each PC-quality workstations will be distributed for image review and consultation purposes to sites throughout the facility. Image archiving will occur using caching strategies that involve decentralized magnetic storage and high density optical juke box technology or emerging optical tape technology. To be fully productive the system must have 'hooks' available for CHCS, the Composite Health Care System which is the DOD standard hospital information system being proliferated in all DOD hospitals in the early 1990's.

Preliminary economic studies of DIN/PACS implementations in Defense Medical Establishment medical centers indicate that, with about a $7 million capital investment in the new facility, the system can pay for itself in about 8 years based upon relatively conservative economic assumptions. Studies at Georgetown University and at the University of Washington indicate that the analysis is sensitive to about 10 key economic parameters in assessing costs and benefits. Papers by Benson[5] and Saarinen[6] in these proceedings address the specifics regarding economics.

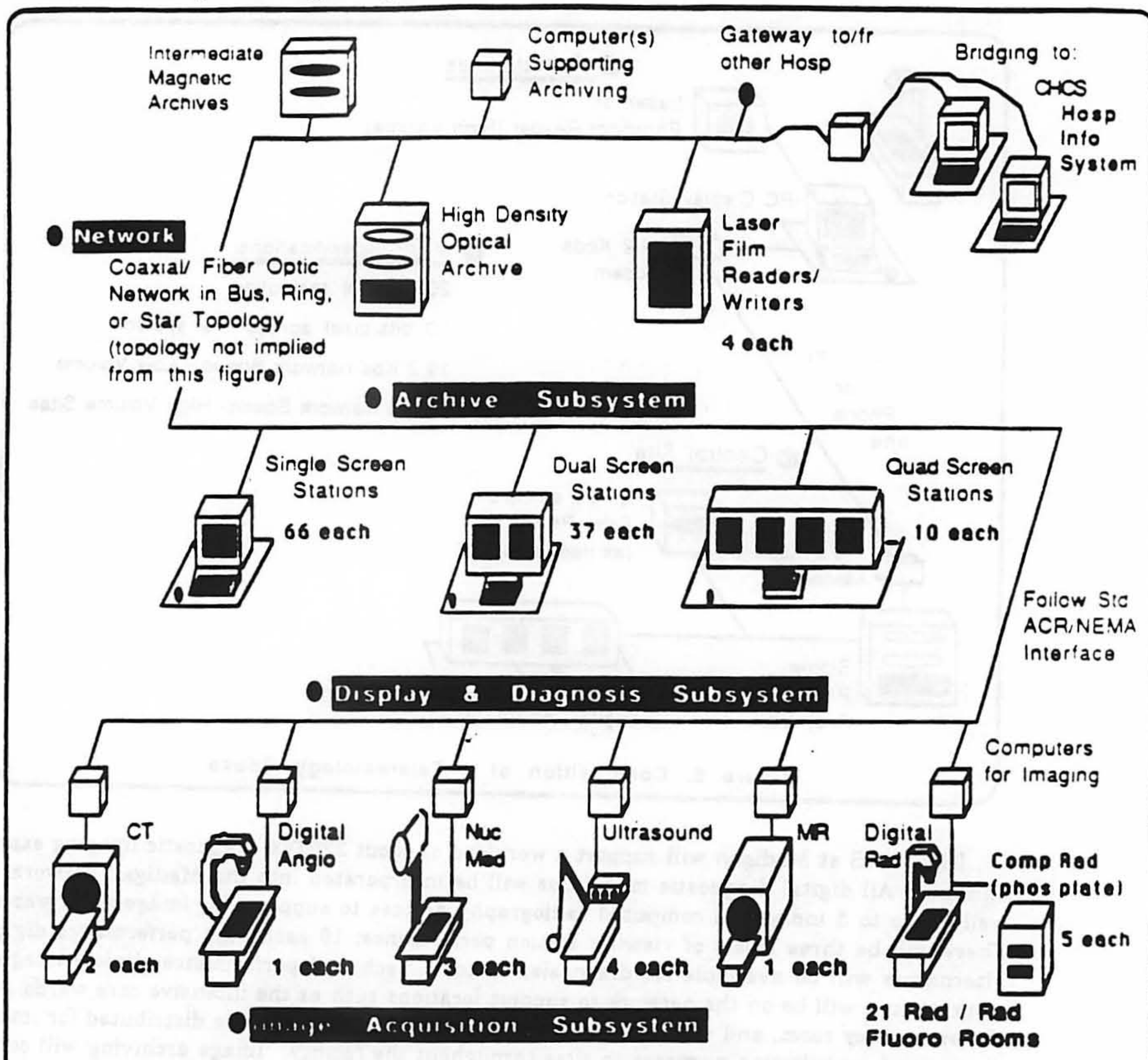


Figure 6. Scope of Work for DIN/PACS at Madigan Army Medical Center

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[5] Harold Benson et al: Cost Analysis of an Image Management and Communication System. 1093-51 in these proceedings

[6] A.O. Saarinen et al : Logistics of Installing a PACS System. 1093-21 in these proceedings

The literature is abundant with the anticipated payoffs associated with implementation of a full scale DIN PACS implementation in health care facilities. Benefits such as the opportunity for image review at several sites simultaneously are typically identified and frequently reported as advantages. However, there are three military-unique benefits which will be derived from a full scale implementation.

- First, a full scale implementation will support a sophisticated clinical understanding of the use and medical efficacy of totally filmless imaging on the battlefield. Technology must be fully exploited to build the kind of medical responsiveness that is required on the modern battlefield.

- Second, DIN/PACS in a military teaching hospital environment will be a significant asset for helping improve physician retention in the military medical services. To be competitive with the civilian sector, the Defense Medical Establishment must employ high technology in its health care facilities that is consistent with the emerging state-of-the-art. This baseline incentive must be there to attract the quality of clinical talent required for quality military health care delivery.

- Third, DIN/PACS in its mature form with crosswalked linkages to the hospital information system will be a significant productivity improver in the health care facility. As stated previously, military health care delivery is characterized by unmet demand due to limited resources in a not-for-profit, nonreimbursable environment. The improved productivity of a mature DIN/PACS system will allow previously unmet demand for health care to now be more fully met.

6.0 Conclusions

Digital medical imaging will make a difference for the Defense Medical Establishment in meeting its battlefield and peacetime health care delivery missions. In devising a macro strategy, the three thrusts described above must be looked upon as one and blended into a whole. For digital medical imaging technology to be successful, an implementation perspective larger than just a single radiology department or a single hospital must be taken. Because of the inherent modularity of this computer-based technology, a global tops-down approach in configuring the technology into incarnations that directly respond to across-the-board health care delivery problems is the only way that the technology will achieve it fullest promise in responding to the unique requirements within the Defense Medical Establishment as well as for national health care in general.

Radiologic Image Communication

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Introduction

A picture archiving and communication system (PACS) consists of four components: acquisition devices, a host computer, image archival, and display stations. These four components are connected together by an image communication network. Currently all four components are well understood and technologies are available to handle most clinical requirements. On the other hand, research and development on the connectivity of these components is still in its infancy. It is generally not difficult to connect the four components together in a simple PACS module. However, the complexity increases greatly as multiple modules are required to be connected in an integrated PACS for an entire radiology department. Connectivity is perhaps the most difficult technical task in a total PACS implementation. This presentation describes two emerging methods for connecting PACS modules together.

Concept of Clusters

A cluster can be loosely defined as a PACS module or a group of imaging components within which images are transmitted. Figure 1 shows the architecture of a cluster. A major component in a cluster is the hub. The function of hubs in an imaging network is to rapidly relay image information between sources and its destinations. In this design there are two hubs, one to accept images acquired from acquisition devices, images sent by the host computer, and by other clusters. The image transfer rate from acquisition devices to the hub will be slow because of the older computers used in the devices. However, image transfer rate from other clusters to the host computer, through the second hub should and can be very fast. The second hub is also used to transmit images very quickly to different display stations. Once the images are in a display station they are stored in a local high speed magnetic disk and can be retrieved and displayed rapidly.

Since we do not anticipate that manufacturers will change the computer in their acquisition device, the image communication speed from the device to the host computer will remain slow. However, we can design high speed communication with state-of-the-art technology between a host computer and a hub, between a hub to another hub, and between a hub and display stations and image archival stations.

Two Emerging Communication Methods

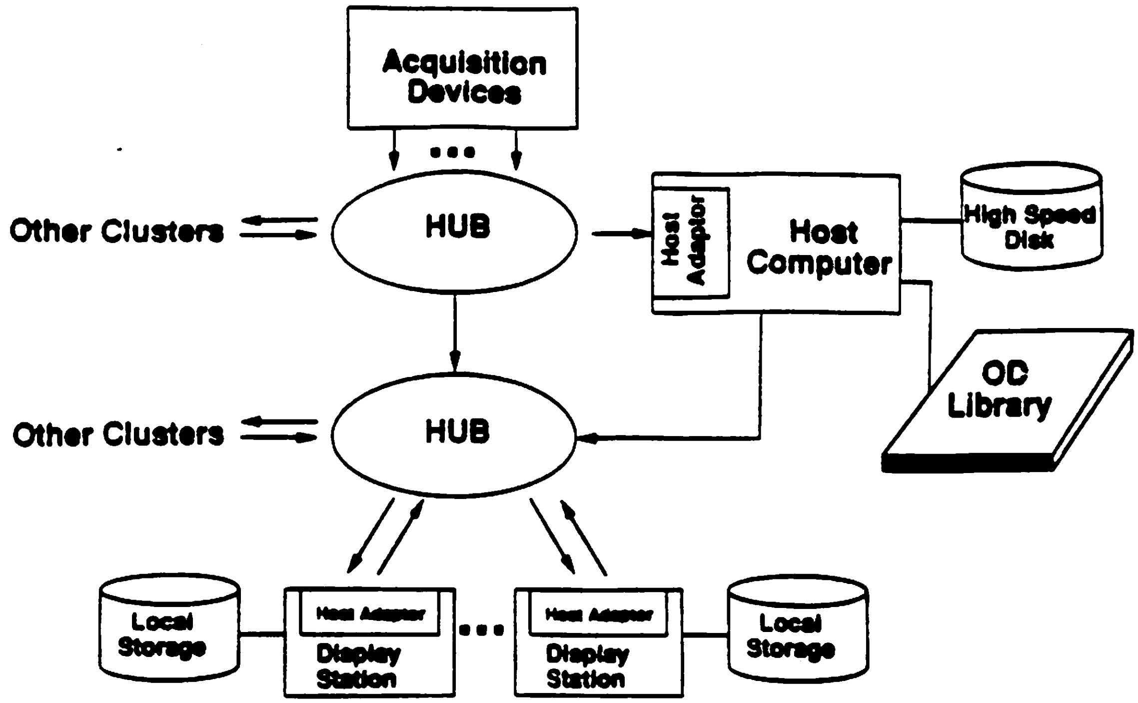
We are currently testing two emerging communication methods, a rooted tree network architecture and a token ring architecture. The rooted tree network we are using is the Canstar Super 100 network (Toronto, Canada). This network consists of two major components, the concentrator (or hub), with a 100 Mbits/sec transfer rate and the host interface unit (HIU) with a 10 Mbits/sec transfer rate (will be upgraded to 100 Mbits/sec in first quarter, 1990). The HIU is inserted in the backplane of the host computer and is connected to the concentrator with duplex optical fiber. The concentrator allows up to eight connections. An example cluster design is a concentrator connected to four acquisition devices, one host computer, a second concentrator and two display stations. Figure 2 shows the experimental set-up of the Canstar network. We compare the performance of this network with that of a standard Ethernet network and some results are shown in Figure 3. Although the HIU is currently limited to 10 Mbits/sec, the Canstar performs much better than the Ethernet. We anticipate that when the host interface unit is upgraded to 100 Mbits/sec, the performance of the Canstar network will be 3 to 4 times faster than the Ethernet for point-to-point communication; and the degradation would be less severe than that of Ethernet for multiple connection because of the 100 Mbits/sec concentrator capacity.

Another image communication method we are testing is the fiber distributed data interface (FDDI) which uses a token ring architecture. The user uses the FDDI as if it is the Ethernet, no computer program modification is necessary. The specification of this communication method is 100 Mbits/sec. Figure 3 shows some preliminary results. We expect that image transfer speed from the host computer to the display stations using the FDDI will be four to five times faster than the Ethernet when it is fully optimized.

Discussion

Radiologic image communication in this context is defined as transferring an image between two computers (processors). These two processors may reside in an image acquisition device, a host computer, an archival station, or a display station. The speed of the communication depends on the type of the processor used, the physical media connecting the processors together, and the software or the protocol which controls the communication between the processors. As an example, in an image acquisition unit the computer in a CT scanner was designed for control function and not for communication, the image transfer speed from the scanner to the outside computer is slow. On the other hand, the processor in a computer, a hub, a display station, and an archival station, can be chosen for facilitating image communication. As a result, high speed image transmission rate can be achieved from a host computer to an archival station and to a display station.

The current methods of transferring radiologic images are mostly DR11-W and Ethernet, both technologies were developed in the late 70s. Although relatively slow, both are reliable image communication methods. The new communication methods are the rooted tree network and the token ring architecture. We are experimenting with these two technologies as an alternate method for radiologic image communication.



Architecture of a Cluster

FIGURE 1

LOCAL AREA NETWORK TESTBED

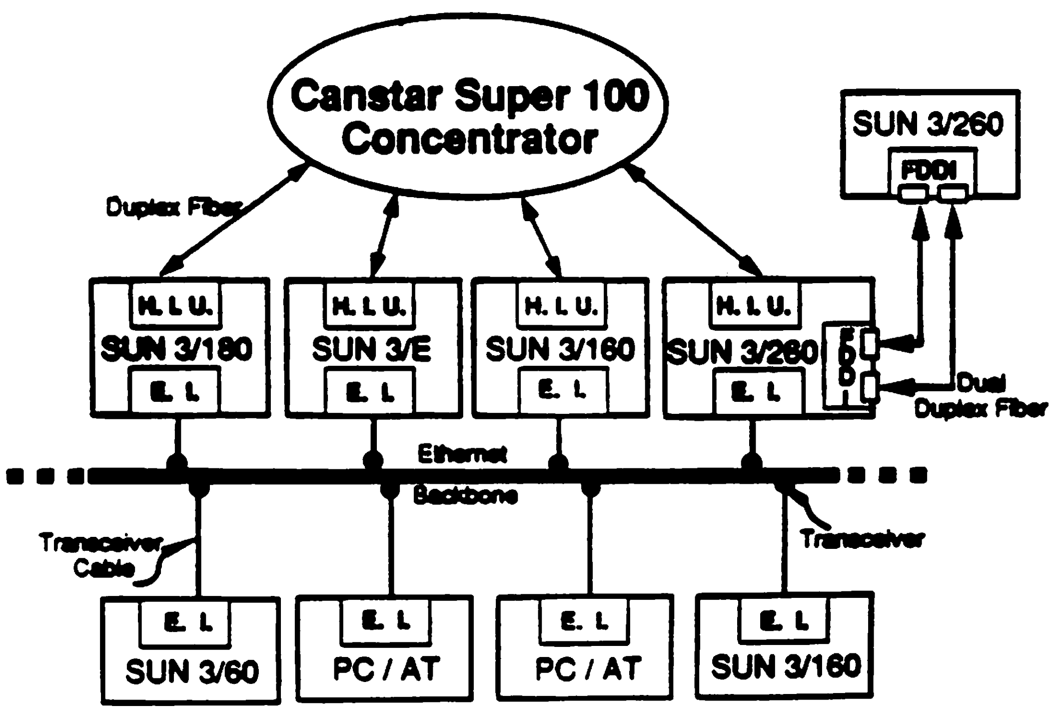


FIGURE 2

POINT-TO-POINT COMPARISON

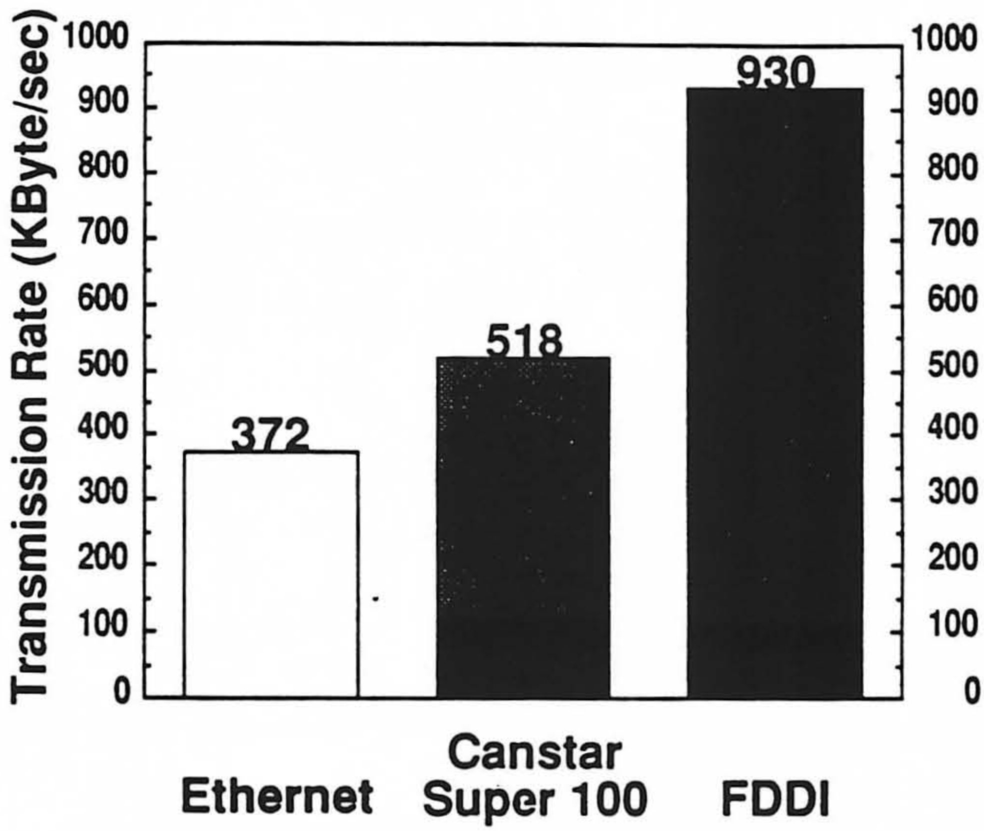


FIGURE 3

Clinical Experience with a Hospital Wide Comprehensive Image Management and Communication System

Seong K. Mun, PhD, Steve Horii, MD, and
Harold Benson, Dept. of Radiology, Georgetown University

Clinical Experience with a Hospital-Wide Comprehensive Image Management and Communication System

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Department of Radiology

Georgetown University Hospital

Washington, D.C.

Abstract

A comprehensive image management and communication (IMAC) network has been installed at Georgetown University Hospital for an extensive clinical evaluation. The network is based on the AT&T Commview® system and it includes interfaces to 12 imaging devices, 15 workstations (inside and outside of the radiology department), a teleradiology link to an imaging center, an optical jukebox and a number of advanced image display and processing systems. Three years experience with the network enables us to plan for the "total" digital department.

1.0 INTRODUCTION

The management of the vast amounts of medical images and information generated by today's clinical services is a growing problem. The solution to the problem will increasingly require the use of advanced computer-based technologies [1] in data storage, image display and communication, and human engineering. The progress of individual technologies has been rapid; however, system integration and user acceptance have been slow in coming.

Though the new imaging technologies have given the radiologist a powerful set of new diagnostic tools, the quality of radiology service has not experienced similar revolutionary improvements over the decade. In fact the use of many imaging modalities has imposed additional difficulties in managing films and data. New imaging systems have created a number of difficulties in managing radiology images and information because (a) they are often produced in physically distant locations, (b) images are presented in varying film formats, (c) radiology service is highly subspecialized and there is a greater need to review multimodality images, and (d) within large and complex medical care facilities there is an increasing number of competing demands for radiological images.

It is generally accepted that the management of radiology images can be improved by using some computer based image system. However, opinions vary. What type of approach would be desirable? The possible solutions [2] will depend on such factors as the nature of radiology service, the types of images, and clinical workload. The use of computer based image management is becoming a major challenge and it is expected to generate a great deal of interest in the near future.

How could this electronic technology enhance the quality and efficiency of radiology service? How should such technical capabilities be utilized to address the critical issues in a cost efficient way? Would the users, radiologists, and referring physicians embrace the use of this new technology? What kind of impact would IMAC technology have in the way that radiology service is performed. The project [3] at Georgetown University is designed to address these questions with close collaboration with a number of universities, government agencies, and the U.S. military. While many specific technical issues involving display resolutions, image processing methods, and data compression techniques are an important part of the project, additional emphasis is placed on the system-wide issues of IMACS as an integral part of patient care.

2.0 DESCRIPTION OF THE COMPREHENSIVE IMAC NETWORK AT GEORGETOWN

Georgetown University has installed a comprehensive IMAC system as a part of a digital imaging network system (DINS) demonstration and evaluation program. This section describes the IMACS based on the AT&T CommView network. AT&T is the primary system developer and integrator for the project.

2.1 Communication and data base system

The network topology used in the CommView system is the star based on primarily optical fiber. It may be susceptible to reliability problems, in that if the central node is down the whole network is rendered unusable. The star configuration, however, does bypass many of the issues that other topologies must consider, such as bus contention, data routing, and data transmission delays. In the CommView environment problems with the central node are not seen as catastrophic because most of the IMAC functions would not cease since the peripheral nodes, such as workstations, have local processing and storage capabilities. The image data quality is preserved at 2K x 2K x 12 bits throughout the system.

The central data management system (DMS) is connected to: (a) acquisition modules (AM) which collect images from the imaging devices, (b) high-speed workstations located throughout the hospital, (c) an archival jukebox of 89 Optical Platters, (d) a radiology information system through a PC, (e) the Montgomery Imaging Center, which is located 13 miles away, over a T-1 dedicated phone line, (f) gateways that support PC based workstations and a research environment on an Ethernet.

The primary transmission medium used to connect key nodes to the central node is a 40 Megabit-per-second (Mbps) fiber optic cable. Its wide bandwidth makes it a good choice for networks with high data traffic. Twisted pair and coaxial cables were also used to transmit text, image, and other data to various parts of the system.

The central node of the CommView system is a general-purpose computer, based on the VME bus and 16 bit Motorola 68010 microprocessor. The node is equipped with 12.5 Mbytes of RAM, a SCSI peripheral interface, a 1/4 inch cartridge streaming tape drive, 8 SMD disks and interface, and a terminal interface which supports RS-232C, 9.6 Kbps asynchronous I/O devices such as transcription, administration, and maintenance terminals as well as printers. The SMD magnetic disks which provide high performance, mass, on-line storage of both image and text data are backed up using a 2-disk mirrored arrangement. Total storage capacity is at the center node 7.5 Gigabytes. Although this mirrored configuration reduces the amount of on-line storage, it significantly reduces the probability of data loss caused by disk crashes, thereby increasing system reliability. The central node is powered by an noninterruptible power system.

All network data are channelled through the Network Communication Module (NCM). The NCM, which serves as the center of the star network, is a hardware device contained within the database management system (DMS). It supports up to 11 peripheral nodes. For each node there is a communication controller which is an intelligent processor that manages the bidirectional flow of data between the DMS and the peripheral node. The NCM is capable of supporting four different types of network communications interfaces. These are a 40 Mbps fiber optic, an 1.5 Mbps T-1, a 56 Kbps or a 4.8 Kbps line.

The long-term storage medium is a two-sided write once read many (WORM) optical disk. Each disk has a maximum storage capacity of 2.0 Gbytes. A Cygnet jukebox holding 89 optical platters and 2 drives is used. It supports an average disk exchange time less that 8.7 sec with data transfer rate of 262 KB per second.

2.2 Imaging and input device group

The acquisition module (AM) is connected to the central node using high-speed fiber optics that operate under AT&T's communication protocol. The AMs are interfaced to imaging systems and film scanners using one of two interfaces, parallel digital or video, depending on the interface capability of the imaging systems. The workstations are connected to the central node via fiber optics for high-speed transmission. Each AM has 360 MB of storage and can acquire images in the absence of DMS. Acquired images are sent to DMS as the DMS is available and its function is transparent to the user. Several AMs are used to avoid bottlenecks on the acquisition side.

Each AM can support up to five modalities. Associated with each modality is a data entry terminal used to enter and view patient information. The AM is also a VME bus, Motorola 68010-based computer. It comes equipped with at least 8.5 Mbytes of RAM, an SCSI peripheral interface, 1/4 inch cartridge streaming tape drive, at least 360 Mbytes of Winchester disk storage and a terminal interface that provides support for a maximum of seven RS-232C, 9.6 Kbps asynchronous I/O devices.

Eight imaging systems (Siemens MRI, two GE CTs, a Siemens Fluoroscopic system, and four ultrasound units) are supported by two AMs. Philips computed radiography (PCR), which is being installed, is supported by a separate AM because of its larger data volume. Laser film scanners (LFS) have DR11W interface and the PCR has ACR/NEMA interface functionality based on DR11W hardware. Other modalities are presently connected through video interfaces. Full ACR-NEMA interfaces are being planned for installation between the network and CT and MRI so as to preserve full digital data. The LFS generates 2000 x 2500 x 12 bit data set for chest films and the PCR generates 2000 x 2500 x 10 bits per image. The entire network preserves all 12 bits of data.

2.3 Workstation group

The IMAC network based on AT&T's CommView system supports three categories of workstation: (a) "turbo" speed display workstations (EDW); (b) results viewing stations (RVS), and (c) special workstations such as SUN, or PIXEL, or PIXAR. The EDW workstations are supported by 40 Mbps optical fiber links and EDWs can be configurated with four, two, or a single screen. Each EDW has 360 MB of storage and can be upgraded to 760 MB. The primary user interface is a set of dedicated function keys and dual track balls, as shown on the following page.

The image data matrix size is 2K x 2.5K x 12 bits for chest images on the network. The workstation displays 1K x 1K images, or a full data set can be accessed using the pan or magnification features. It is possible to enter a diagnosis at the workstation through a key board. The user interface to the workstations is analogous to the physical patient folder. Patient folders can be requested, and images or text can be pulled from the folder for display. Images can be moved from screen to screen, zoomed, rotated, panned, or flipped. Window level and width can be changed, and the lookup tables can be modified in real-time.

The RVSs are PC based workstations that can be supported on Ethernet or over a 19.2K modem. Each EDW and RVS has a separate data terminal with a keyboard and CRT. An EDW has a number of dedicated function keys for each operation. The function keyboard is shown on the following page. The workstation can handle 2K x 2.5K x 12 bit image data, however the CRT displays 1K x 1.2K x 8 bits.

The GUH system provides multiscreen high resolution workstations to the following subspecialty areas: Neuroradiology, Abdominal Imaging, Ultrasound Imaging, and General Radiography. The following services with single screen EDW are on the network: Radiation Oncology, Emergency Room, Nuclear Medicine, Cardiac Surgical Intensive Care Unit and Pediatric Intensive Care Unit. Additional services with RVSs that will be on the network are: Cardiac Radiology, Oncology, Neurosurgery, and other remote sites.

An advanced workstation development environment has been established to research a number of fundamental aspects of a radiology user interface. The facility includes a Sun workstation, a PIXAR system, AT&T's latest PIXEL Machine, and 2K displays.

2.4 Teleradiology group

The GUH radiology department operated an outpatient imaging center in Rockville, Maryland. Montgomery Imaging Center (MIC), located 13 miles north of GUH, has a complete radiology service, including CT and MRI. All the neuroradiology service for CT and MRI has been provided by GUH. Siemens 1.0 T MRI and Siemens CT are connected (video) to an AM and the AM is connected to the GUH DMS over a T-1 line that costs $750 per month. The T-1 line has a transmission capability of 1.5 Mbps. Images transmitted to the GUH workstation can appear within a few seconds. The link, however, has been terminated this past November, for the clinical service relationship with the imaging center was terminated.

2.5 Research environment

A research environment consisting of a number of advanced image processing and display devices has been developed to test basic concepts [13] in IMAC in the absence of daily clinical operational requirements. The developmental network is based on Ethernet and it is connected to the CommView network through a gateway. Image and information can be exchanged between the clinical and developmental environment. The network has several sections: image processing, network research, and a Konica facility.

The image processing section supported by SUN computers, PIXEL and PIXAR, is primarily concerned about data compression, workstation and image handling issues. The network research section with AT&T PC386 and a shared SUN concentrates in RIS interface and network modelling and validation.

The Konica facility has a dedicated chest system using the Konica direct digitizer (KDD)[1] based on Konica's phosphor plate, a Konica laser film digitizer, a and Konica laser printer. The facility is supported by a microVAX which is connected to the Ethernet.

3.0 NETWORK OPERATIONAL EXPERIENCE

Operating a large network in a clinical environment has given us an opportunity to evaluate the impact of IMAC technology on a network scale. This section describes our experience with the network in taking on a major portion of the radiology department. The discussion here is rather qualitative since specific data are presented in other publications from our project.

The capabilities and limitations of the current system at Georgetown are summarized in the following section. They are discussed in several groups: acquisition, storage and archive, work station, communication and operations.

3.1 Acquisition Devices and Interface

The success of IMAC technology first depends on clinical acceptance of image quality. The question of image quality in an IMAC environment has not yet been fully resolved, but a growing number of papers suggest that 2K x 2K x 10 (12 bit) acquisition for a chest image is quite acceptable. For other digital modalities such as CT, MRI, nuclear medicine, and ultrasound, the image quality is preserved as the images are transferred from the imagers to the network. The quality of the chest images is the most technically demanding. A careful comparative study of 250 occupational lung disease digitized images is currently underway at Georgetown in collaboration with the National Institute of Occupational Safety and Health (NIOSH). Preliminary evaluation indicates that the network does not compromise the image quality when the images are digitized at 2K x 2K x 10 (or 12) bit.

Image acquisition can be characterized by image quality, data quality, speed, and operations. Video interfaces and currently used for CT, MRI, and ultrasound imagers.

The laser film digitizers by Du Pont and Konica have digital interfaces to the network. The video interface has two shortcomings: image quality degradation and the inability to acquire images automatically. In the case of CT and MRI, the reconstructed images have a dynamic range greater than the 8 bits which are not allowed in the video interface. The video interface unit redigitizes the video signal of post-processed digital images.

One shortcoming in video interface is the level of operational difficulty. As mentioned earlier, a switch needs to be pressed for each frame or image. This requires constant attention of the technologist. Noncompliance by the technologist has been a serious problem. In a video interface environment a system operator has to enter patient information twice: once on the information system and then on the acquisition device. Once the studies are completed and ready for hard copy production, two buttons must be employed which slows down the overall operation. Of course, if hard copies are to be eliminated, the extra efforts could be reduced. New digital imaging equipment is adopting batch hard copy capability, which make video interface to the operation impossible.

An ideal interface should place a full set of images on the network as soon as the study is completed. This would operate in the background, transparent to the user. One objective of the ACR/NEMA interface is to allow this type of data transfer.

4.4 The workstation and its environment

The workstation is indeed a communication center from the users point of view, in that it can access images, patient data, and medical records and produce proper reports for distribution. It should have means to bring all the necessary information together, and accept a user's commands as automatically as possible

Workstation performance is the most critical factor affecting user acceptance in the IMAC network. The workstation forces radiologists and users of the radiology service to change the traditional way of reading images. The performance of the workstation cannot be viewed in isolation, since workstation performance depends on the capabilities of the rest of the network. A number of workstation specific issues, however, are discussed here: image quality, image processing, display capability, user interface and reporting.

Image quality in IMAC environment depends on the image matrix size (resolution), bit depth (dynamic range), uniformity, data compression and display characteristics. In a majority of chest cases, an image data set of 2K x 2K x 8 bits is acceptable as long as 8 bits of dynamic range is carefully selected from 10 or 12 bits of data. In other cases such as CT, MR, Ultrasound, and nuclear medicine, the image matrix defined by the imaging systems is preserved. Because of the video interface, however, a selected eight bits of the dynamic range is used. This has not degraded the image quality in comparison to film hard copies. In the case of CT images, multiple window settings for video capture are preferred as done in the case of current hard copy procedures.

In digitizers, it was found that the digitizing bit depth should be greater than eight bits. For a 12 bit analog-to-digital converter (AID), the lowest 4-bits were found to be noise and for a 10-bit A/D, the lowest 2-bit were noise.. Reduction to 8 bits from the 10- or 12-bit provides the advantage of reducing data volume and to allow the use of 8-bit hardware devices that are much less expensive and more readily available.

A number of image processing and display capabilities are needed as they are practiced even in the film based environment. The capabilities include: contrast enhancement, magnification, minification, sharpening, smoothing, flip, rotation, image movement, placement of images, image display sequencing and display of support data.

Most of the processing functions are available in the current workstations, but one major difficulty has been the display speed. The display speed has improved and we can now display 80 MR/CT images in 1. seconds, which has shown to be clinically acceptable. A combination of novel display techniques and faster hardware will be able to speed up the display further.

The display characteristics of the CRT's need more study. Brightness, color, persistence, uniformity and sharpness define the display screen. Compared with film boxes, current display are significantly dimmer. Brighter displays will be available in the future. Not much work has been done to select the most pleasing brightness, color, or persistence. Uniformity and sharpness should also be studied further to optimize the viewing quality.

The user interface is a complex subject. The system should be designed to mimic the thought processes of the user, and the operation of the workstation should be friendly rather than intimidating. Much work has been done to model the radiology user interface in the software and hardware environment. User interface questions cover: patient selection, image selection, data base imaging, sequence of activities, image handling, and other activities demanding services fr.

the network. Better understanding and better hardware devices have contributed significantly to the development of more friendly user interfaces, but more work remains to be done.

One of the major deficiencies in workstation function is a lack of efficient report generation. The final product of the radiology service is the report. The ability to make images available alone without efficient report handing capability will not meet the primary objective of image management. The incorporation of efficient reporting and simultaneous management of reports is essential to IMAC. Report generation is currently difficult and nonautomatic because speech recognition technology has been poorly accepted by the radiology community.

A better workstation environment is desirable. A noisy, hot or cold, or poorly lighted environment cannot be attractive. In many cases, a radiologist can spend half a day in front of a workstation. If the workstation environment can be comfortable and efficient it will go a long way toward helping win clinical acceptance.

Radiology film library users usually require several minutes to recover a film jacket as they must walk through several hallways and ride slow elevators. However, the users of computer systems become irritated if the response time of a network is several minutes. They are irritated further if the performance of a computer system fluctuates. Users expect more from technology intensive devices. The expectation can be greater in terms of speed and/or other qualities. The shortest possible response time alone is not useful, if it varies much. Operationally speaking, it is better to have consistent response times, even at the expense of peak performance. If the performance is consistent, the users will adapt to the system better.

4.2 Network operation and data base

Network operation refers to the flow of the images and information through the network, from one station on the network to another. For example, data moving from an acquisition device to a database to a display station. Many aspects of the network can affect its performance: the configuration of the network, the communications media used for transferring data, or the speed of the storage devices for reading and writing. Since we have control over some of the features of the network, it is important to understand the bottlenecks along the network, that is, those areas that cause transfer to slow down.

An important aspect of the network is the database management system (DMS). This system controls the local storage, archiving, and retrieval of images and patient information. An efficient DMS can help increase network performance and control the load on the network. Much work still needs to be done in this area to determine the optimal patient archival and retrieval methods using various forms of high density storage media.

Images are stored at a number of places on the network: the acquisition node, magnetic storage at the central node, the archive workstations, and the image processor. Efficient interaction of all these storage devices is a critical issue for network performance.

As images are acquired at the acquisition module, the digital data are transmitted to the central magnetic storage. The central storage also stores images called out (dearchived) of the optical juke box archives. When images are requested at any of the workstations, images are copied to the magnetic disk of the workstations. If the same images are requested at several workstations, the same images are copied to various storage devices on the network. Images are loaded to memory on image processing boards for rapid display and processing. If the images are viewed and no longer needed at the workstation, the data file is deleted to make room for more images. The images in the central magnetic disc are periodically archived (moved rather than copied) to an optical juke box that contains 89 platters of 2 Gbyte storage capacity each.

The acquisition node should have enough capacity to store 1 to 2-days' work. In the case of the Georgetown IMAC system, the acquisition can take place even in the absence of the functioning central node. The central node should be able to store 7 days worth of new and previous studies which can be reviewed throughout the hospital. Each workstation should have enough capacity to handle two days' data volume. The actual storage capacity depends on the workload and clinical environment. At Georgetown we are studying the storage requirement as the network gains wider user acceptance.

Image archiving is a third area of concern. Currently image data are written on optical disks in a chronological order as they become available. Eighty-nine platters each with 2 Gbyte capacity are stored in a juke box. At the current rate of data acquisition the juke box will hold approximately one year of data. The directory of image location is kept in the magnetic storage device that drives the juke box. Storage technology is improving rapidly. In radiology applications higher density is more important than higher input/output speed, because archiving or dearchiving can be done during off hours in most of the cases. New devices such as optical tape or super high density optical disks offer some very interesting possibilities in image storage.

4.3 Communication flexibility and options

The Communication of images, text data, and other control information in the network require a combination of several communication capabilities and media. In the case of the Georgetown system, images travel on the fiber optics network for the high performance workstation, and on Ethernet for the P/C based review stations. The twisted pair cables are used for text and control information. The teleradiology link to an imaging center located 13 miles away is supported by T-1 (1.5 Mbps) lines. Because of the extremely high data volume of diagnostic images, it is generally accepted that the fiber optics is the preferred means of image transfer.

Fiber optic links, a T-1 link, a 19.2 kbaud dial up modem, and Ethernet have all been tried at Georgetown. While the combination of these has been successful implemented, additional flexibility would be helpful. The fiber optics provides a 40 Mbps high-speed transmission capability. It is extremely responsive, but the current CommView system can only support a dozen such high-speed links. More than a dozen high-speed workstations are needed throughout the hospital. The other workstations are supported by Ethernet or by a 19.2 Kbps dial up modem. They are fast enough for our teleradiology and review workstation uses. The T-1 links are fast and highly reliable, but expensive. Communication speed about 0.5 Mbps that can cover wider areas (within a mile radius) would be highly useful.

One should note that overall, throughput on any communication media (fiber or not) is significantly lower than specified. Often the specification is based on the raw signalling speed. In reality, the resultant throughput depends on communication traffic, error checking, communication overhead, and the input/output speed of devices at each end of the link. This tends to reduce the throughput by as much as a factor of 10 over the signalling rate.

Managing the network is more than a technical issue. A large network such as the Georgetown system requires close coordination with many people and organizations. Constant training is required as the personnel turns around and the system performance improves. For a network of 10 or more workstations one has to train radiologists, radiology residents and large number of physicians throughout the hospital. Technologists and the administrative staff need to be trained as well.

4.5 Interface to radiology information system

It is essential for an IMACS to exchange information with a computerized Radiology Information System (RIS). Conceptually, IMACS is a subset of RIS. A RIS maintains textual information about a patient, such as demographics, exam information, reports, and billing. Some of this information is needed for storage of the images in the PACS and documenting them as they are displayed on the workstations. Sharing this information between the RIS and the PACS is not a trivial task. A year was spent developing an interface between the RIS and IMAC system at Georgetown.

The goal of the RIS - PACS interface is to exchange information between the two systems in a relatively timely, efficient, non-user intensive manner. This would allow for the registration of a patient on one system only, while allowing the other system access to the information. Currently, most hospitals which contain a PACS must enter a patient into both the RIS (or the HIS) and the PACS separately. This increases the risk of more errors in the data and of incompatibility between the two databases. Also, during busy times, the possibility that data will not be entered into one of the systems is increased. Such a user intensive system for entering information into the systems will not be tolerated by busy technologists, receptionists, etc. Therefore, without an interface between the systems, the full impact of a IMACS on a radiology service cannot be complete. The interface with RIS has significant operational impact. A patient scheduling module within RIS can initiate data transfer and merge, and provide scheduled data movement to avoid bottlenecks.

Communication, or the movement of images on the network, should be automatic and transparent to the users. In radiology operations, image movement is mostly predictable. The Radiology Information System has the scheduling module which contains which patient is scheduled for what type of study. Such information should be sent to the IMAC network so that related images can be retrieved from the archive in the background and sent to appropriate workstations and merged with the new image set. When a viewer wants to read necessary images, they images should be presented to the reader in a pre-defined predictable manner. Once the reading is completed, if there is no longer a need to view the images at that location, they should be deleted at the workstation and be kept at the active storage (central magnetic storage), or be archived. A great deal of sophisticated image management is needed to fully automate the network operations.

The use of the IMAC network changes the way radiology service is provided and used. What is the best way to use this expansive and complex technology? What would be the impact of such capability? Can it be cost effective? A number of important questions have yet to be answered.

Some are skeptical of the IMAC concept for various reasons. It is clear, however, that IMAC in one form or another will be implemented in radiology services due to the increasing difficulties in managing radiology images. There are already many IMAC related activities in small and large scale all around the world. The explosion of new capabilities in communication, data storage, and display will all have a powerful influence in developing IMAC technology. Close collaboration of the user community, research teams, and industry will be necessary to bring about a graceful implementation of the components of IMACS.

5.0 CONCLUSION

Integration of new diagnostic imaging systems within routine radiology practice has been relatively straightforward since a single imaging system does not affect the basic operation of radiology servic and the associated cost can easily be computed and justified. The rapid acceptance of new systems such as MRI and CT by the radiological community was accelerated in part because these new imaging modalities enhanced the role of radiology service and radiology professionals in patient care.

Unlike imaging modalities, implementation of IMAC technology is not straightforward. It involves many services beyond radiology and it may change the way the radiology service is practiced. The traditional image medium, film, has been around for almost one hundred years and it has many desirable features in image recording and presentation. Many radiologists are happy to continue the use of film as they have been doing all of their professional lives. Support from the radiology community is difficult to sustain in part because the IMAC concept, unlike MR or CT, is not considered "diagnostic medicine."

One of the most difficult issues in the implementation of IMAC is the identification of the primary objective of the network. What problems in managing a radiology service is one attempting to address? IMAC is a broad concept with many subcapabilities, and one may not need all the capabilities. The technology has to be targeted to specific issues. The primary objective many be any of the following: solving the difficulties of managing a massive film library, providing images to radiologists and referring physicians at distant locations, reductions in film dependance to reduce operating cost, providing flexible image presentation and processing capabilities, developing a comprehensive data base system including image and text data, providing radiology service to distant locations, improving the radiology report turn-around time, or developing in-house expertise on new technologies.

Once the objective is established, it is essential to go one step further and identify specific problems that one needs to address. For example, in the case of the film library, what are the real problems? They could be any one or a combination of the following: storage space, decentralized storage system, difficulties in recruiting film library personnel, too many competing users, better control over images, or lost films. The clear definition of objectives in response to real needs or specific needs for solutions will greatly improve the utility of IMAC technology. The objectives will also aid the development of priorities in developing the IMACS network in a radiology service. Without such a definition of goals and priorities, the users of IMACS, physicians and other health care personnel, will often be discouraged due to unrealistic expectations.

Our experience at Georgetown provided us with a rare opportunity to see the future of fully automated radiology service. There are a number of major obstacles. There are a number of new emerging technologies, such as digital radiography, high speed displays, high speed networks and super high density storage devices. System integration has been possible, but functional integration [15] will take more time. The network that we have at Georgetown has been a robust communication platform from which the next evaluation can take place.

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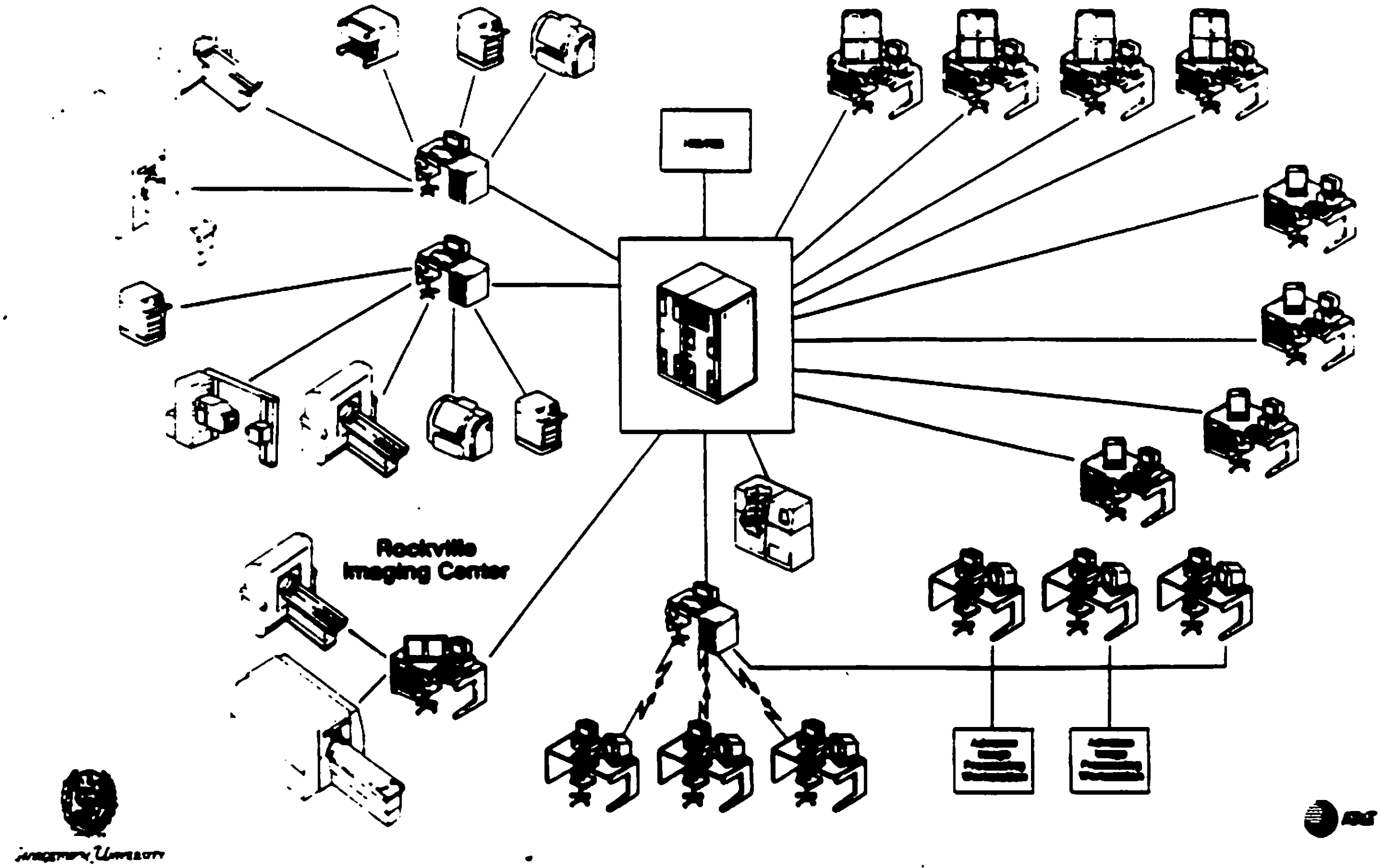
Georgetown University
Image Management & Communication System



Architectural Options Analysis:

State-of-the-Art and Future Prospects

The Role of ISDN in Networked Imaging Applications

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I've been asked to take a half hour to explain the potential role of ISDN in networked imaging applications, both today and tomorrow. To say the least it will be a whirlwind tour. From my perspective, this is essentially an applications case study. From your perspective, I hope it will be a broadening of your thinking about the role of computers and multi-media networks in your profession.

This first slide is representative of today's typical networking schemes. The LAN will link workstations and servers or multi-user hosts at transmission rates in the range of a few to hundreds of megabits per second. The industry has converged on a handful of accepted topologies and low level protocols. Topology may be bus, ring, dual ring, counter rotating rings, etc. In common practice, all of the equipment on the LAN may spontaneously generate traffic for any other equipment without formally establishing a connection first. This is the generalized connectionless networking philosophy.

LANs are fast and efficient in locally administered environments. And there are many product options, with a lot of existing and emerging applications and software support. In the case of imaging workstations, it is practical to implement a distributed architecture with storage intensive image files residing on a remote server that provides a file and/or directory structure that is virtually local to the workstation.

The same server or a separate server may contain a text and/or graphics data base which is correlated to the image records, say for comprehensive patient records. As the discipline progresses I expect we will see many more software and networking tools evolve for applications development of this nature. In fact I will explore the incorporation of voice or more generally audio, as a third component in a multi-media workstation environment. You will see that this is significant from a networks point of view. It is equally significant in terms of creative freedom afforded to applications developers.

One typification of ISDN is as a networking environment for the integration of voice, data, and image; just what I have prescribed. The trick is to realize that the state of the art requires some finesse in capitalizing on the potential of ISDN while retaining the advantages of existing connectionless networking. ISDN has evolved in the culture that provides us with ubiquitous and highly reliable telephone communications. In the telephony world, we virtually always establish a connection between parties before we communicate. You do it every time you make a telephone call.

I don't mean to insult your intelligence with this discussion. It turns out that these issues of connectionless versus connection oriented networking are truly profound. It pervades the entire arena of open network communications standards. I will show you in the following slides how these two communities of thought will be perpetuated and yet how the underlying network technologies and topologies will be merged. I will also apply these factors to the specific case of distributed imaging applications.

A second historical factor is that voice communications generally utilize the twisted wire pair medium in a point-to-point star topology. Initially ISDN has followed this historical norm. There are great advantages in the utilization of the installed wire plant, and once your communications requirements extend beyond the boundaries of your privately owned property, either you communicate over telephone cable, or you pay a dear price for alternatives. In the early incarnations, ISDN represents the transition from analog and voice specific use of the massive wire and switching plant in this country, to a digital transmission environment using the same installed plant. When we digitize voice at the source, namely the telephone, then we establish a network that can carry all forms of data, inclusive of voice. When we add the intelligence to allow computers owned by the user to communicate with computers that reside in the network, in significant ways, then we have the intelligent network.

Until recently, digital voice has required a 64 Kbps "pipe", as it were. For this reason, the initial ISDN service definitions dwell on 64 Kbps transmission rates. You should note that these pipes are dedicated and connection oriented. Local area networks typically provide much higher transmission rates, but you should remember that all stations on the network must share the bandwidth. Still, LANs have a performance edge that is substantial and should not be ignored by the ISDN culture. Now ISDN also provides for connection mode packet data communication, which is well suited to some kinds of applications, and which represents great economy where it is applied.

So, if we are to be practical, in terms of developing multi-media applications which can be made widely available over a broad geography, such as citywide, or countrywide, or internationally, then we will apply local area networks on premise, and ISDN in the wide area. In addition, if we are to be practical, we will recognize that some of our communication will be connectionless, and some will be connection oriented. If we wish to have voice as a component of our multi-media, it will be in a circuit switched connection oriented mode, at least for the coming years. We will see that connection oriented data is also useful for wide geographies and spontaneous network attachments.

So, in this picture we see two local area networks with some composition of workstations and file or data servers, and ISDN as a means of simultaneously providing economical wide area voice and data connections. What can we do with this, remembering of course that we also have upgraded the telephone network to an intelligent network where the customers computers can talk directly with network computers in the negotiation and control of services.

The first feature is the addition of the telephone symbol to the workstation graphic. I can in fact show you, right now today, commercial ISDN products which replace telephone terminals of the highest functionality, by a pc expansion board and software which implements the telephone hardware as a graphical user interface element. So the ability to make calls, place calls on hold, conference call, auto dial, etc, are now all internalized.

Remember I'm talking about voice calls and data calls and packet data virtual calls. And unlike modem communications, this is an intelligent network. When calls are made, when special services are used, when error conditions arise, my computer stays fully informed by network computers. With a modem I get an audio recording if the dialed number is not in service. With ISDN the network switch notifies my computer of the situation using a standard cause code. When I'm not around, my computer can negotiate a conference call, or retry a call without my assistance and in synchronization with the network. This has great applications implication.

In the case of the host or server attached to the ISDN, many functions can occur which are triggered transparently from within an applications program. So, for instance, we can envision these local area environments which may be separated by hundreds of miles, staying in sync while using a networking scheme which is practical. And note that the workstation in the lower right corner has connectivity by virtue of the ISDN connection alone.

Now, image records on the two hosts can be routinely updated during the night using low speed data connections over ISDN. These connections can be set up and torn down without operator attention, and new servers can be added quickly by attachment to the ISDN rather than by long laborious dedicated circuit provisioning. Infrequent data downloads can be carried out between servers or between a server and an isolated workstation on an as needed and spontaneous basis.

Perhaps more importantly, ISDN has provided people connectivity. Voice communications are intrinsic to the multi-media workstation. Envision that the workstation is attached to your organizations PBX, so all telephone functionality as it is provisioned in your organization and the public telephone network now extends to your workstation. With intelligent networking, I can ask my workstation to arrange for images and associated records to be transferred to another specialists workstation and for the network to call me back when the conference is ready. It may take longer than it would over a LAN to move the files, but my time is not lost. How inconvenient is a delay in the records transfer, if I can simply notify my workstation that say, four physicians from different locations in the U.S. should be brought together in a voice, data, image conference call to consult on a particular patient case, at some pre-specified time.

In this scenario, the initiator's workstation might notify the appropriate host to transfer the image and patient data records to the other hosts or workstations, then send notification of the time of the conference call to the other participants, and ask for confirmation of availability. The request for confirmation may be in the form of a synthesized voice mail message on the other M.D.s PBXs! At the time of the conference, my workstation brings up the appropriate image records, and rings me back along with the other participants. Using circuit switched services and a conference bridge the physicians can talk together naturally. Using packet mode connectivity, each physician might be given a unique pointer icon, and control of the session could be passed between participants. The controlling participant could for instance scroll, zoom, or perform image enhancements. These low rate operator interface functions could readily be handled by the ISDN in real time, with the invocation of bandwidth intensive operations at each workstation independently.

This is ISDN today! But not really. We are missing the applications. It has been a long haul to convince applications developers that ISDN will be a viable networking component.

It has been difficult to communicate the advantages of ISDN in applications scenarios such as this. And it has been particularly difficult to bridge the datacom and telecom cultures. For ISDN to reach its full potential, there must be a marriage of the telephone and the personal computer. This is what I would call the first true personal workstation. There must also be a marriage of the data server and the software controlled telecommunications switch. Culturally this will be a shotgun wedding. But I assure you that it is happening.

An ISDN applications developer is going to face new challenges. He will need to understand telephone switching technology and values, and he will have to understand the regulated wide area nature of telecommunications. Foremost he will have to understand the ISDN architecture and reference model and respond accordingly. It is like teaching an architect to use masonry, when he has never seen any other material but wood.

As ISDN networks evolve, the availability and variety of access to network services will expand. ISDN interfaces will be deployed from privately operated PBXs and multiplexers, and interfaces are now available and will increasingly be made available from public telephone network serving offices. At this point we see the payoff of using the existing twisted wire infrastructure. The scenario I previously described can include geographically independent locations; emergency medical facilities, private operating room facilities, private medical offices, teaching universities, etc. In the future we may add digital cellular communications to the list.

Using this modus operandi, enhanced services offerors can establish medical record keeping and archival services which appear to the ISDN customer to be a part of the network. Imaging applications can be integrated with other ISDN enabled services such as on line medical data base services. In our present case study, one could contract for legally significant conferences to be recorded and maintained transparently in the network with subsequent access on a demand basis. The value of ISDN is the following. It permits the use of widely distributed transmission and computing facilities in a harmonious fashion. If I only need to hit the archive once a week, why build a static network attachment to the archive. If many facilities can economize through the sharing of one central archive facility, why should each install, maintain, and protect a separate facility.

So let's continue our case study with this new advantage of transparently accessible assets in the network. Suppose for a beginning, we assume that the experts' conference call was bridged, meaning the place where the individual voice and data connections came together; was bridged at an archival center which was not local to any of the participants work places. The server holding the image records is identified to the archives host and so it can retain this information without actually retaining the image record itself. The archival host does retain the audio and data session control records though, and this is known by the image server. Meanwhile all of the conference participants workstations retain full knowledge of the reference to both the image server and the audio conference record.

What we have constructed is a distributed patient record which holds references to audio, data, and image records. The patients medical records can reflect all of this information content without the intensive memory requirements that would exist if all the information were stored in one place in a flat data file structure. Part of the patients portfolio is a multi-media conference call that could reside hundreds of miles away in the archives of a company which is independent of the patients serving hospital or clinic. In most cases the full content of the record would never be reconstructed.

Hypermedia is the programming discipline which correlates to this networking and distributed data base scenario. A hypermedia medical record would contain inferences to the various information content but reconstruction of the full record would require a retrieval of the distributed components. The justification of diagnosis and treatment might also include references to other similar expert conference records. In this case the attending physician uses the composite network archive as a research library. Rather than calling for an experts conference for each case, he can now look for precedence in the central archive. Note that a precedent case retrieval could trigger the archival center to retrieve data and Image records in servers not directly accessible by the researcher. The virtues of a highly distributed and connection oriented networking scheme come to light here.

On the nuts and bolts side, there are some inefficiencies in the independent local area and wide area topologies of the last two slides. There will also always be the desire for higher throughput at more attractive dollar per bit rates. Projecting the future is always a dangerous business, but today's emerging standards do suggest ways in which the previous networks may become even better.

One standard of interest is the draft IEEE 802.9 standard. It comes to us from the same folks that give us Ethernet style contention networks and the token ring standards.

The 802.9 standard is very interesting in two respects. First, it has been designed from the beginning to be an integrated access to both connectionless local area networks, and connection oriented ISDNs. It has also accommodated the technical requirements for passing digitized voice data, in a packetized manner along with other data types. The interface has a point to point topology using twisted pair wiring, but the access unit on the network side can separate LAN traffic from ISDN traffic and send them in their respective directions. The 802.9 interface has a transmission rate of 4 Mbps, as contrasted to the ISDN Basic Rate Interface effective transmission rate of 144 Kbps.

If the 4 Mbps rate seems slow, remember that this is a dedicated point to point link as opposed to the shared medium of conventional LANs. It will have an effective throughput greater than that of a typically loaded local area network.

An 802.9 network board would replace both the ethernet board and the ISDN board in the workstation. Low level software revisions would be required. But, at least in theory, no modifications to the application software would be required.

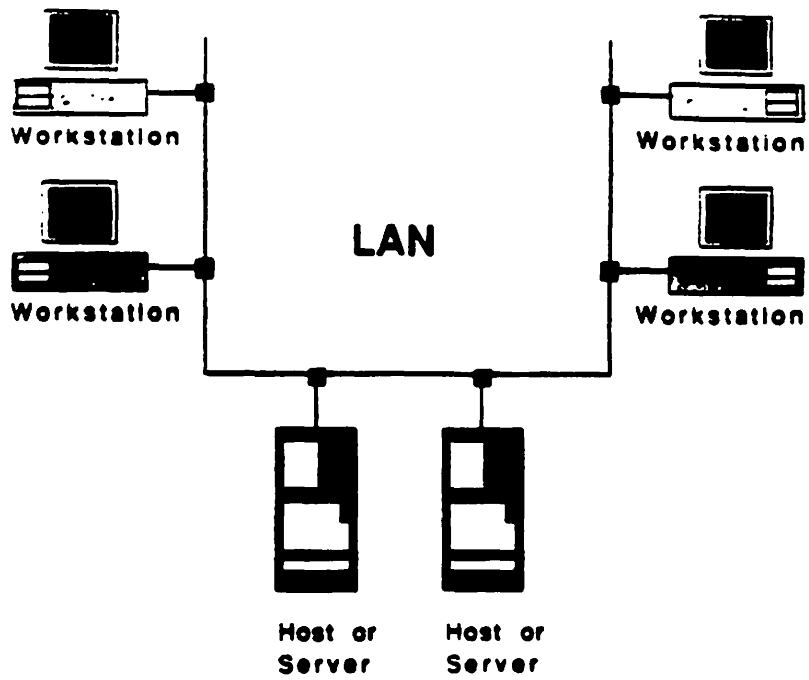
We should see VLSI components for 802.9 in the next couple of years.

Looking down the road once more, there is the promise of fiber optic based, high speed integrated networks under the title of Broadband ISDN. These networks will boast very high bandwidths and like the 802.9 standard, are designed to be supportive of both connectionless LAN protocols and connect oriented and real time critical services including voice and full motion video.

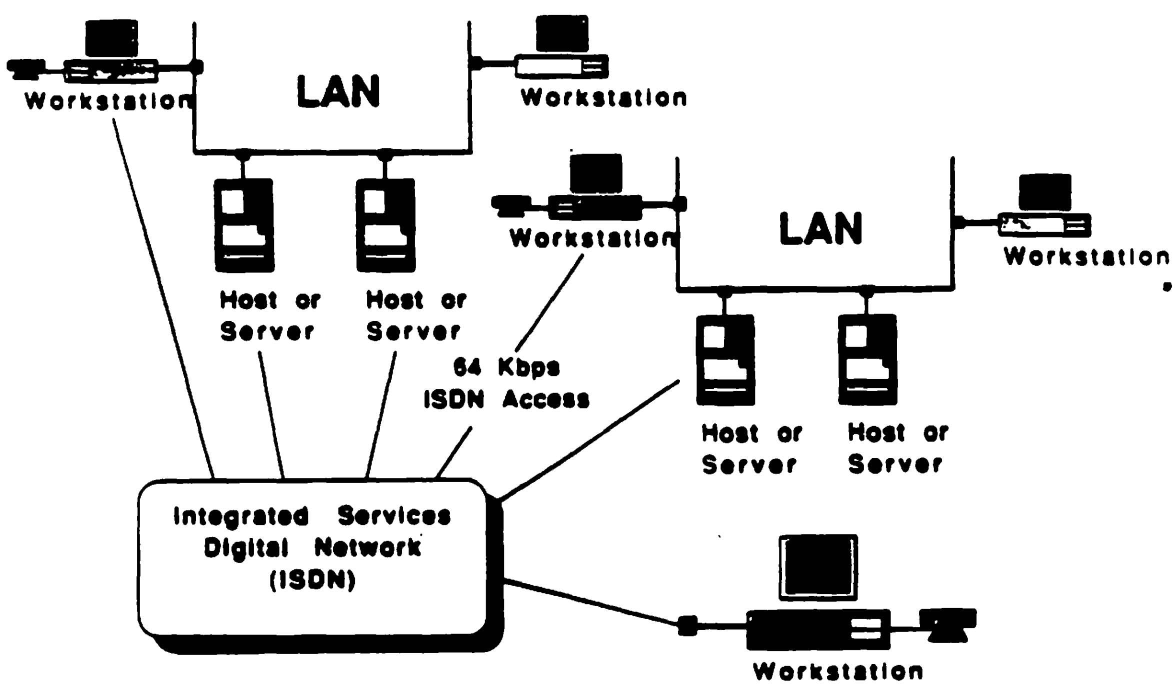
Broadband ISDN will give credence to the wide area high speed networking vision. But make no mistake, there will be associated costs. Broadband ISDN will first be made available to the customers of network services with the deepest pockets. Traditional LANs and ubiquitous ISDN interfaces will not be supplanted.

So when the data communications people tell you that LANs can be all things to all people, don't you believe them. And when the telephony folks tell you that ISDN will make the connectionless LAN a dinosaur, take them with a grain of salt. If you want to stay strategically on top you should look both ways for networking solutions to meet your applications requirements.

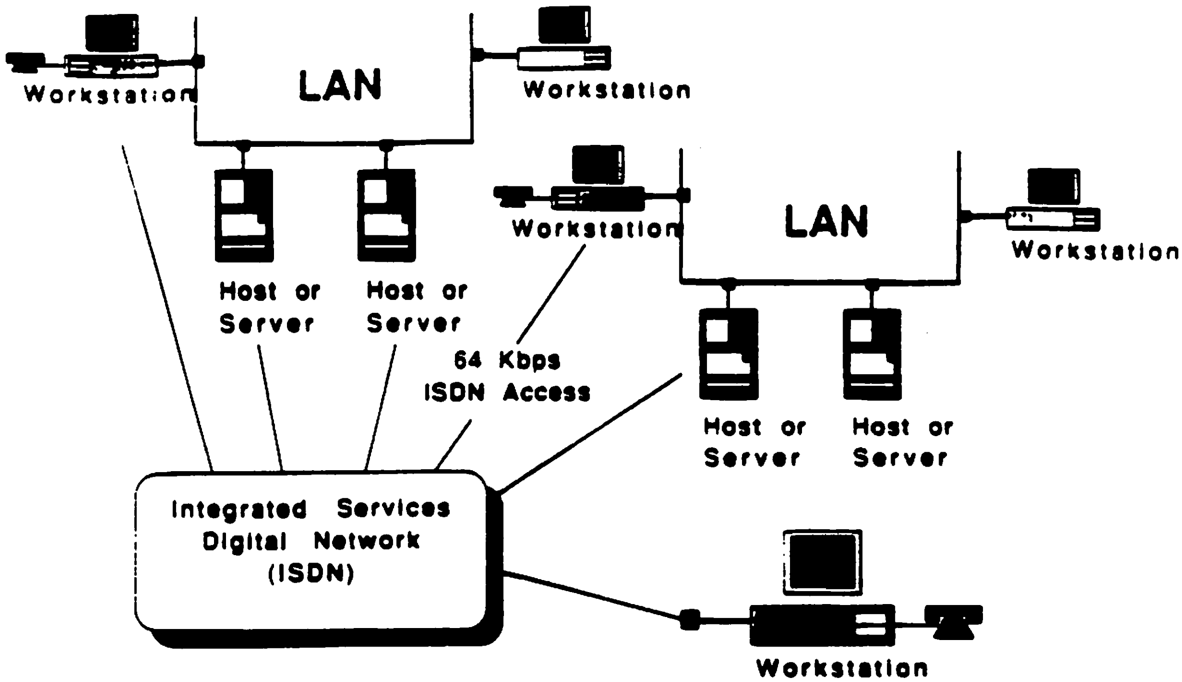
Imaging Workstation/Network Environment TODAY



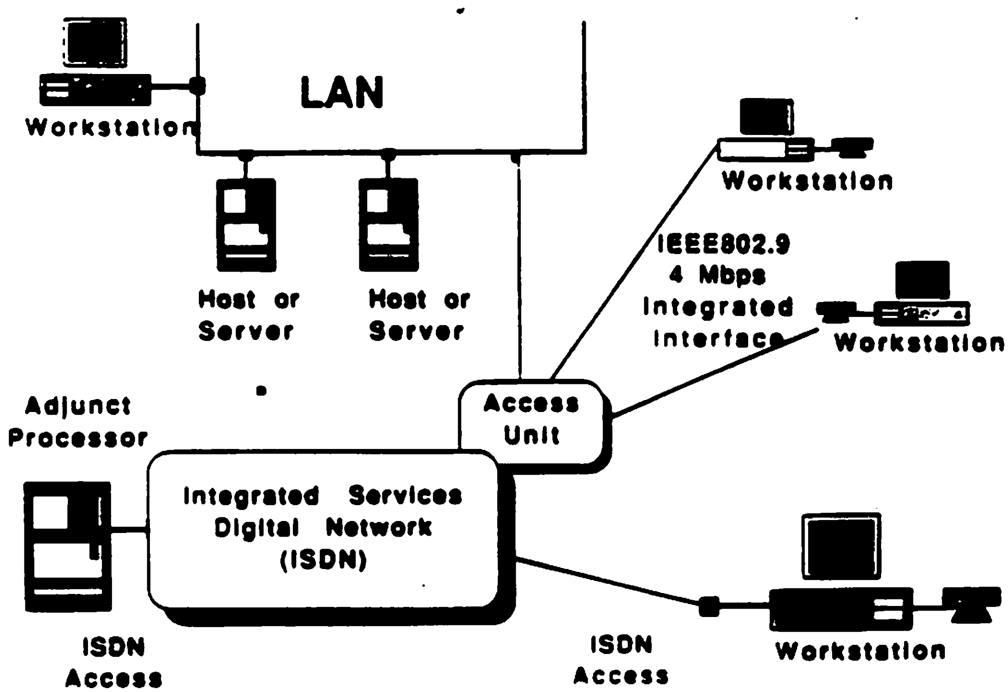
Multi-media Workstation/Network Environment ISDN TODAY



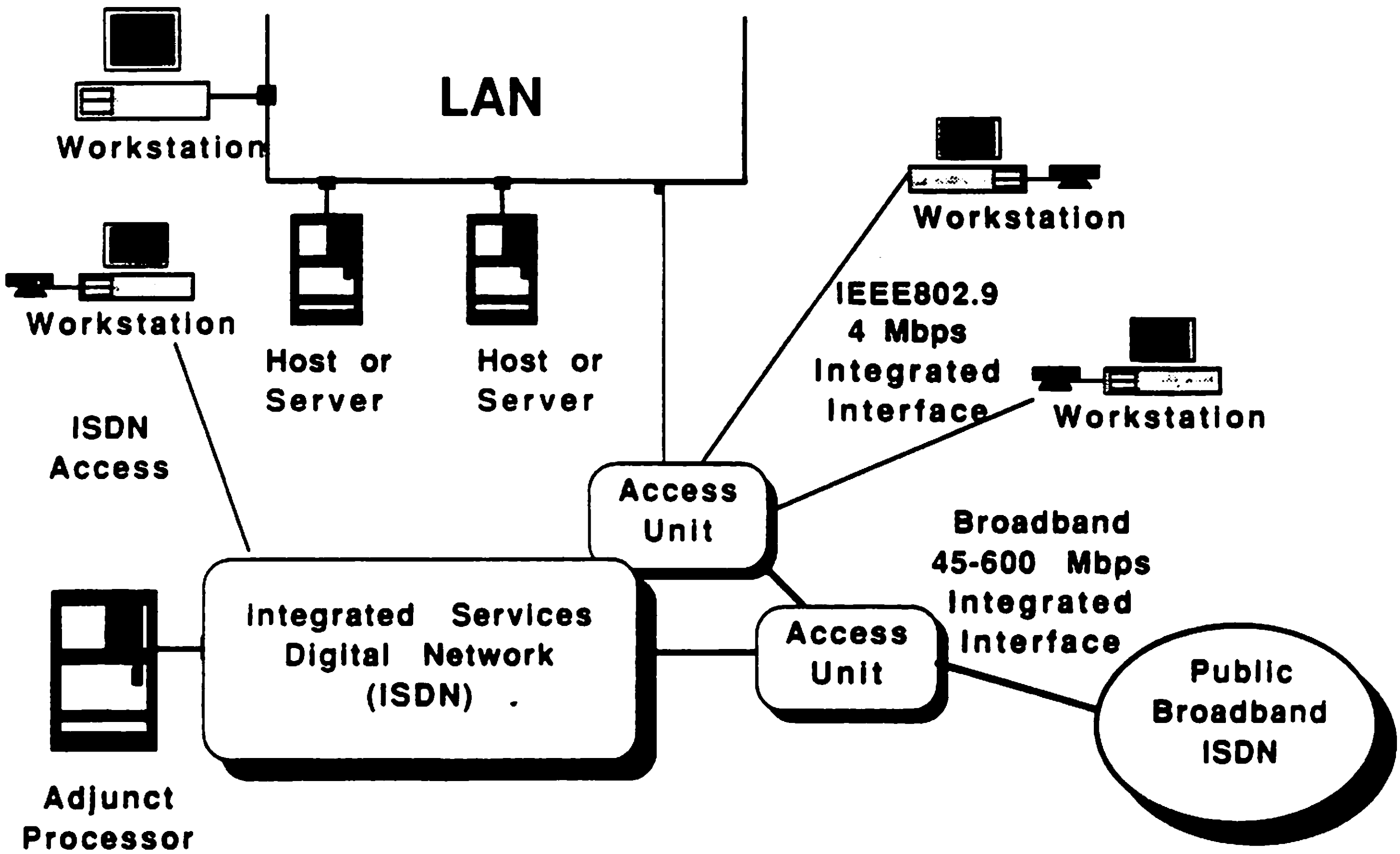
Multi-media Workstation/Network Environment
ISDN TODAY



Multi-media Workstation/Network Environment
IEEE 802.9 Interface- TOMORROW



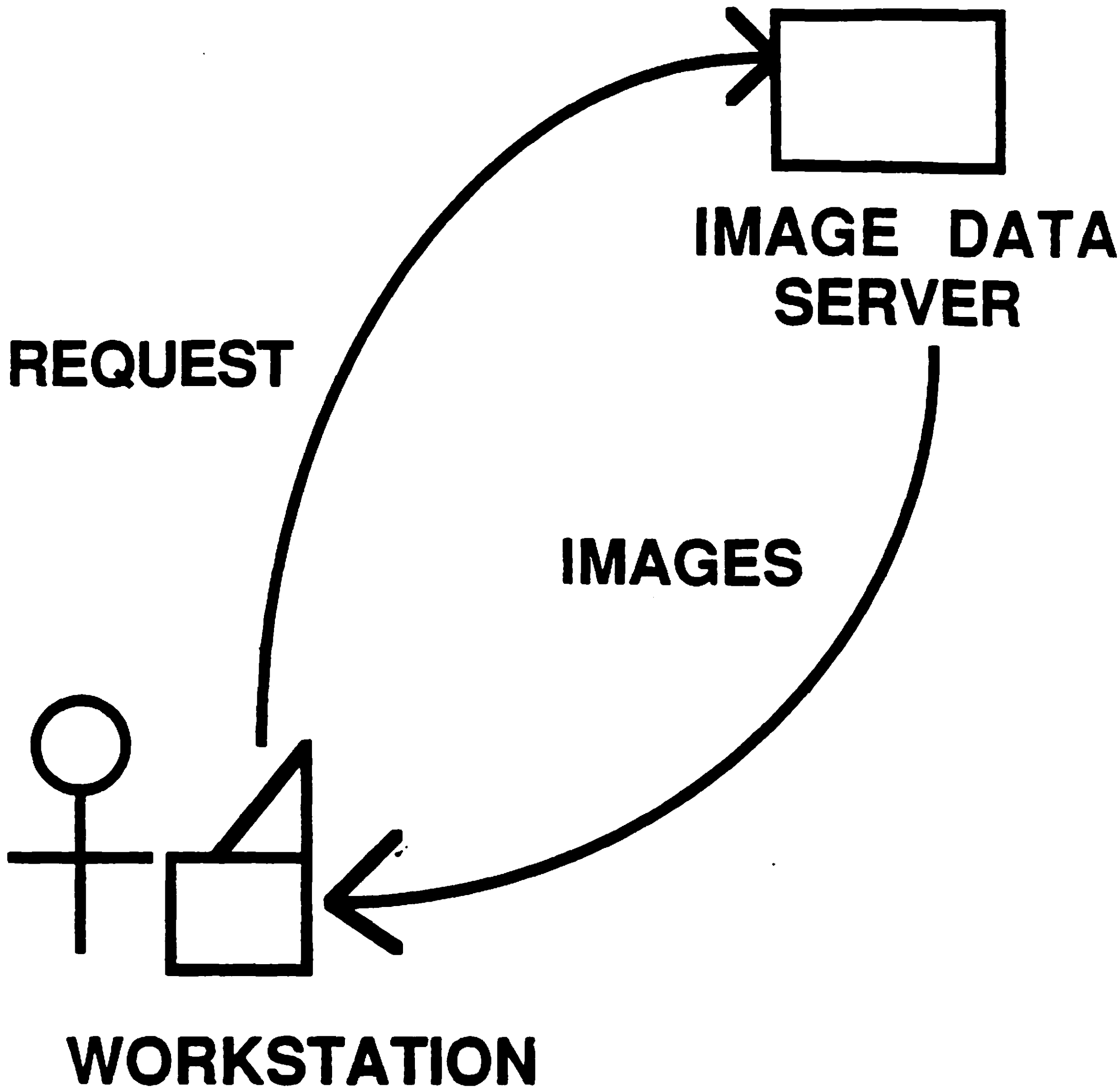
Multi-media Workstation/Network Environment
Broadband ISDN- TOMORROW



High Throughput Communications Protocols

Sharon Heatley
National Institute of Standards and Technology (NIST)

IMAGE TRANSMISSION



RESPONSE TIME = TOTAL IMAGE DATA / THROUGHPUT

ASSUME TARGET THROUGHPUT 10 Mb/s

OUTLINE

PROTOCOL STACK

PROTOCOL IMPLEMENTATIONS

OTHER POTENTIAL BOTTLENECKS

ARE NEW HIGH-SPEED PROTOCOLS NEEDED ?

— LONG-HAUL NETWORKS
2.4, 9.6, 19.2 Kb/s
BOTTLENECK - TRANSMISSION MEDIUM

— LOCAL AREA NETWORKS
ETHERNET 10 Mb/s
TOKEN RING 4, 16 Mb/s
BOTTLENECK - PROTOCOL PROCESSSING

— HIGH SPEED NETWORKS
FDDI 100 Mb/s
B - ISDN 43 - 100 Mb/s
BOTTLENECK - PROTOCOL PROCESSING

TWO TYPES OF HIGH PERFORMANCE

SHORT MESSAGES / VERY SHORT LATENCY (MILISECONDS)

- MILITARY
- PROCESS CONTROL

LARGE FILES / HIGH THROUGHPUT

- MILITARY (RADAR)
- IMAGE DATA
- DOCUMENT TRANSFER

NEW TRANSPORT PROTOCOLS

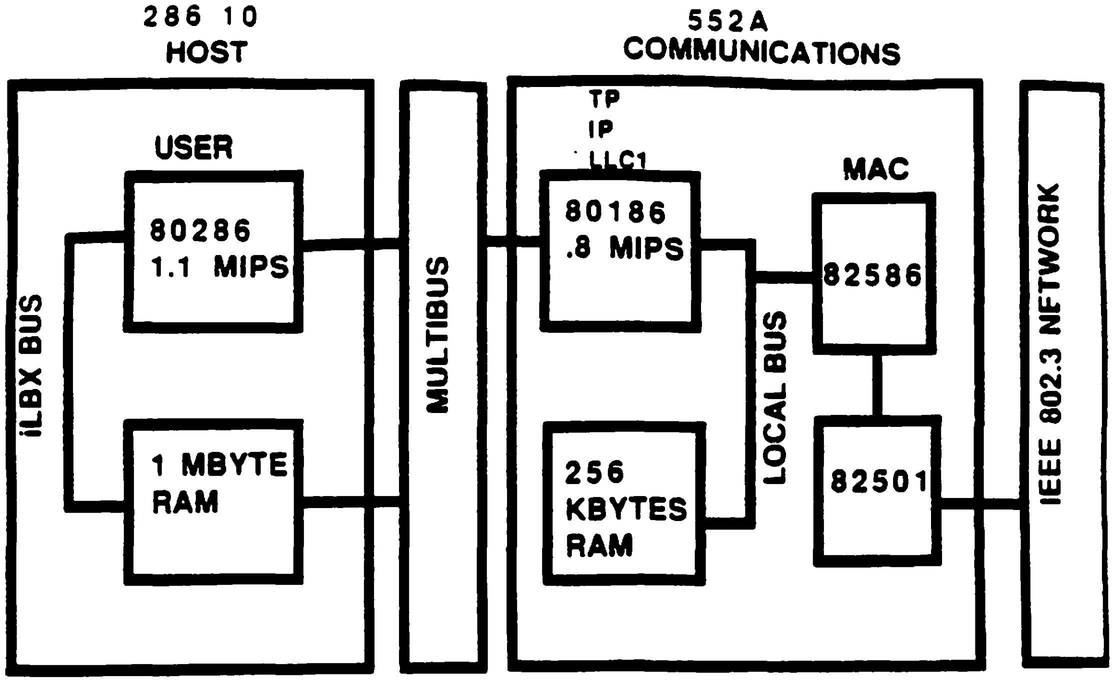
XTP	GREG CHESSON PROTOCOL ENGINES, INC
VMTP	DAVID CHERITON STANFORD
DELTA-T	RICHARD WATSON LAWRENCE LIVERMORE LABS
NETBLT	DAVE CLARK MIT
GAM-T-103	FRENCH MILITARY PROTOCOL GERARD LELANN INRIA

OSI PROTOCOL STACK

APPLICATION	FTAM
PRESENTATION	PRESENTATION
SESSION	SESSION
TRANSPORT	TRANSPORT CLASS 4
NETWORK	INTERNET PROTOCOL
DATA LINK	LLC1
	MAC
PHYSICAL	ETHERNET FDDI

TRANSPORT CLASS 4

- END TO END
- FLOW CONTROL
- ERROR DETECTION AND RECOVERY
- ACKs
- TIMERS
- IN-ORDER DELIVERY
- SEGMENTATION AND REASSEMBLY



INTEL 310 SYSTEM OVERVIEW

THROUGHPUT

USER TO USER

TUNED FOR MAXIMUM THROUGHPUT

- USER BUFFERS
- WINDOW SIZE
- NO RETRANSMISSIONS

MAXIMUM THROUGHPUT

TP4/IP	1.76 Mbits/sec
TP4/NULL	2.2 Mbits/sec

LOWER FOUR LAYER PERFORMANCE ISSUES

FRONT-END BOARD

PROCESSOR MEMORY BUS SPEED

IMPLEMENTATION OF TRANSPORT CLASS 4, IP, LLC1 AS A SINGLE LAYER

IMPLEMENT AS FEW PROCESSES AS POSSIBLE

REAL TIME OPERATING SYSTEM

OPTIMIZATION OF TIMER MANAGEMENT, BUFFER MANAGEMENT, CONTEXT SWITCHING, INTERRUPT HANDLING

MINIMIZE DATA COPIES
OR USE DMA OR SEPERATE CPU

MAXIMIZE SIZE OF BUFFERS
PASSED TO COMM BOARD

MAXIMIZE TPDU SIZE
MUST FIT INTO NETWORK PACKET
(ETHERNET 1518, FDDI 4500 BYTES)

OPTIMIZATION OF NORMAL DATA
TRANSMIT RECEIVE CODE

ONE TIMER PER CONNECTION

ACKNOWLEDGE MORE THAN ONE DATA TPDU WITH EACH ACK

UPPER THREE LAYER PERFORMANCE ISSUES

MAY BE IMPLEMENTED ON HOST OR OTHER PROCESSOR

PROCESSOR / MEMORY / BUS SPEED

IMPLEMENT FTAM, PRESENTATION, AND SESSION AS ONE LAYER

IMPLEMENT AS FEW PROCESSES A: POSSIBLE (TRANSMIT, RECEIVE)

NO DATA COPIES

MAXIMIZE SIZE OF DATA BUFFERS PASSED TO FTAM

OPTIMIZATION OF NORMAL DATA TRANSMIT / RECEIVE CODE

REAL TIME OPERATING SYSTEM

OPTIMIZATION OF TIMER MANAGEME BUFFER MANAGEMENT, CONTEXT SWITCHING, INTERRUPT HANDLINC

OTHER BOTTLENECKS

DISK SPEED

SYSTEM BUS SPEED

NETWORK (FDDI) SPEED

- MULTIPLE USERS
- ISOLATE USERS WITH A LOT OF TRAFFIC BETWEEN THEM ON SEPERATE RINGS
- CONNECT SEPERATE RINGS VIA FDDI BACKBONE

WORKSTATION FUNCTIONS

- CAPTURE, STORAGE ON DISK AND DISPLAY OF VIDEO IMAGES
- RETRIEVAL OF PATIENT TEXT DATA
- IMAGE MANIPULATION AND PROCESSING
- IMAGE RETRIEVAL AND STORAGE ON DISK

WHICH OF THESE FUNCTIONS WILL GO ON AT THE SAME TIME ?

THIS MAY AFFECT

- DISK SPEED
- SYSTEM BUS SPEED
- PROCESSING POWER

REFERENCES

PROTOCOLS FOR HIGH SPEED NETWORKS
~~IFIP~~ WORKSHOP MAY 9-11, 1989
ZURICH (PROCEEDINGS IN PROCESS)
IFIP/WG6.1 -WG6.4

IEEE COMMUNICATIONS, JUNE 1989
SPECIAL ISSUE ON PROTOCOLS FOR
HIGH SPEED NETWORKS

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FDDI: Present Status and Future Developments

William E. Burr
National Institute of Standards and Technology (NIST)

Progress in Computing

1983

- $4,000 bought IBM PC /XT
  - 256 kbyte RAM
  - Norton SI: 1 (200 kops)
  - 10 Mbyte hard disk with 100 ms access time
  - 360 k 5.25 in floppy
  - 320 by 200 by 4 color display

1989

- For $4,000 I just bought a 386 clone
  - 4 Mbyte RAM
  - Norton SI: 26 (4-5 Mops)
  - 120 Mbyte hard disk with 28 ms access time
  - 1.2 Mbyte 5.25 in and 1.44 Mbyte 3.5 in floppies
  - 1024 by 768 by 16 color display

Progress in Local Area Networks

1983

- ARCNET was major commercial product
- IEEE 802.3 just getting going
  - 10 Mbit/s
  - Early Ethernet sort of available

1989

- 802.3 & 802.5 LANs all over
- LAN servers are hurting the traditional minicomputer business
- FDDI standard nearly complete
  - 100 Mbit/s
  - Early product availability

W E Burr
13 SEP 1989

The Future: 1995

Personal computers

- $4,000 buys 4/586 PC
  - 16 Mbyte RAM
  - Norton SI: 200 (30 MOPS)
  - 1 Gbyte hard drive (20 ms access time)
  - 20 Mbyte 3.5 in floppy
  - 1600 by 1000 by 256 color display

LANs

- FDDI is for PCs
- 1Gbit/s Super FDDI nearing market for major applications
- Some Metropolitan Area Network offerings
  - DQDB/DS-3 (45 Mbit/s)
  - DQDB/STS-3 (150 Mbit/s)
  - FDDI (100 Mbit/s)

W E Burr
13 SEP 1989

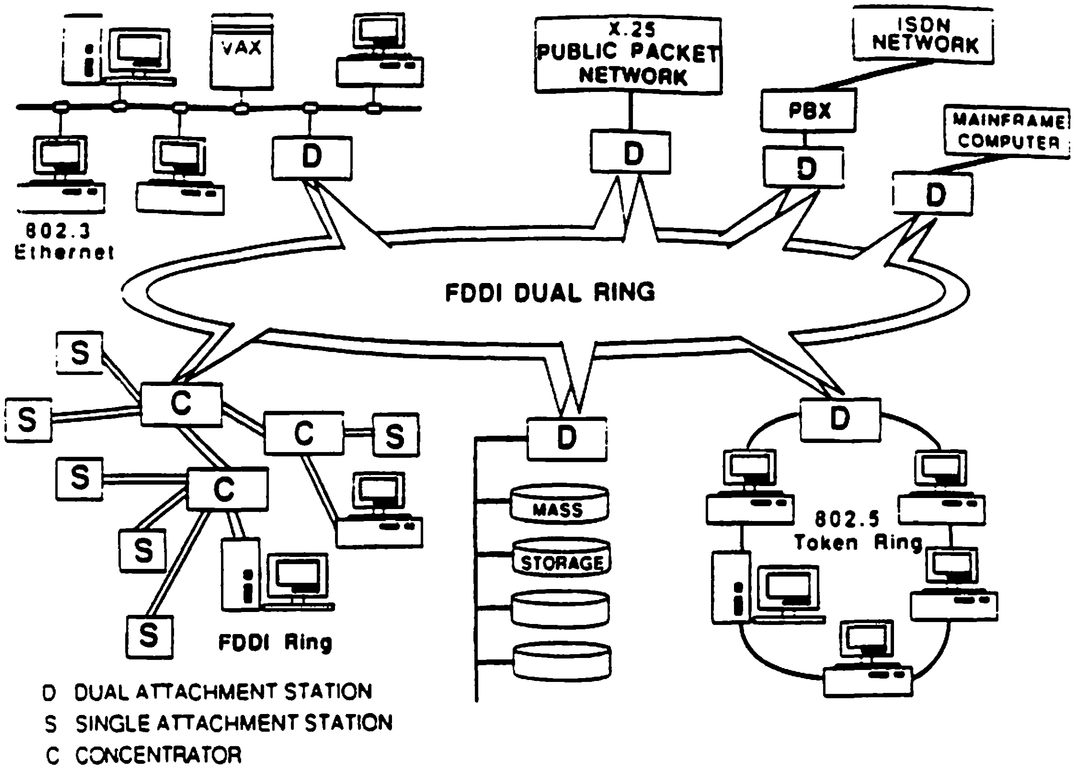
The Future

What will we do with all that horsepower?

- Images
  - "paperless" office
  - publishing
  - graphics arts
  - CAD/CAM - 3 dimensions
  - medical imaging
  - generated full motion video
- Modeling & simulation
- AI

Burr's LAW

- Applications quickly expand to exceed the computational power, storage capacity and data transmission bandwidth available, however great it may be

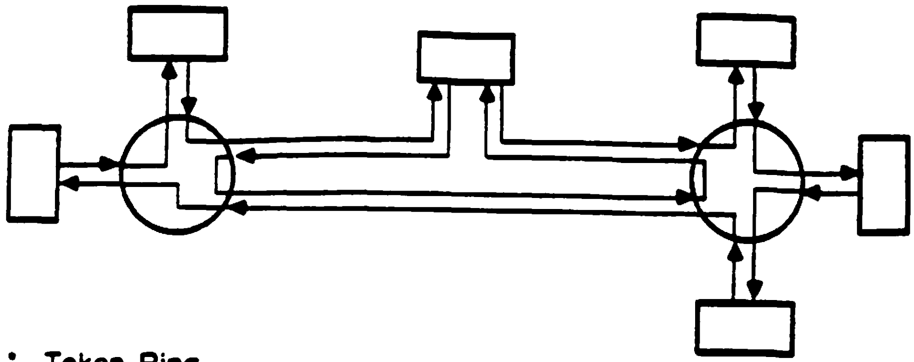


FIBER DISTRIBUTED DATA INTERFACE (FDDI) NETWORK

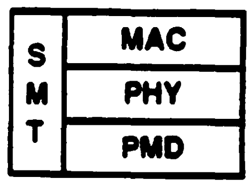
FDDI
COMPUTER DATA TRAFFIC

- HIGHLY "BURSTY".
- WHEN TRANSFERING WANT VERY HIGH RATES.
- NEED NETWORK ACCESS TIMES SIGNIFICANTLY LESS THAN THE 20-40 MS ACCESS TIMES OF DISK DRIVES.
- OVER BRIEF INTERVALS TEND TO HAVE LOW BANDWIDTH IN ONE DIRECTION, HIGH BANDWIDTH IN THE OTHER.

Fiber Distributed Data Interface (FDDI)



- Token Ring
- Fiber Optic : 62.5/125 fiber, LED source @ 1300 nm
- 100 Mbit/s data; 4 of 5 code for 125 MBaud rate
- Up to 2 km between up to 1000 "attachments"
- IEEE P802.2 and P802.5 compatible
- Four layered standards:



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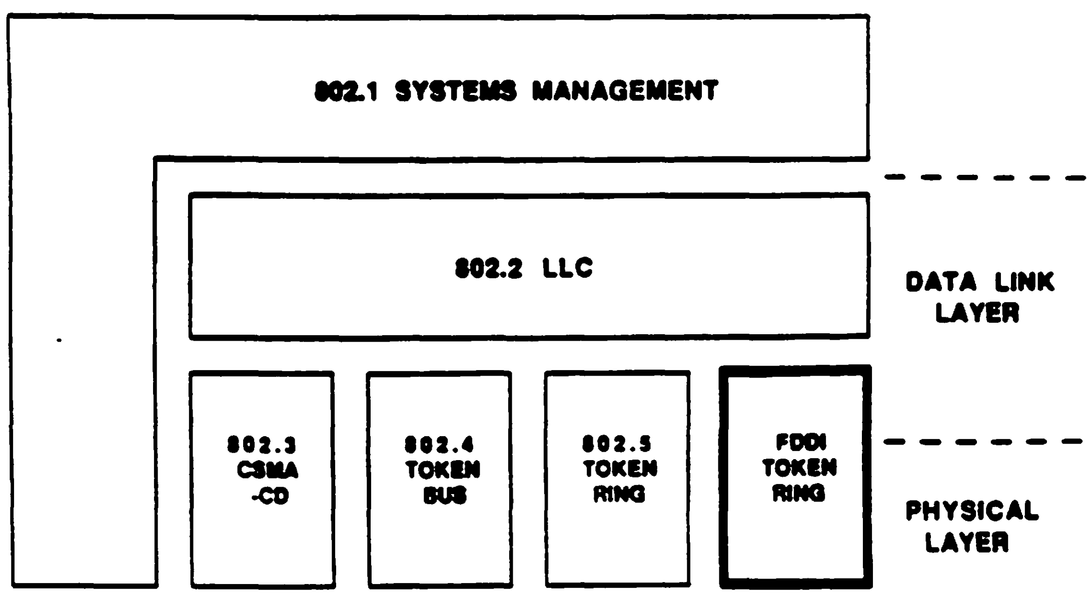
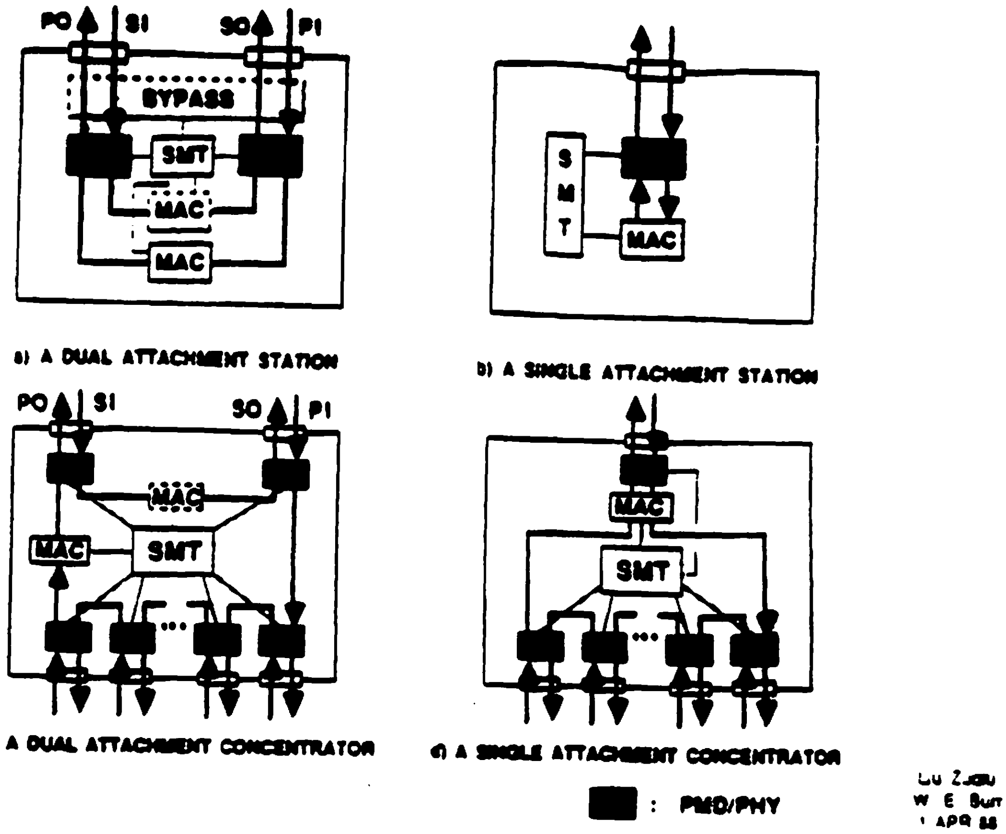
15 JUN 8

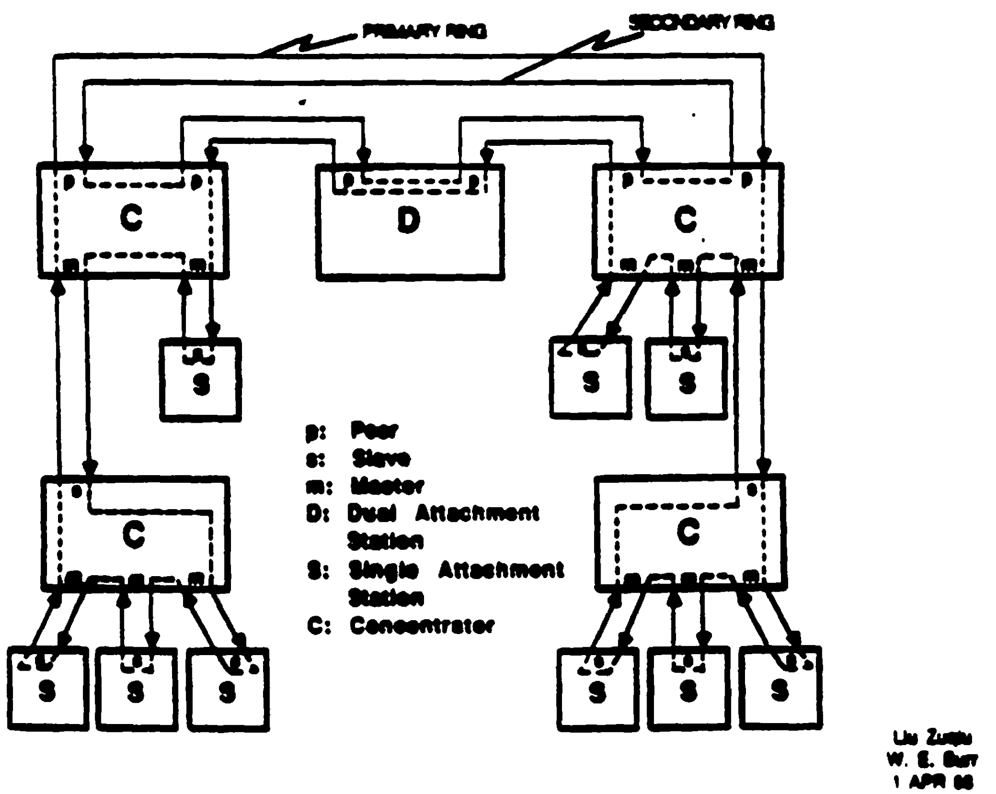
FDDI/IEEE 802 Relationship



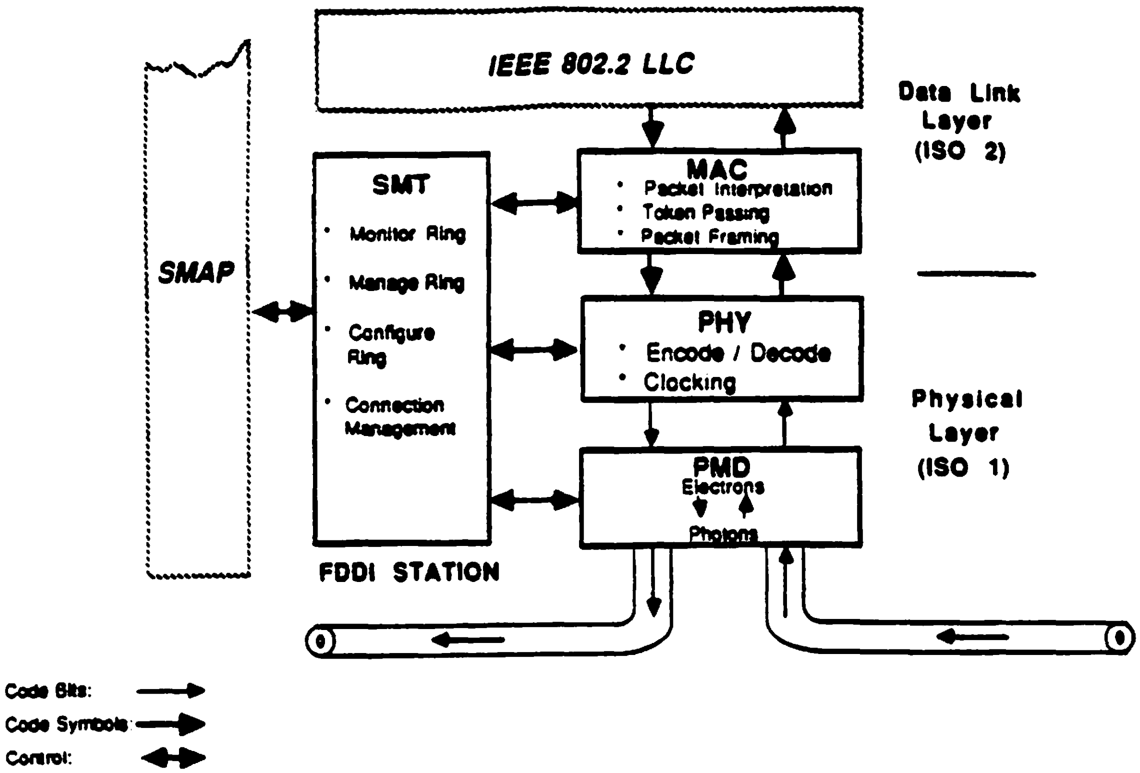
FDDI Station Types



FDDI Topology: Dual Ring of Trees



FDDI Block Diagram

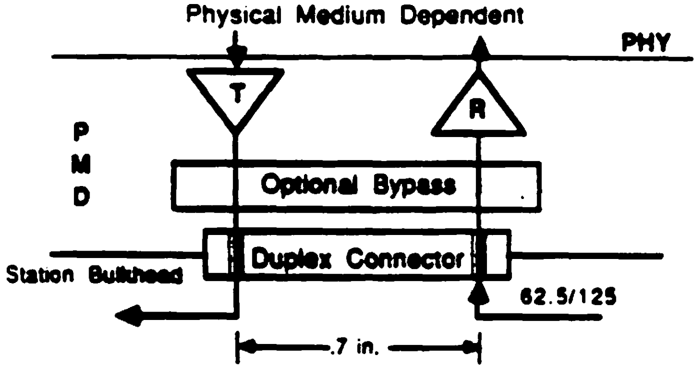


Liu Zuqiu
W. E. Burr
30 MAR1988

FDDI PMD X3.166-198X

X3 Project 541D
DP 9314/3

Physical Medium Dependent



- 62.5/125 (or other) graded index multimode fiber
- Duplex Connector: "ST" type ferrule
- LED source: 1300 nm, -20 dBm avg. min. power
- PIN Diode Detector: -31 dBm snstv. @ 2.5×10^{-10} BER
- 125 MBaud: 8 ns pulse width
- Standard defined at station bulkhead

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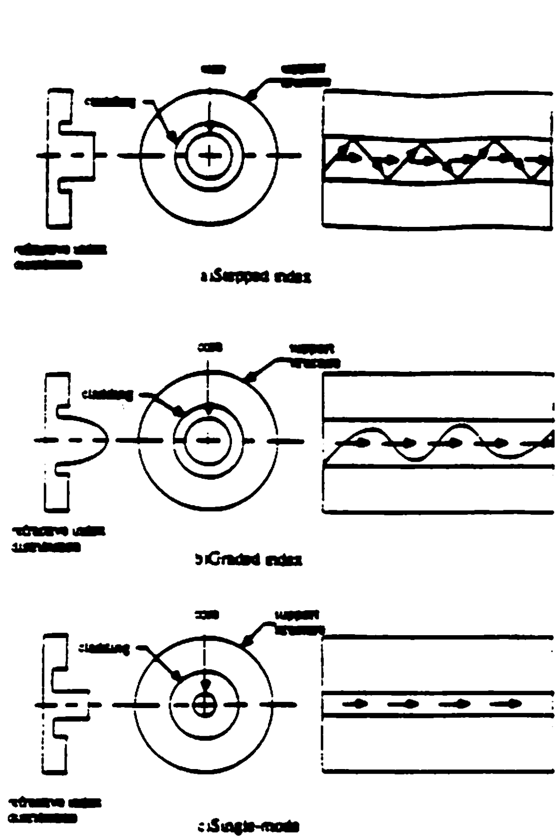
29 MAR 88



OPTICAL FIBER TYPES

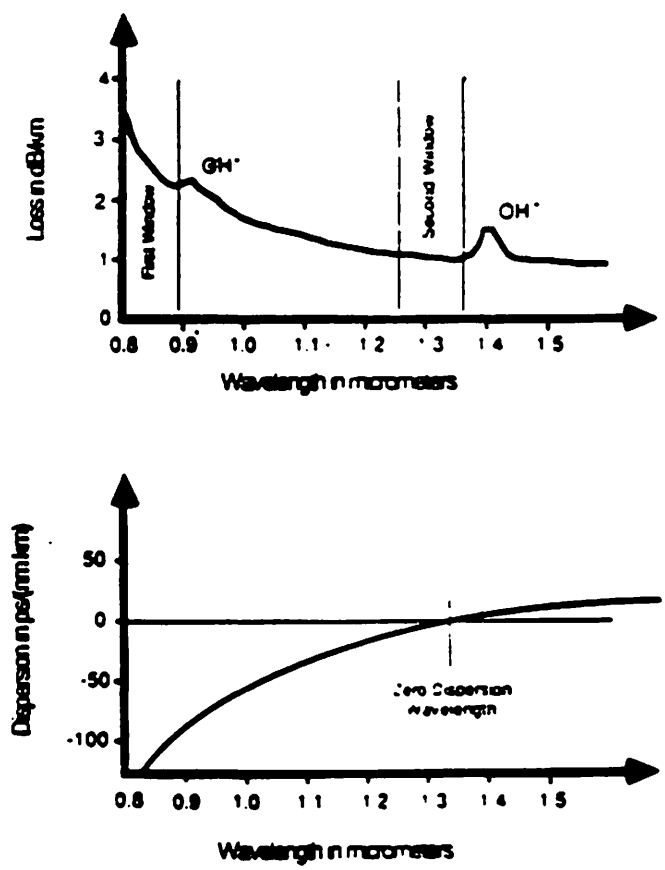
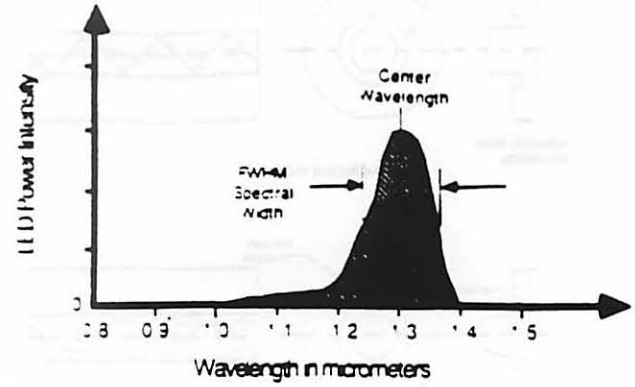
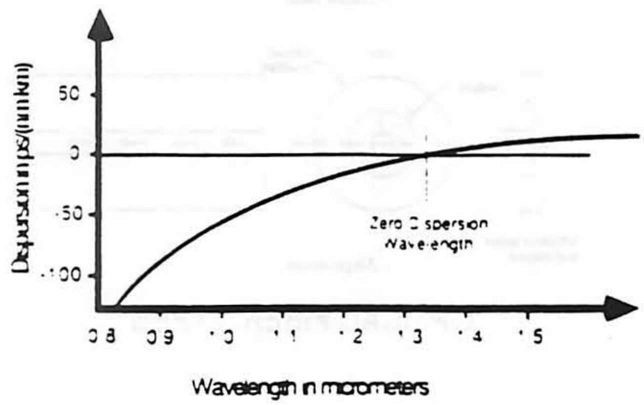


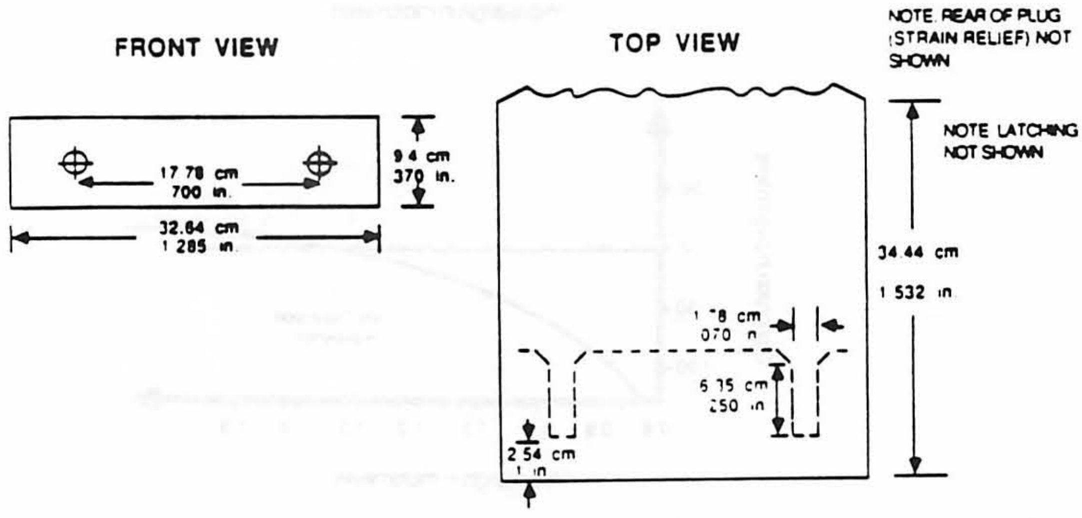
Figure 3. Fiber Attenuation and Dispersion





FDDI CONNECTOR PLUG

(NOT TO SCALE)

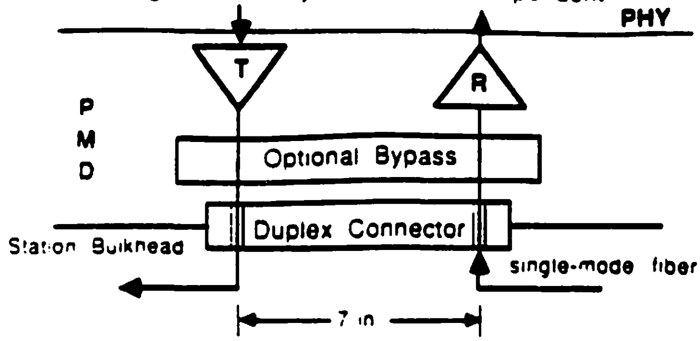


NOTE RECEPTICLE, NOT PLUG, IS SPECIFIED

FDDI SMF-PMD

X3 Project 5510

Single-Mode Physical Medium Dependent



- Single-mode fiber, 125 micron OD, 9-10 micron MFD
- Duplex Connector: "ST" type ferrule
- Category I
  - Laser, but power compatible with MM
  - Distance less than 20 km
- Category II
  - More powerful laser, more sensitive rcvr.
  - Tighter spectral width (5 nm)
  - 32 dB power budget, up to 60 km or so

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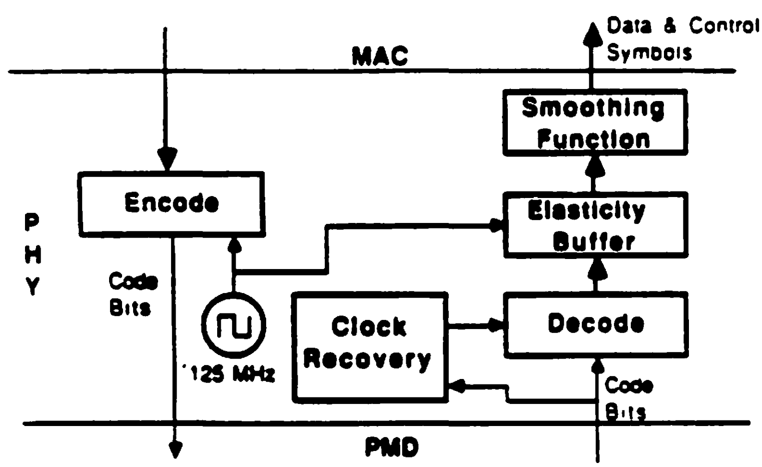
9 May 89

FDDI PHY X3.148-1988

X3 Project 3790
IS 3914-2

Physical Layer Protocol



- Point to point clocking with distributed elasticity
- Max. packet: 4500 bytes
- 4 of 5 line code:
  - 16 Data Symbols
  - 8 Control Symbols
  - 6 Line States
  - ± 10% DC unballance

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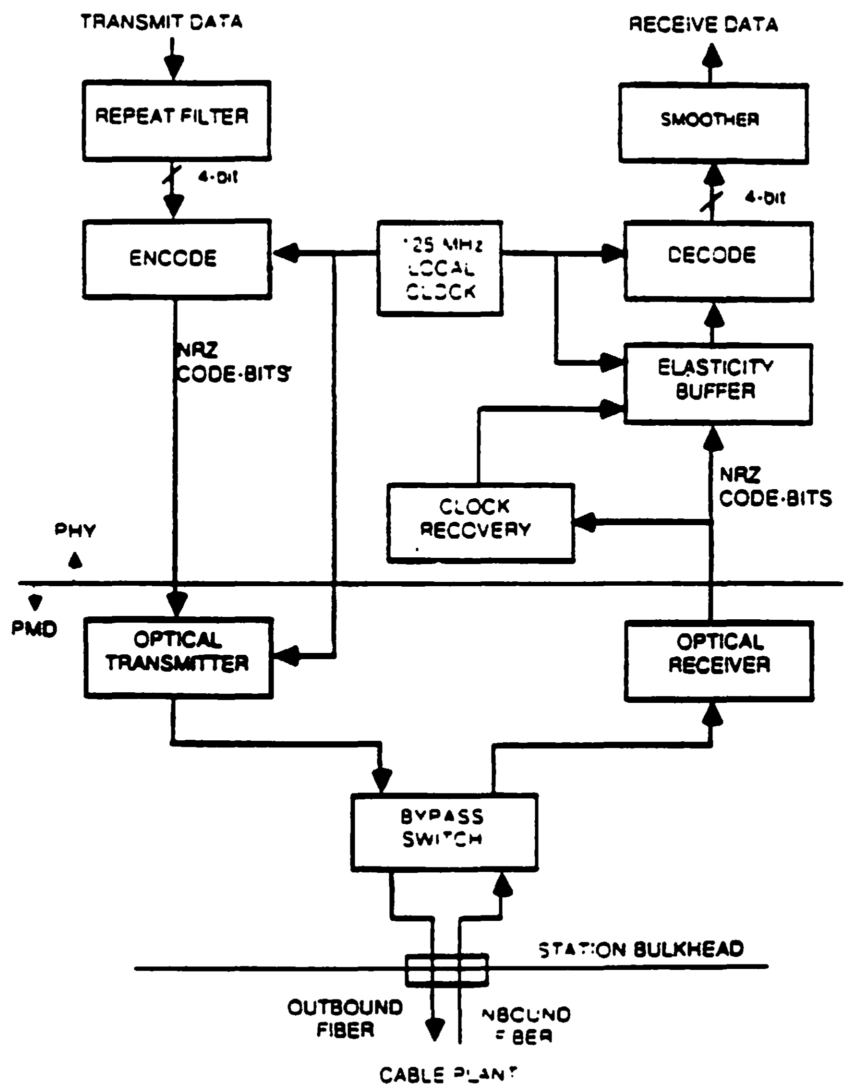
10 May 89

TABLE 3: FDDI 4 OF 5 CODE

SYMBOL	CODE GROUP	SYMBOL	CODE GROUP
Data Symbols		**Line State Symbols**	
0	11110	Q	00000
1	01001	I	11111
2	10100	H	00100
3	10101		
4	01010	**Starting Delimiter**	
5	01011	J,K	1100010001
6	01110		
7	01111		
8	10010	**Ending Delimiter**	
9	10011	T	01101
A	10110		
B	10111	**Control Indicators**	
C	11010	R	00111
D	11011	S	11001
E	11100		
F	11101		

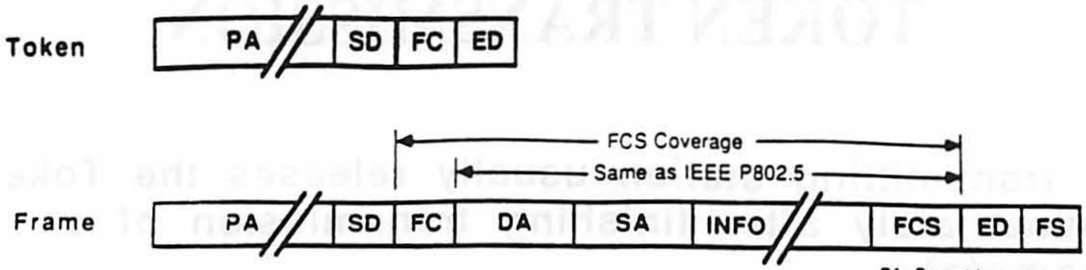


W E Burr
9 May 1989

FDDI MAC X3.139-1987

Medium Access Control

X3 Project 380C
IS 9314.1



PA: Preamble
SD: Starting Delimiter
FC: Frame Control
DA: Destination Address
FCS: Frame Check Sequence
ED: Ending Delimiter
FS: Frame Status

- User frame fields same as IEEE P802.5
- Fully distributed protocol including initialization
- Source strips frame
- Token released as soon as frame is sent
- Timed Token Protocol for:
  - Asynchronous Bandwidth
  - Synchronous Bandwidth
- Restricted and Nonrestricted Tokens

WEB
10 May

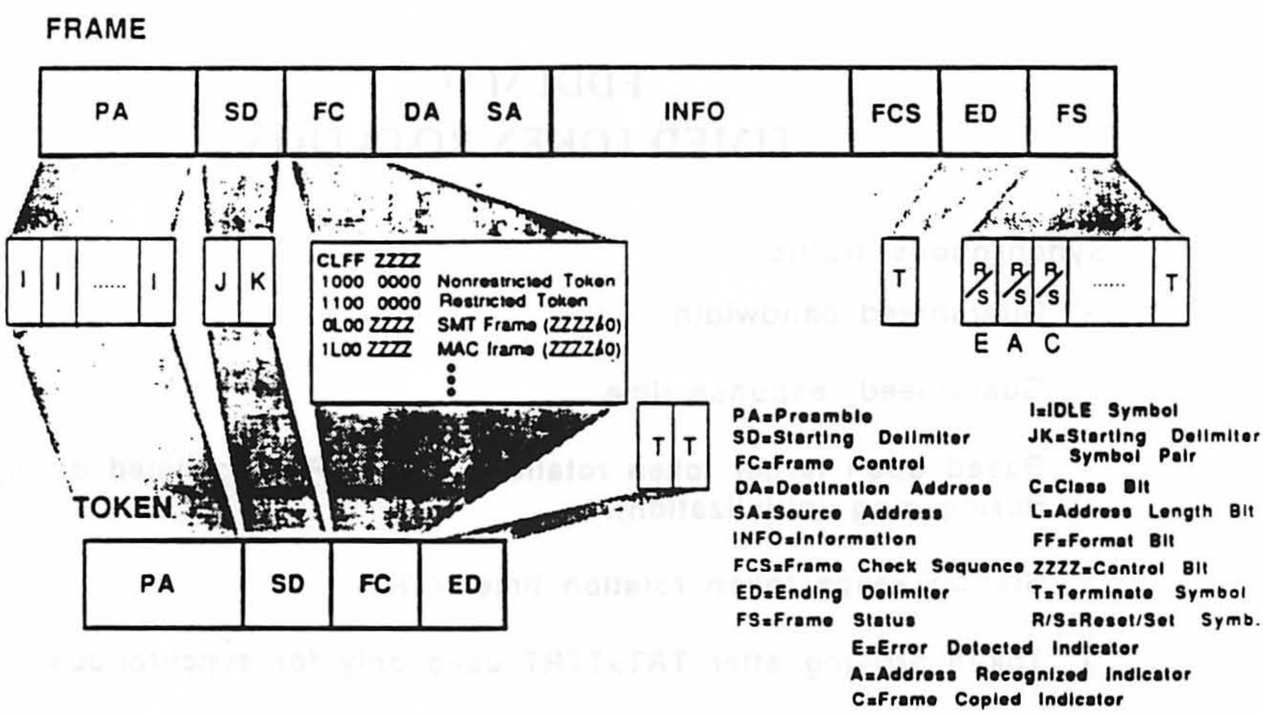


Figure 2. Frame and Token Formats

FDDI MAC
TOKEN TRANSMISSION

A transmitting station usually releases the Token immediately after finishing transmission of a frame(s).

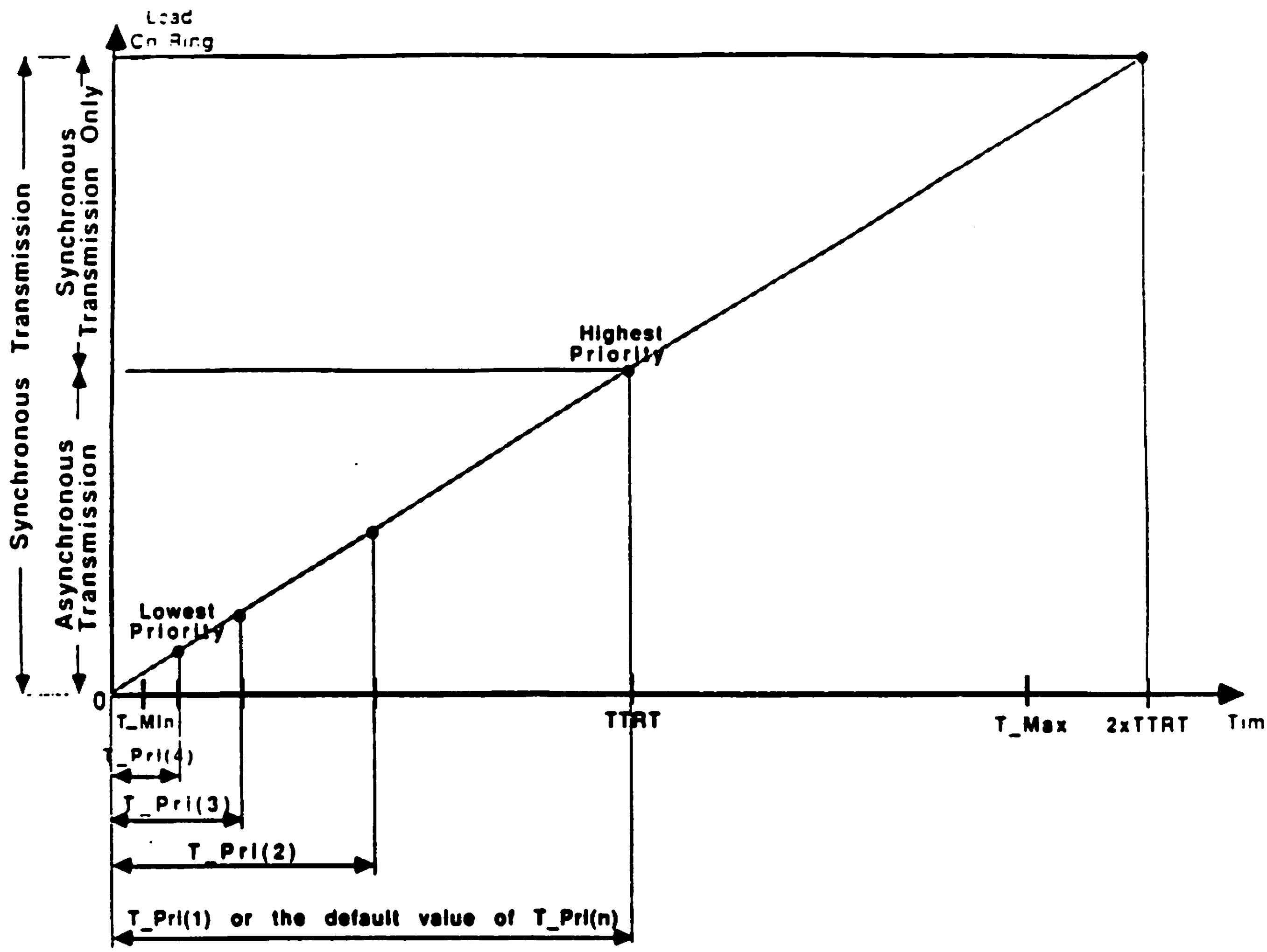
But, SMT functions may hold Token until one or more frames return.

This is different from 802.5 when the transmitting station always waits for the return of frames before releasing the Token.

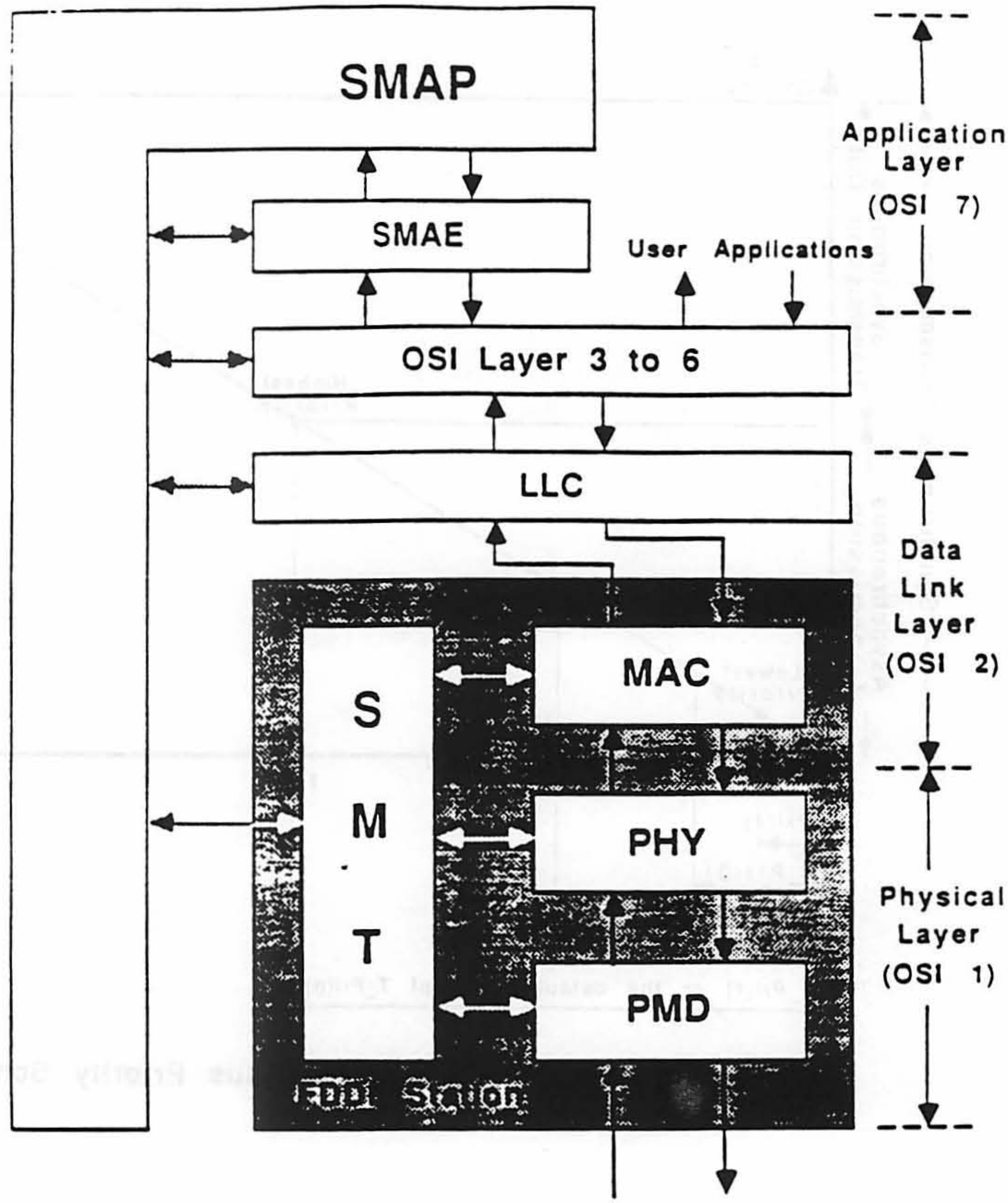
FDDI MAC
TIMED TOKEN ROTATION

Synchronous traffic

- Guaranteed bandwidth.
- Guaranteed response time.
- Based upon target token rotation time (TTRT-negotiated during during ring initialization).
- Station keeps token rotation timer (TRT).
- Token arriving after TRT>TTRT used only for synchronous traffic.
- This protocol guarantees an average synchronous response time not greater than TRT and a worst case not greater than 2 TRT.



The Multiple Asynchronous Priority Scheme



SMAP: System Management Application Process
SMAE: System Management Application Entity

FDDI Station Relationship to OSI Model

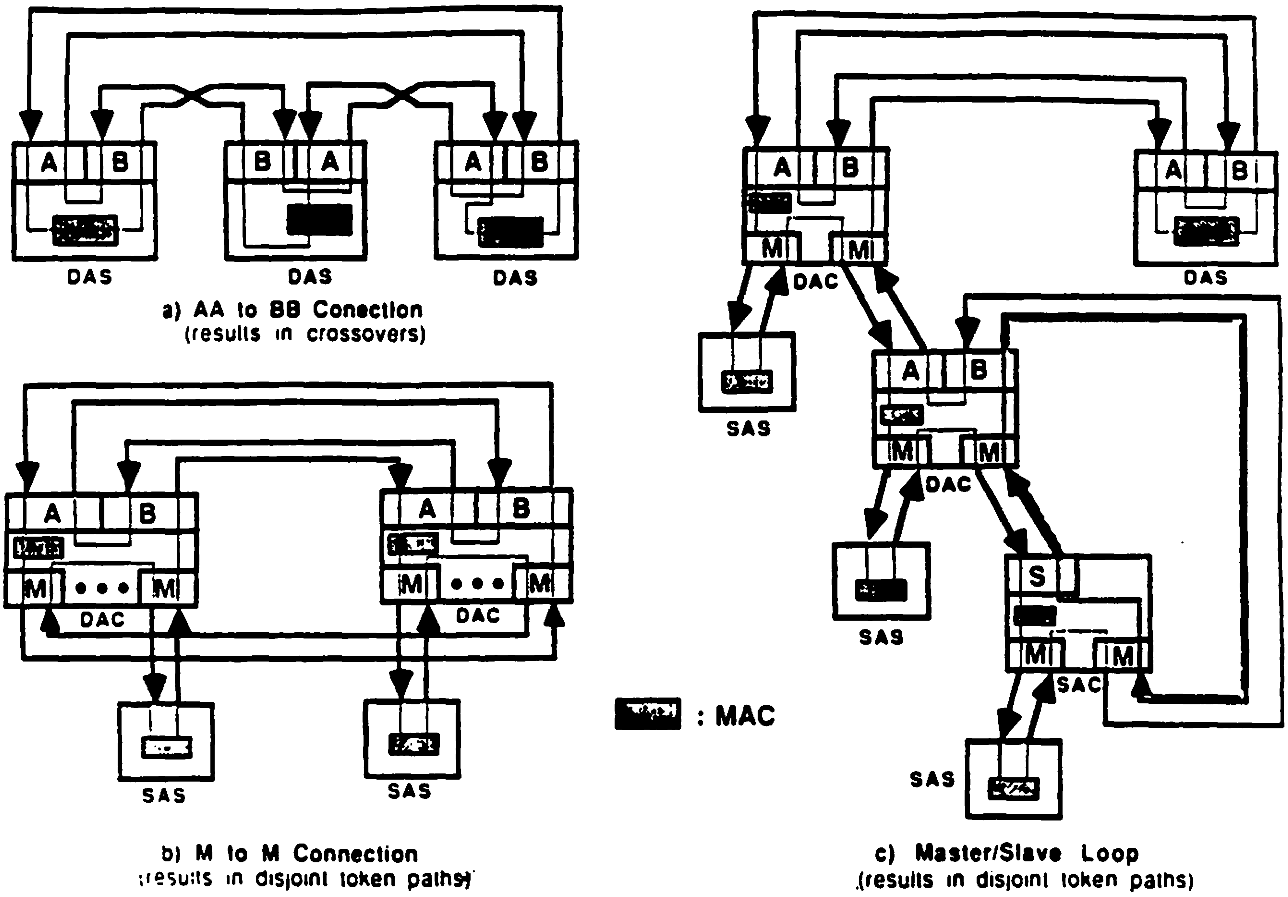
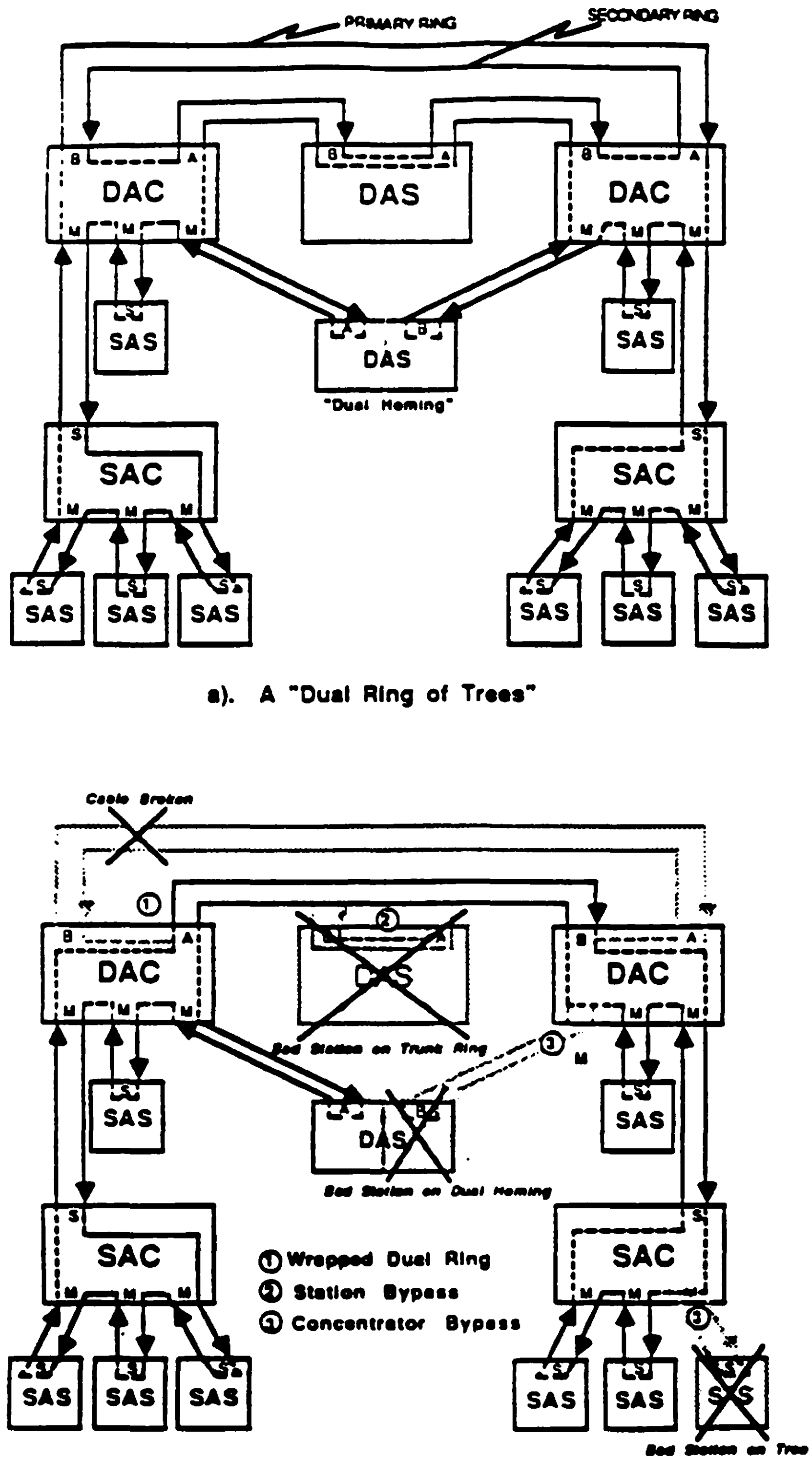


Figure 1. Examples of physical connection errors in FDDI



a). A "Dual Ring of Trees"

b). Ring Reconfiguration against failure

Figure 7. FDDI Network Topology and Reconfiguration

FDDI-II Block Diagram

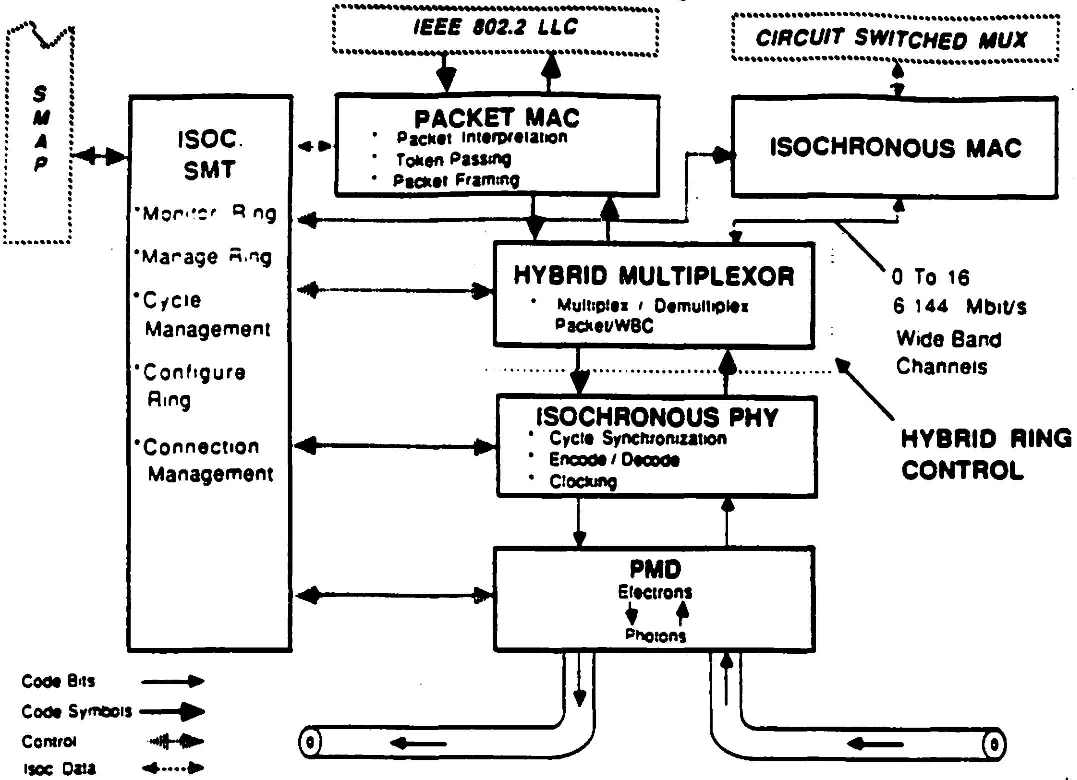


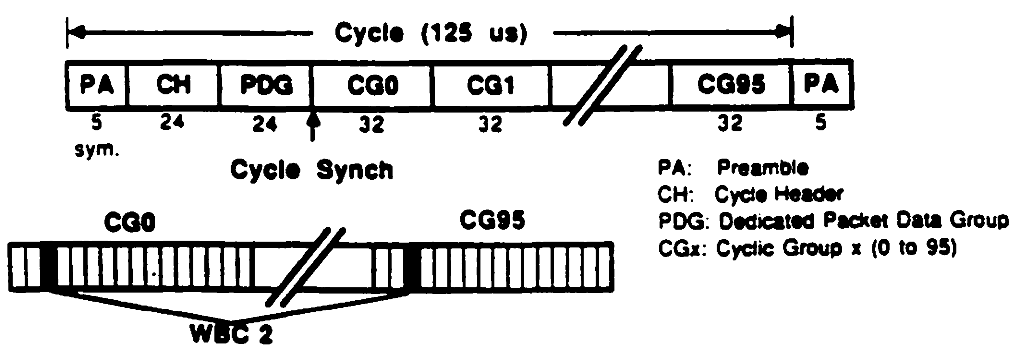
Figure 4

Liu Zuqiu
W E Burr
30 MAR1988

FDDI-II HRC

Hybrid Ring Control

X3 Project: 503D



- Adds Circuit Switched Service to Token Service
- 125 us Cycle for synchronism with telephone network
- Zero to sixteen 6.144 Mbit/s Wide Band Channels (WBC)
- Isochronous WBCs may be suballocated many ways
- .768 to 99.328 Mbit/s FDDI token ring packet service

WEB
7 JUL 87

FDDI Status

PMD

- Out for second public review
- Little remaining controversy
- Estimated approval: Dec. 1989.

SMF-PMD

- Out for first public review
- Estimated approval: Oct. 1990.

PHY

- Approved ANSI standard.

MAC

- Approved ANSI standard.

SMT

- First "stable" draft May 1989.
- Estimate first forwarding Dec.1989, final approval Oct. 1991.

FDDI-II (HRC)

- Out for first public review
- Estimated approval: June 1991.

Interconnecting LANs

Bridges

- Data Link Layer
- Two Major Camps
  - Learning Bridges
  - Source Routing Bridges
- Big disagreement about maximum size of FDDI networks before bridging
  - Some vendors will recommend not more than 100 stations on one token path
  - Others apparently contemplate an order of magnitude more

Interconnecting LANs

Transparent Learning Bridges

- DEC is proponent
- Bridge comes up forwarding all traffic
- Bridge keeps records of source addresses
  - Stops forwarding from LAN if sees SA on that LAN
- Uses Spanning Tree Algorithm for Routing
  - Easy to incorporate redundancy
- Simple station protocol
  - Station doesn't know destination is remote
- Complex bridge protocol
  - Routing tables
  - Spanning tree

Interconnecting LANs

Spanning Tree Algorithm

- Protocol ensures that there is precisely one path between any two subnetworks (no loops)
- Each Bridge has 2 or more links
- Each Link in one of 4 states
  - Forwarding
  - Backup
  - Pre_Forwarding
  - Pre_Backup
- Bridges periodically transmit "HELLO" messages
- Protocol Picks Bridge with Lowest ID as "Root"
- On each LAN the bridge nearest the ROOT becomes the "Designated" Bridge (ties resolved by ID)
- Self healing if redundant paths available
- Works with "simple" bridges
  - Provided the simple bridges do not themselves form loops

Interconnecting LANs

Source Routing Bridges

- IBM is proponent
- Source station transmits "discovery" packet
  - Bridges propagate adding path information
  - Destination typically receives multiple copies
  - Destination returns all routes to source
- Source selects specific route
  - supplies specific route to bridges in special routing field added to link level header
  - flexibility to select best route
- Simple bridges
  - No connection state or routing tables maintained
- Complex station protocol
  - Make routing selection
  - Maintains routing information
- Problems for bridges meeting FDDI frame strippiong specs
  - Bridged packets identified by bit in SA field
  - Begin stripping by first byte of Info field

History

- In 1950s, microwave made transmission cheap, switching was expensive
- In 1970s digital logic & computers reversed the relative costs

Now

- We now are using protocol stacks and architectures based on 1970's designs.
- With (relatively) fast networks like FDDI, protocols are often the bottleneck
- With fiber optic media, transmission costs are falling fast

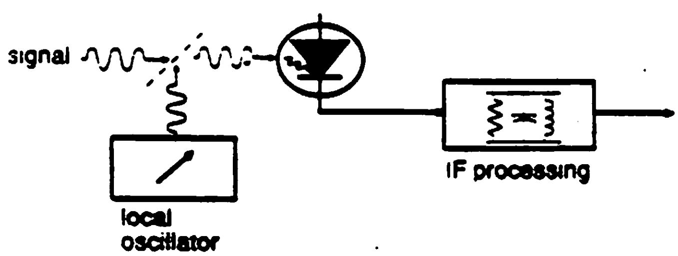
Future

- In 1990s fiber will make transmission cheap & switching expensive
- TDMA network architecture (such as FDDI) with electronic stations cannot fully exploit fiber bandwidth
  - Electronics cannot keep up with fiber
- Optical computers might possibly change this some day
  - This technology is probably a long way off
- Near term solution is frequency division multiplexing
  - Many coherent experiments to date

Fiber: the Future

Present use (FDDI & SONET) is primitive: barely scratches the surface

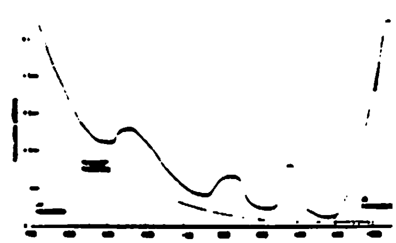
- Analogy:
  - Electrical communications is the stone age
  - Present noncohereant fiber is bronze age
  - Coherent fiber will be iron age



Coherent Heterodyne Optical Detector

Intrinsic bandwidth of single mode fiber is huge

- On order of 10,000 to 50,000 GHz
  - One voice channel is 4 kHz
  - One TV channel is 4.5 MHz
  - Entire broadcast TV spectrum is 408 MHz
  - FDDI channel bandwidth is about 100 MHz
- One fiber can, in theory, carry:
  - The entire North American peak voice load
  - More than a million TV channels



Optical Fiber Attenuation vs. Wavelength

Image Management and Display System

Ronald Levin, ScD, Biomedical Engineering and Instrumentation Branch, and Etienne Lamoreaux, MS, National Cancer Institute, National Institutes of Health

Introduction

The medical community is faced with the dilemma of making critical decisions and judgements which directly or indirectly affects the quality of patient care. How well physicians and scientists perform their tasks depends on how effectively they process information.

Various computer systems have proven to be effective tools in helping physicians and scientists process information. Computer hardware and software have matured to the point that computers are an important part of daily medical research and practice.

One clear direction in using computers in medical applications is the need to develop an affordable and easy to use medical sciences workstation that can be either standalone or networked. The early phase of this project will provide a system that is useful both as a clinical service and as a research tool. The initial phase will be R & D involving the medical imaging sciences departments. In latter phases we will hopefully be able to link into an Ethernet/FDDI system installed at the NIH and possibly to the MIS system; in addition, we plan to disseminate the system to other medical facilities. To that end we will be concerned with issues of uniformity, standards, and affordability from the inception of the project. A generally adopted system will have the advantages that users will be able to trade software and know-how. The NIH will benefit in many ways from this dissemination process.

Applications will include image comparison, 3-dimensional data superposition, image superposition, 2-, 3- and 4- (time) dimensional reconstruction, image archiving, image analysis, radiation therapy and surgical planning and assistance.

Clinical service will be greatly enhanced when bi-directional links to the MIS can be made (so that imaging physicians have access to patient data and referring physicians have access to images). This will be done when suitable network and computer support are available.

Such a project is best handled by combining both internal and external resources. Combining the vast resources of the NIH, which includes unparalleled medical and scientific expertise, with the contributions made by our colleagues outside of NIH will enable us to reach our goal.

RADIOLOGY

Space-Age Techniques for Generating Images

Victorian Methods for Retrieving Images

Clinical Goals

- Optimize patient care
- Make better use of existing clinical techniques
- Develop new and better clinical techniques

Research Goals

- Gain a better understanding of the basic physiological and biochemical mechanisms influencing life
- Develop methods to help the biomedical community localize and classify disease
- Develop methods to help the biomedical community understand how best to treat illness

Clinical Research and Development Examples

- Treating Brain Tumors:
  - Neurosurgery (NINDS)
  - Radiation Therapy (NCI)

- Brain Imaging Consortium
  - NIAAA, Section of Clinical Brain Research
  - NINDS, Experimental Therapeutics Branch
  - NIMH, Clinical Brain Disorders Branch
  - NIMH, Section on Clinical Brain Imaging
  - NCI, Radiation Oncology Branch
  - DRS, Biomedical Engineering and Instrumentation Branch

- Benefits of these parallel research and development efforts:
  - State of the art imaging techniques (registration, etc.)
  - Atlas (Alan Evans)
  - Establish safe and effective clinical procedures
  - Excelerate investigators research efforts

Information Processing needs of Physicians

- Access medical records
- Integrate medical records from various sources
- Reference medical data bases
- Communicate with consulting physicians
- Analyze results of various medical tests
- Analyze multimodality images
- Generate accurate medical reports

Information Processing needs of Scientists

- Acquire laboratory data
- Store and retrieve data
- Integrate data collected from various sources
- Utilize scientific data bases
- Communicate with colleagues
- Numerically analyze data
- Graphically analyze data
- Process images

General Hospital
Department of Nuclear Medicine

Robert Helton, M.D. **Ann Arbor, Michigan**

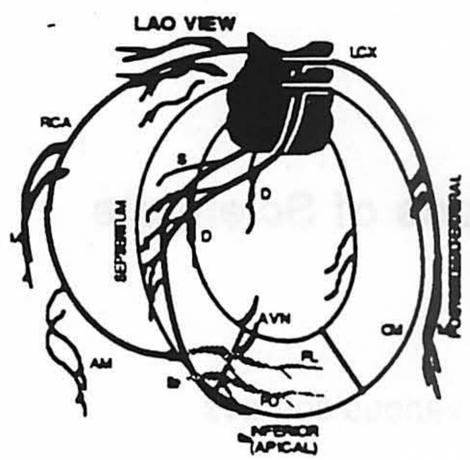
Patient	Hedden, Jean	**Study Requested**	Thallium
ID #	Planar TL	**Date of Study**	2/19/88
Birthdate	00/00/00	**Diagnosing Phys.**	

Procedure

The patient underwent treadmill/bicycle exercise, and was then injected with 3.2 mCi of 201-Thallium as Thallous chloride at peak stress. Immediate and delayed scintigraphic images of the heart were obtained in multiple projections. SPECT imaging was/was not performed.

Results

Abnormal stress/delay thallium study. The redistribution of radiotracer in the septal and infero-apical walls on the delayed images is consistent with myocardial infarct. Distribution of tracer in the anterior wall is consistent with myocardial ischemia.



Stress

Delay

Impression

There is left ventricular dilatation. There is decreased radiotracer uptake in earlier images in the septal and anterior myocardial walls. There is evidence of slow tracer uptake in the anterior wall in the delayed view. The remainder of the myocardium shows normal distribution of radiotracer.

Diagnosing Physician

General Hospital
Department of Nuclear Medicine

Robert Helton, M.D. Ann Arbor, Michigan

Patient : **Keyes, Jan**
ID # : **163287**
Birthdate : **00/00/00**

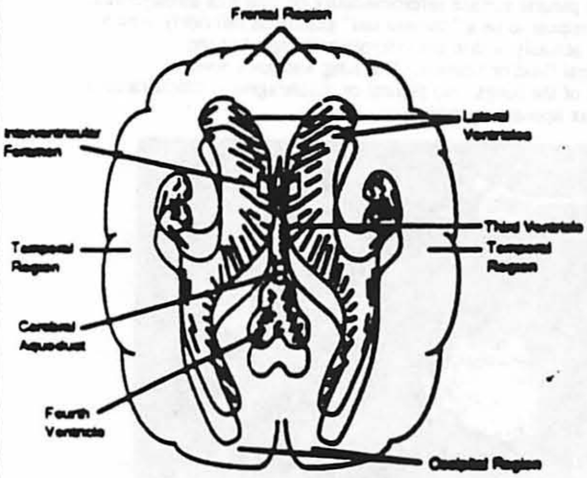
Study Requested : **Brain Tomo**
Date of Study : **5/1/88**
Referring Phys. : **Smith**

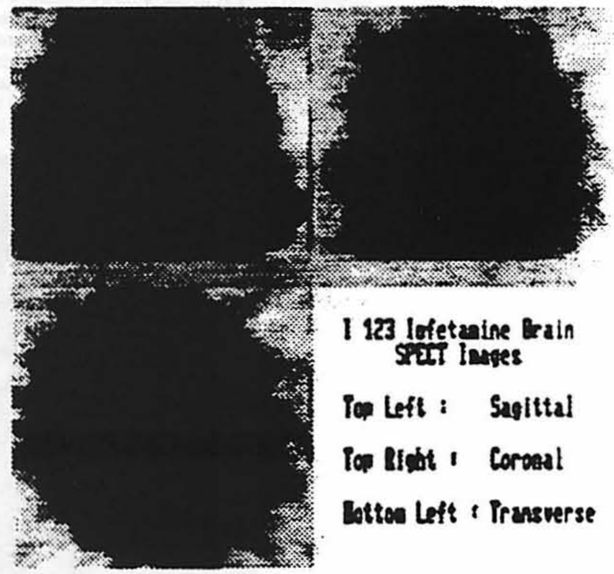
Procedure

Following the intravenous administration of 5.5 mCi of I-123 Iodoamphetamine, a head tomographic acquisition was made and subsequently coronal, sagittal and transverse tomographic images were generated.

Results

Photopenic areas larger than what is considered normal were seen in the regions of the lateral ventricles. There is significantly reduced tracer activity in the regions of the cortices of the occipital and parietal regions on the right side. There is an area of increased tracer activity seen in the base of the brain, approximately in the midline.





I 123 Iofetamine Brain SPECT Images

Top Left : Sagittal

Top Right : Coronal

Bottom Left : Transverse

Impression

Abnormal Iodoamphetamine brain scan.

There is scintigraphic evidence for dilated lateral ventricles.

The cortices of the occipital and parietal lobes on the right side are seen as being thinned.

There is scintigraphic evidence to suggest neoplastic process in the base of the brain approximately at the midline.

Van Riper

Diagnosing Physician

SAMPLE

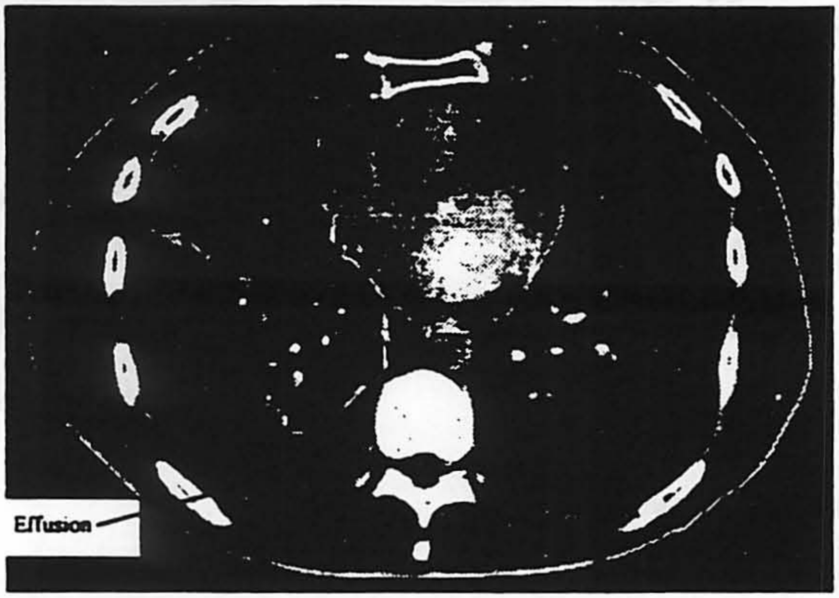
Physician: ROBERTSON, FRED O., MD RG-20

162134 17-Aug-88 0739 CT CHEST WO/W CONTRAST

INDICATION:
Patient with malignant pleural effusion of unknown etiology.

DESCRIPTION:
Scanning was performed at 1cm. intervals from the inferior liver margin through the chest following administration of oral and during administration of intravenous contrast material.

FINDINGS:
Pleural thickening is noted within the right hemithorax involving primarily the posterior lateral pleura but also involving the anterior mediastinal surface along the free edge of the thymic remnant on the right. A well circumscribed 3mm. calcification is present in the right upper lobe consistent with a calcified granuloma. A small to moderate sized pleural effusion is present with some loculation along the posterior paraspinal region in the inferior chest. Two parenchymal densities are present in the right hemithorax. One of these measuring roughly 2cm. in diameter abuts the pleural surface inferomedially on cuts #28 through #22. A portion of this appears to be aerated and there does appear to be a "comma tail" extension inferiorly which is suggestive for round atelectasis. Another density is actually within the inferolateral aspect of the oblique fissure and may represent some loculated pleural fluid or fibrosis. The lung windows reveal emphysematous changes in the posterior basal aspects of the lungs. No pleural or diaphragmatic calcifications are identified. The pleural surface in the left hemithorax appears normal.



IMPRESSION:

1. RIGHT PLEURAL EFFUSION WITH SOME LOCULATION INFEROMEDIALLY.
2. DIFFUSE PLEURAL THICKENING CONSISTENT WITH ASBESTOS EXPOSURE.
3. INFERIOR PULMONARY PARENCHYMAL DENSITY MOST CONSISTENT WITH ROUND ATELECTASIS.
4. EVIDENCE OF OLD GRANULOMATOUS DISEASE.

I request supplementary medical insurance payments to University Physicians on its claims for services furnished to the enrollee on this report. I certify that the services shown on this report were furnished by me personally or under my personal direction, that the services were medically necessary, and that the professional fees were exclusive of teaching effort.

Approved by: John Smith, M.D.

Transcribed on: 18-Aug-88 0842
Denise James

UNIVERSITY OF WASHINGTON HOSPITALS
UNIVERSITY HOSPITAL
HARBORVIEW MEDICAL CENTER
SEATTLE, WASHINGTON

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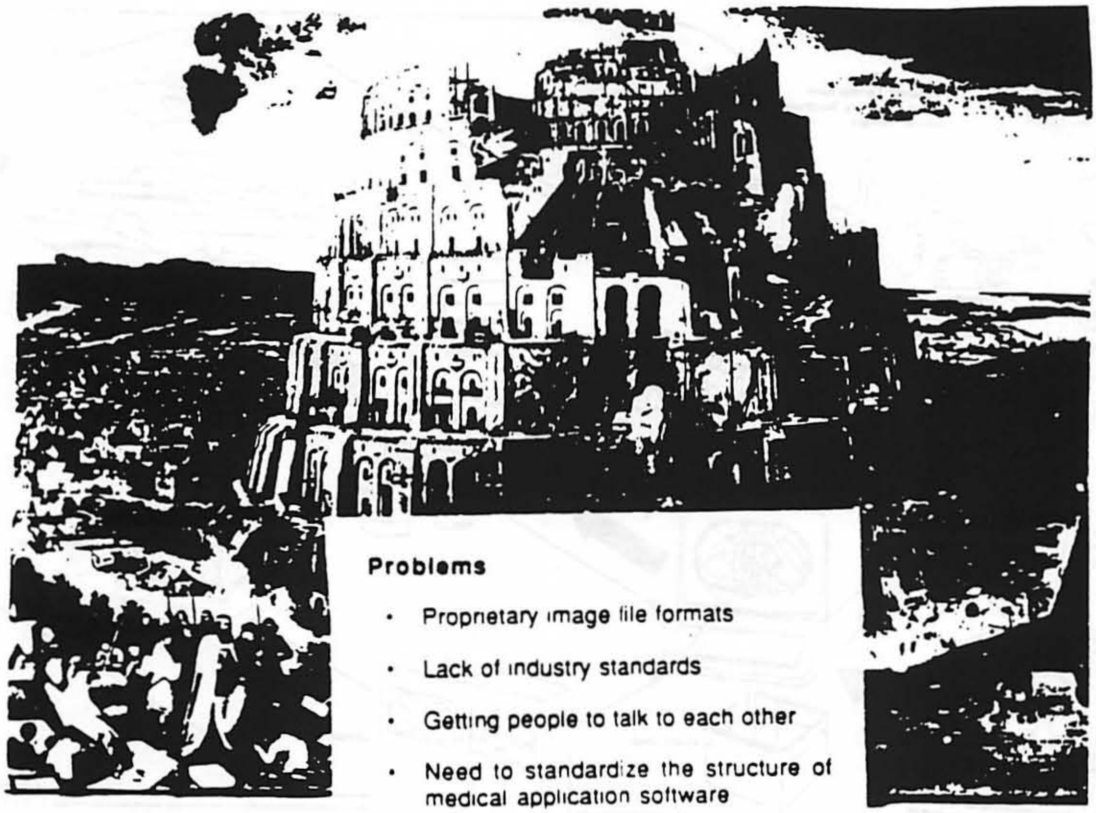


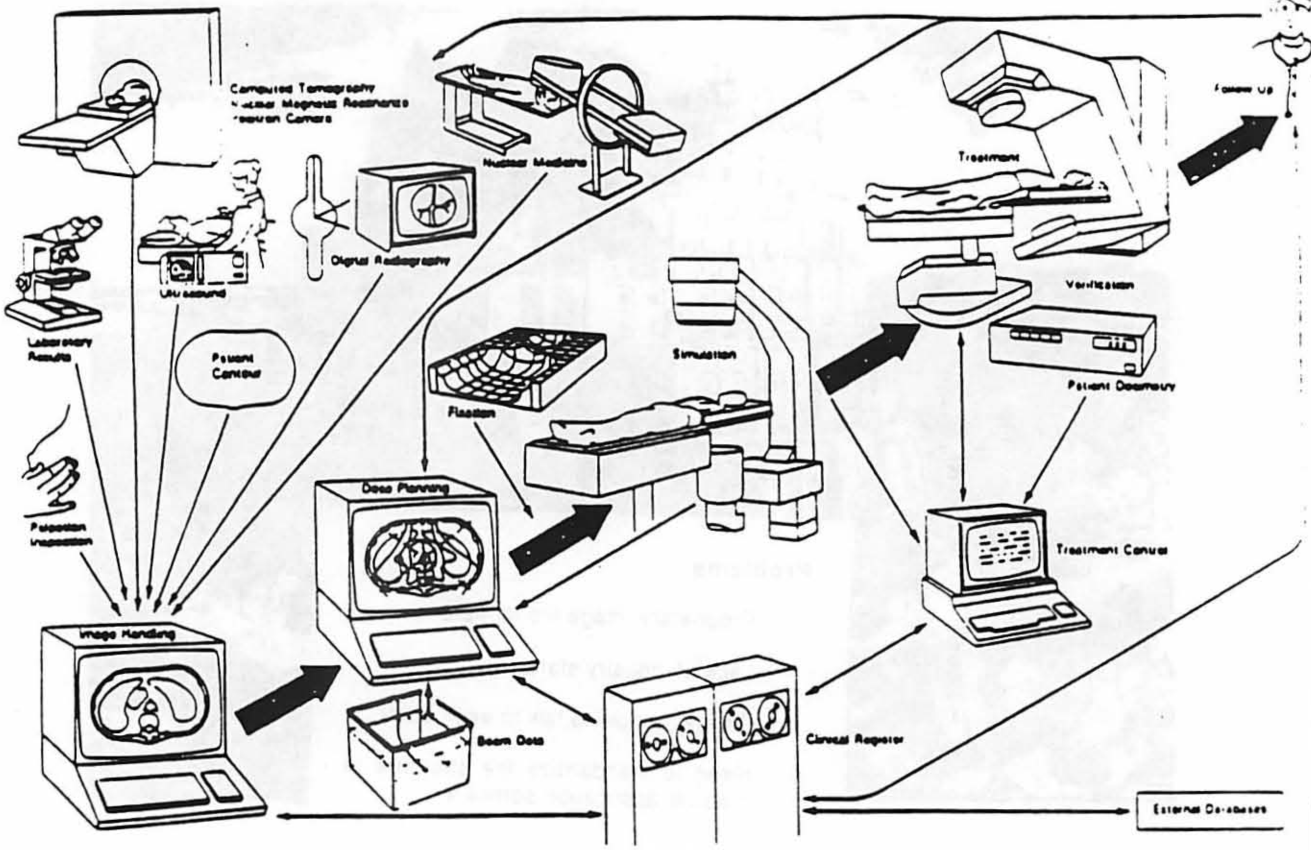
Implementation Strategies

- System Design
  - Top-down design
  - Bottom-up implementation

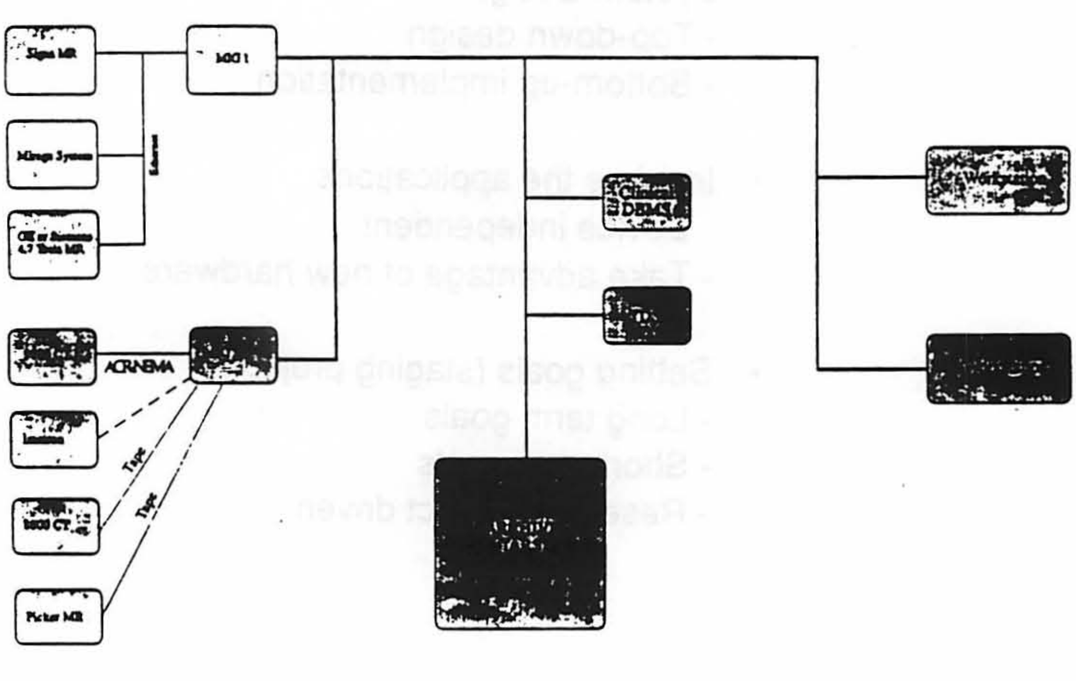
- Insulate the applications
  - Device independent
  - Take advantage of new hardware

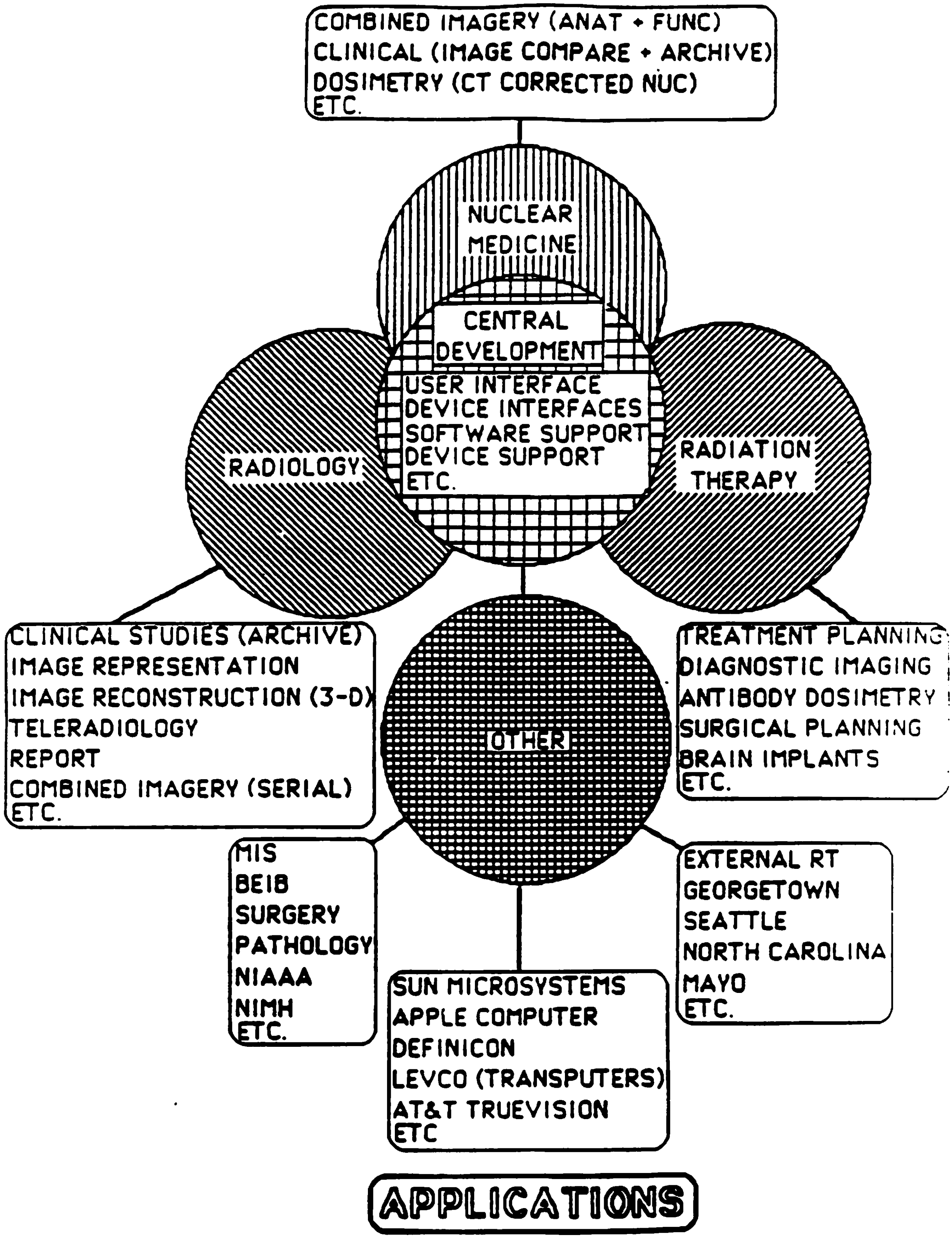
- Setting goals (staging project)
  - Long term goals
  - Short term goals
  - Research project driven

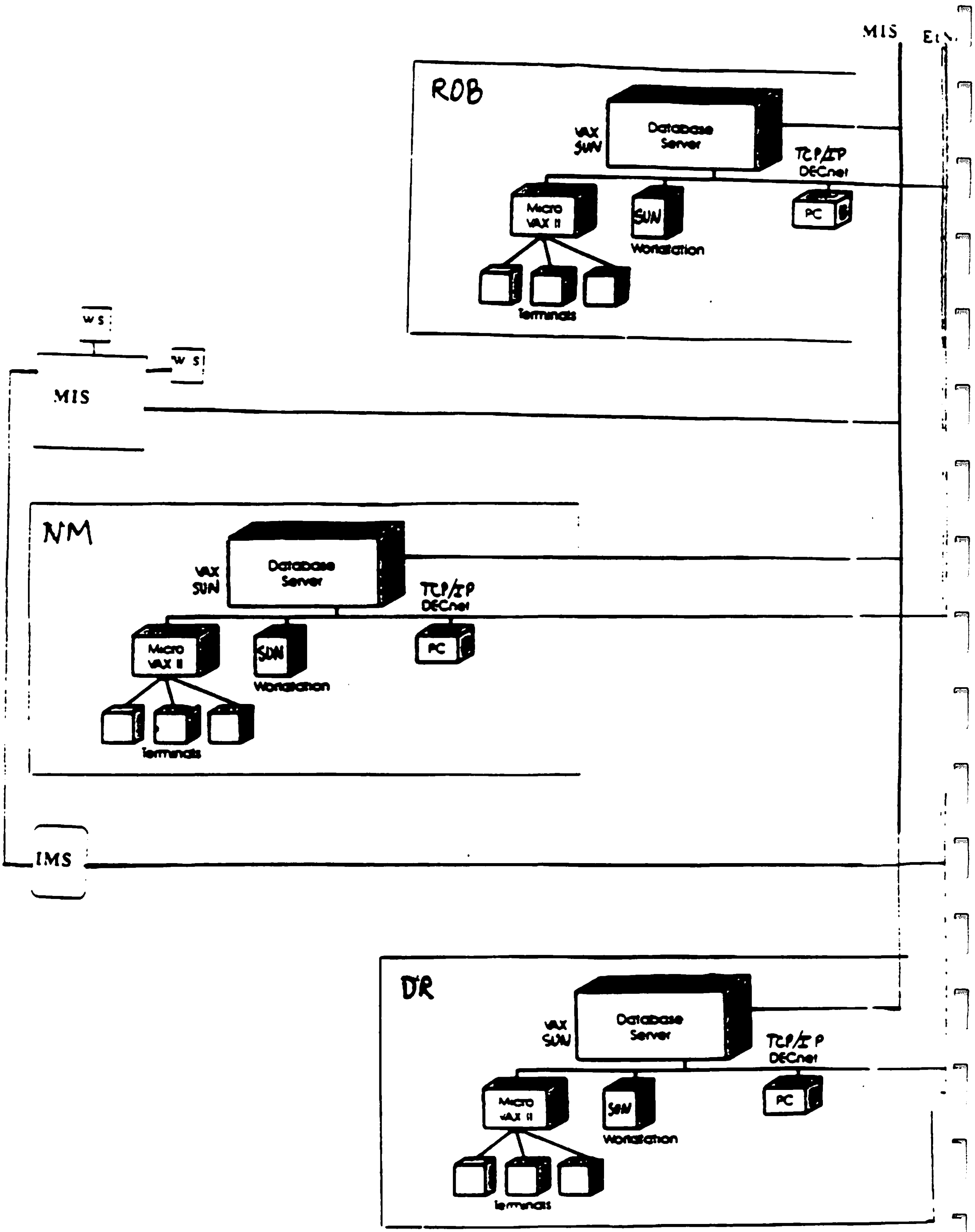
CART



NIH Logical Architecture

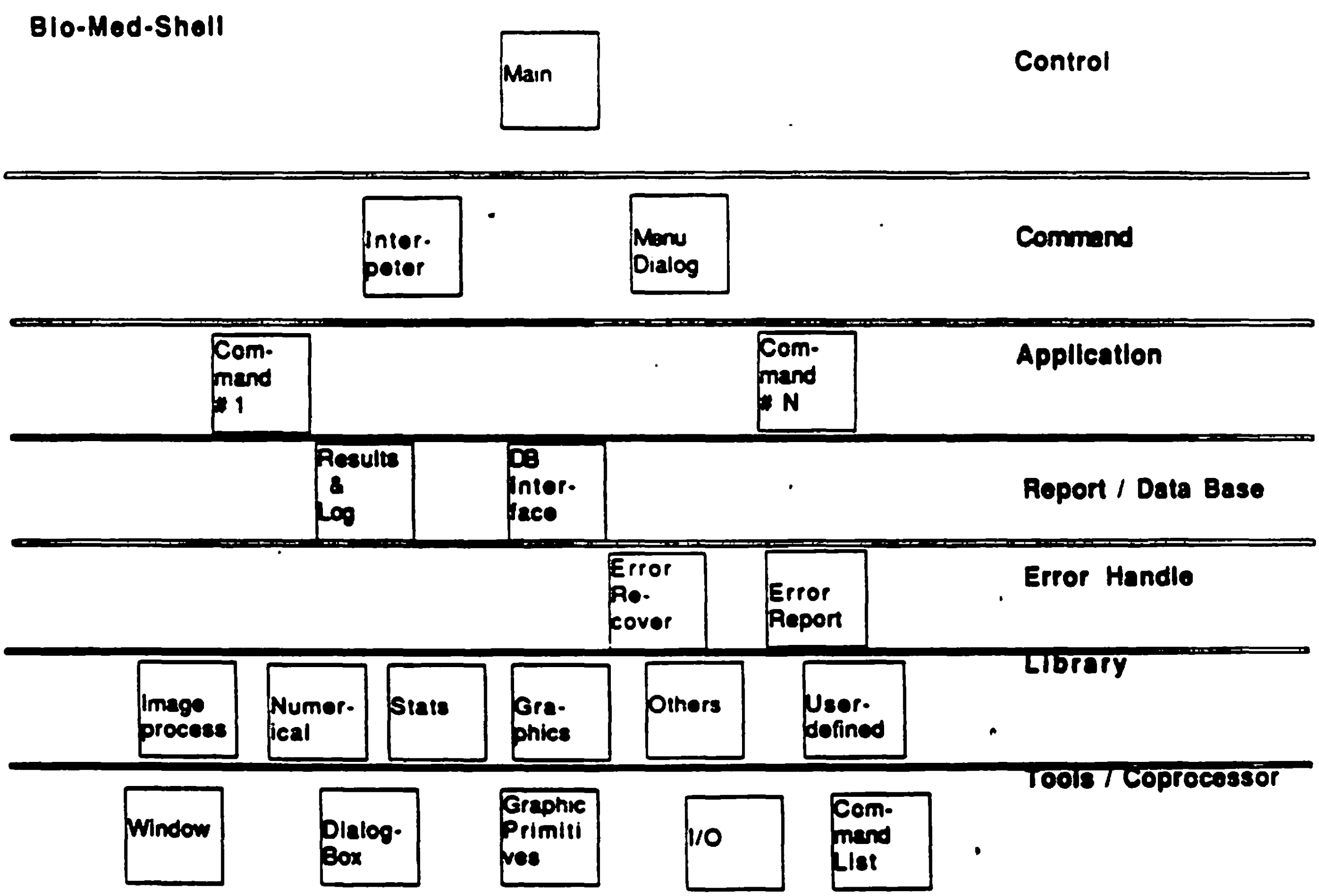



COMBINED IMAGERY (ANAT + FUNC)
CLINICAL (IMAGE COMPARE + ARCHIVE)
DOSIMETRY (CT CORRECTED NUC)
ETC.
NUCLEAR MEDICINE
CENTRAL DEVELOPMENT
USER INTERFACE
DEVICE INTERFACES
SOFTWARE SUPPORT
DEVICE SUPPORT
ETC.
RADIOLOGY
RADIATION THERAPY
CLINICAL STUDIES (ARCHIVE)
IMAGE REPRESENTATION
IMAGE RECONSTRUCTION (3-D)
TELERADIOLOGY
REPORT
COMBINED IMAGERY (SERIAL)
ETC.
OTHER
TREATMENT PLANNING
DIAGNOSTIC IMAGING
ANTIBODY DOSIMETRY
SURGICAL PLANNING
BRAIN IMPLANTS
ETC.
MIS
BEIB
SURGERY
PATHOLOGY
NIAAA
NIMH
ETC.
EXTERNAL RT
GEORGETOWN
SEATTLE
NORTH CAROLINA
MAYO
ETC.
SUN MICROSYSTEMS
APPLE COMPUTER
DEFINICON
LEVCO (TRANSPUTERS)
AT&T TRUEVISION
ETC
APPLICATIONS


MIS
ROB
Database Server
VAX SUN
TCP/IP DECnet
Micro VAX II
SUN
Workstation
PC
Terminals
WS
WS
MIS
NM
Database Server
VAX SUN
TCP/IP DECnet
Micro VAX II
SUN
Workstation
PC
Terminals
IMS
DR
Database Server
VAX SUN
TCP/IP DECnet
Micro VAX II
SUN
Workstation
PC
Terminals

Platforms for Medical Applications

- X-terminals (low end applications)
- Macintosh IIs (medium end applications)
- UNIX workstations (high end applications)



The VA File Manager in a Distributed Workstation Environment

Dr. Gunther Schuller, University Wurzburg, West Germany

Distributed Processing in the Hospital

Future requirements and possibilities

- image processing
- permanent reliability (NON-STOP Operation)
- Heterogeneous Systems
- Affordable Hardware (PC and LAN)

LAN Requirements

- Redundancy
- Automatic Reconfiguration
- Network Control Center
- Fiber Optic
- Speed > 10 mbit/sec
- Hierarchical Cabling (Segmentation)
- Packet (and circuit) Switching Protocol

Data Processing Equipment Requirements

- Distributed Hardware
- Distributed Software
- Non-Stop Service Software

Data Security

- Use of Certified Hardware and Software
- Prevent Unauthorized Access to Server
- Prevent Passive Recording of Traffic

Software Level 1: Network Layer

(ISO Level 5; ^%netbios)

Connection Control:

- Connection Password
- Permanent Authentification
- Namespace Password
- Permanent Session Control (against File Manager Database)

- Message Encryption/Decryption
- Forced Loading of All Workstations from a Server
- Transparent Error Message Handling ($zzerr)
- Automatic Session Restart
- Remote JOB Command (node = '...')
- Remote Process Status Control (%mjob)
- Remote Session Control (%netbios)
- Synchronization of Workstation/Server ($ZSYNC)

Software Level 2: MUMPS Layer

- Global Distribution (MUMPS DBD) (Redirection)
- Lock Command (network wide)
- File Replication (MUMPS, DBD)
- (journalling transactions)
- Read only data sets
- Optional mount
- Namespace Switch (MUMPS, DBD)
- Error
- interrupt trap
- Halt

Software Level 3: Tool Layer

- **ZTM Remote Task**
  - **Session Control**
  - **Remote Task Control**
  - **Remote Job Activation**
  - **Backup/Restore Process**
  - **Namespace Synchronization**
- **Errortrap in XQ**
- **Namespace Switch in XQ (%zosf ("PROD"))** (MUMPS DBD)
- **File Manager Windowing (DIWEZ)**
- **XQ, XQM Windowing**

Experiences of Wurzburg

- PC Network stable
- Very Flexible in Hardware and Software
- Inexpensive solution (high speed, optimal user support, high redundancy, non-stop solution)
- 240K Global Transactions/second (1 KB each) per server

  (INTEL 80386, 16 MHz, 4MB RAM, no disk access)
- 80286 machine (12 MHz, 1-2 MB RAM) is fast enough

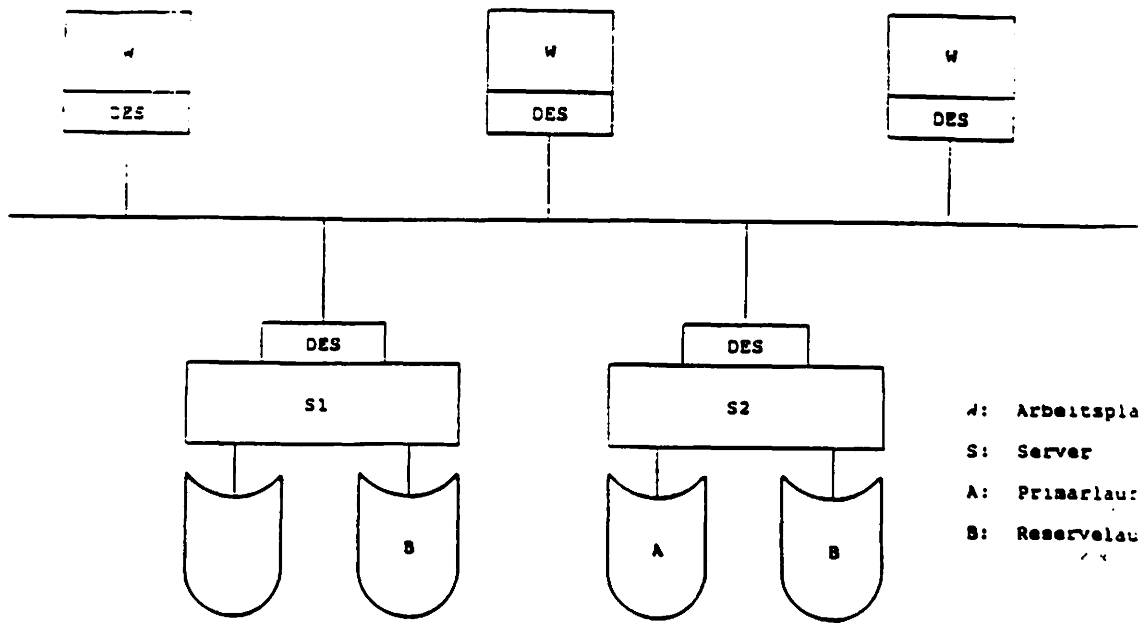
Non-Stop Solution

When a node encounters an error ($zzerr) in one of the servers, S1:

- Start a process at the server S2 (ZTM) and wait for reply
- The process at S2 controls all sessions, processes and data sets of S1 and decides whether S1 should be switched off in part or in total
- S2 forces all workstations to switch to the new namespace and go on
- After repair of S1 and after the daily backup and restore process (ZTM) all workstations are informed to do a namespace switch to the normal mode (replicated servers)

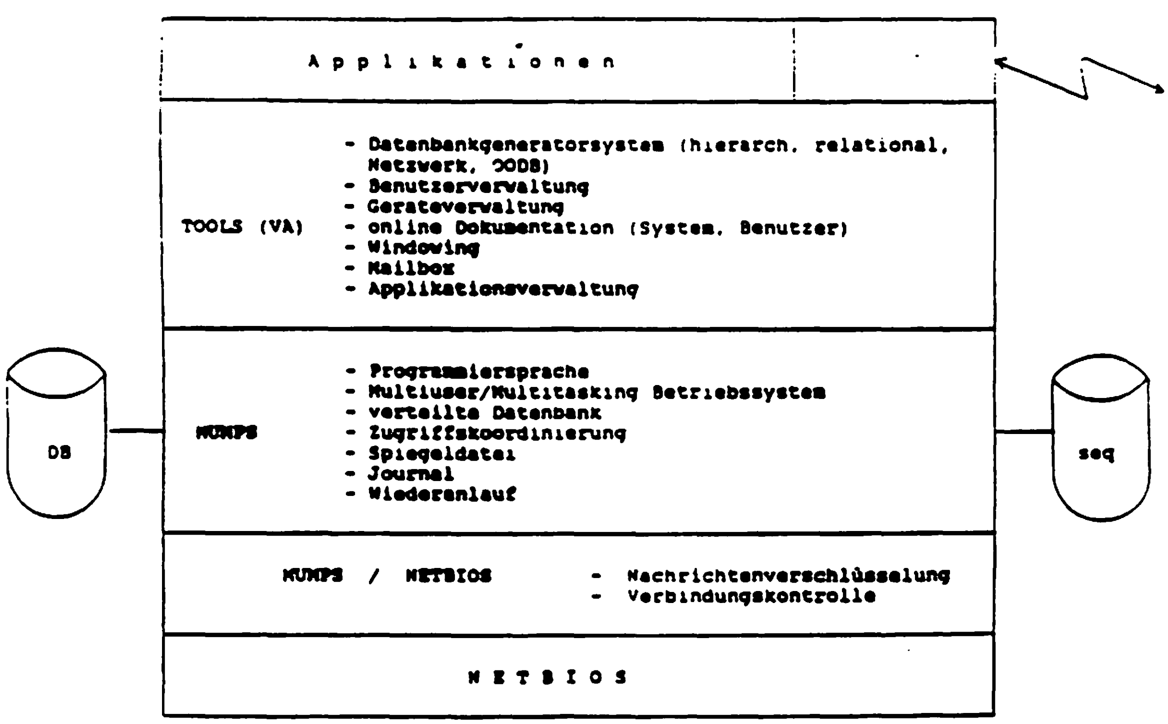
Systems '89

PC-Konfiguration

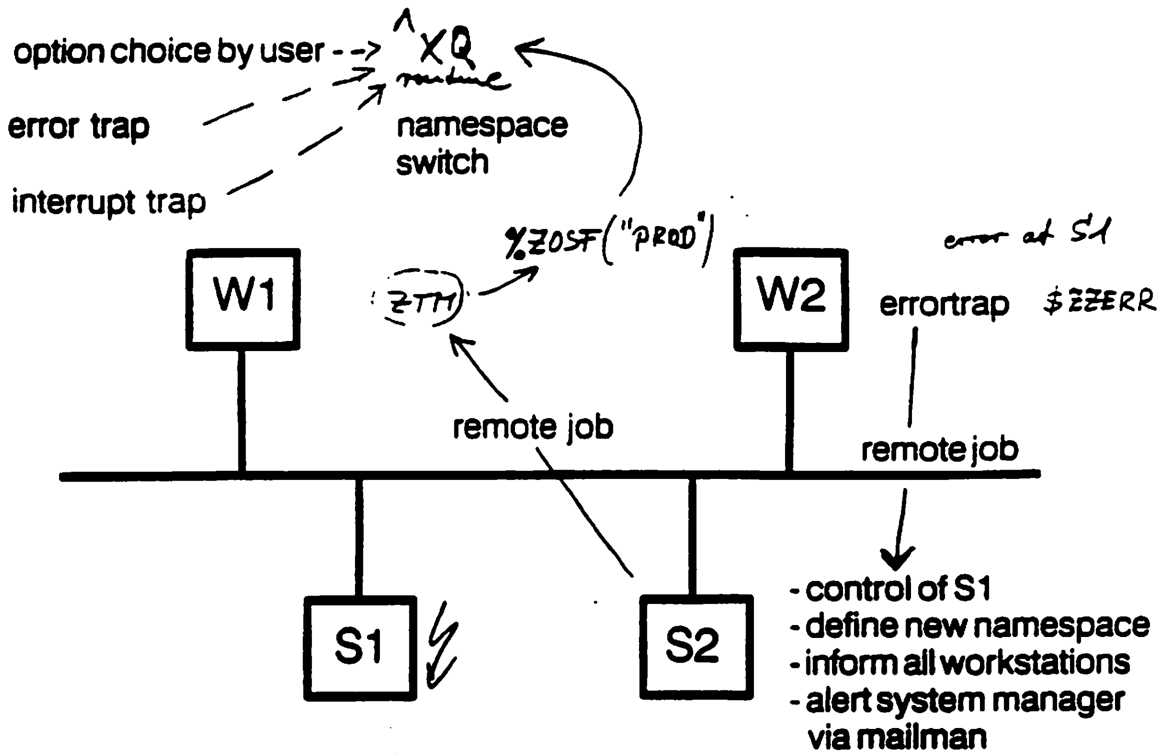


Universität Würzburg, Rechenzentrum

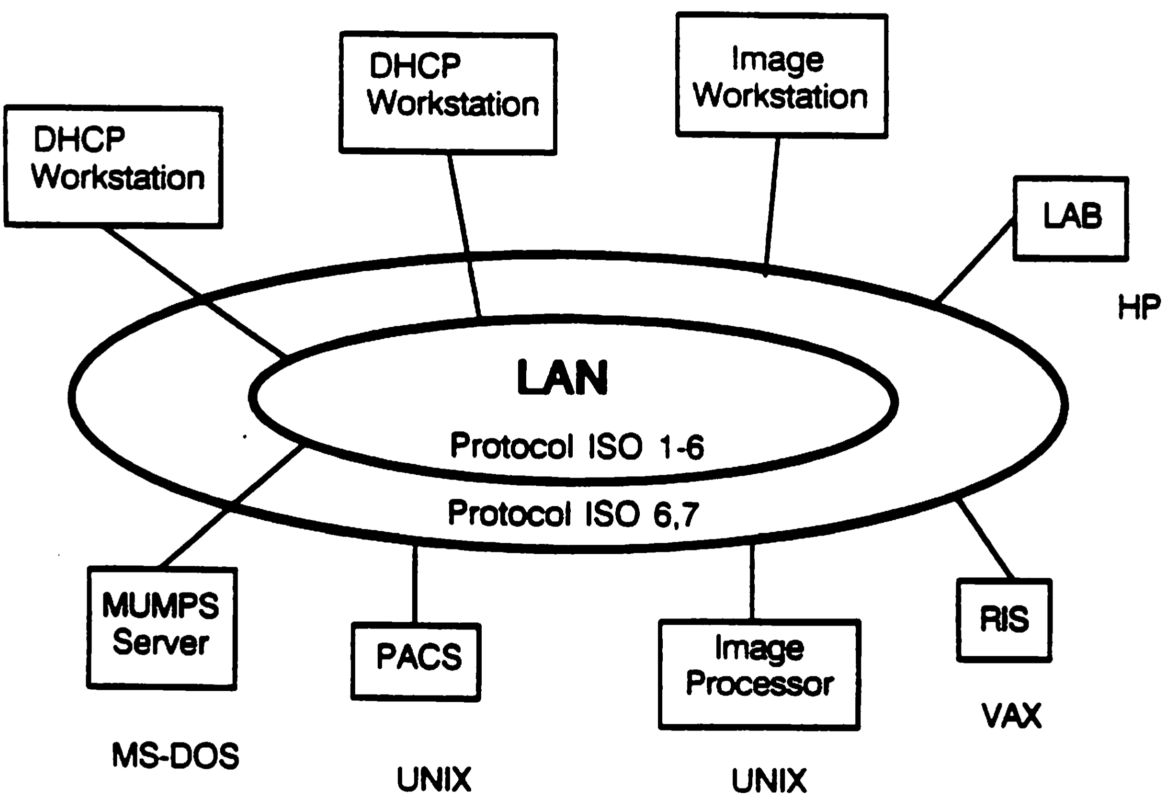
Systems '89



Universität Würzburg, Rechenzentrum



Heterogeneous Network



Clinical Imaging Project

Drs. Shima and Takahashi, Fujita Gakuen Health University School of Medicine, Japan

Paper submitted by Drs. Shima and Takahashi

FUJITA GAKUEN HEALTH UNIVERSITY

SCHOOL OF MEDICINE

CLINICAL IMAGING PROJECT

UNIVERSITY MEDICAL CENTER PROFILE

1,600 beds in multiple hospital buildings
2,000 outpatient clinic patient visits per day

GENERAL BACKGROUND

In Japan, almost all large hospitals use computerized information systems for the major patient registration, billing and accounting, inventory control, and other business-oriented applications. Many of these hospitals have installed order entry systems.

The majority of these business-oriented systems are written in COBOL, and are operated on mainframe computers supplied by Fujitsu, NEC, and IBM. Several hospitals have fairly extensive MUMPS-based systems, operated on VAX or UNIX-based minicomputers.

MEDICAL IMAGING

There is extensive research being conducted on PACS for medical imaging support. Several hospitals are using PACS extensively in clinical activities: for example, the university medical centers of Hokkaido University, Kyoto University, Kochi University, and Kitazato University. Hokkaido University Hospital is integrating PACS into a Total Hospital Information System, with plans to replace all Xray films with digital images. In other hospitals, PACS are used only in the Radiology departments.

A Medical Information Processing Standard (MIPS) Committee was organized by the Japan Society of PACS, the Ministry of International Trade and Industry, and Japanese manufacturers of PACS systems. The committee adopted a subset of the ACR NEMA standard, provided a capability for handling Japanese characters, and released it for broad use.

NETWORK BASED COMMUNICATIONS

Some of the national university hospitals have installed, and others plan to install, LANs, which mainly are Ethernet using coaxial cable, but also include some high speed LANs using fiber optics. Among these national university hospitals, an inter-university network is being developed by the end of this fiscal year. At present, several universities are connected using a DDX packet exchange service on a dedicated NTT channel.

THE FUJITA GAKUEN UNIVERSITY SCHOOL OF MEDICINE PROJECT

Dr. Takahashi of the Department of Radiology is directing a project to develop a low cost, modular medical imaging system to meet the personal professional needs of clinicians, especially for the continuing education and clinical research uses. In parallel, Dr. Shima is designing a full clinical data base system oriented toward clinical decision making. The design includes use of the U.S. Department of Veterans Affairs File Manager system, extended to handle medical images, and hosted in FIPS 125/ANSI X11.1 standard software technology, extended to provide object oriented programming and database capabilities.

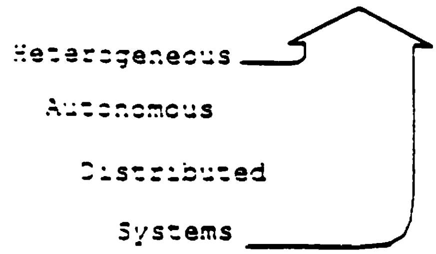
An initial prototype has been developed for proof of concept. It is based on the U.S. NIH Macintosh-based prototyping experience.

The second phase of the project is concentrating on developing the clinician-machine interface that will provide full support for physicians' clinical activities. The design is following object-oriented principles.

Software Standards and Imaging: The NIST Software Backplace Project

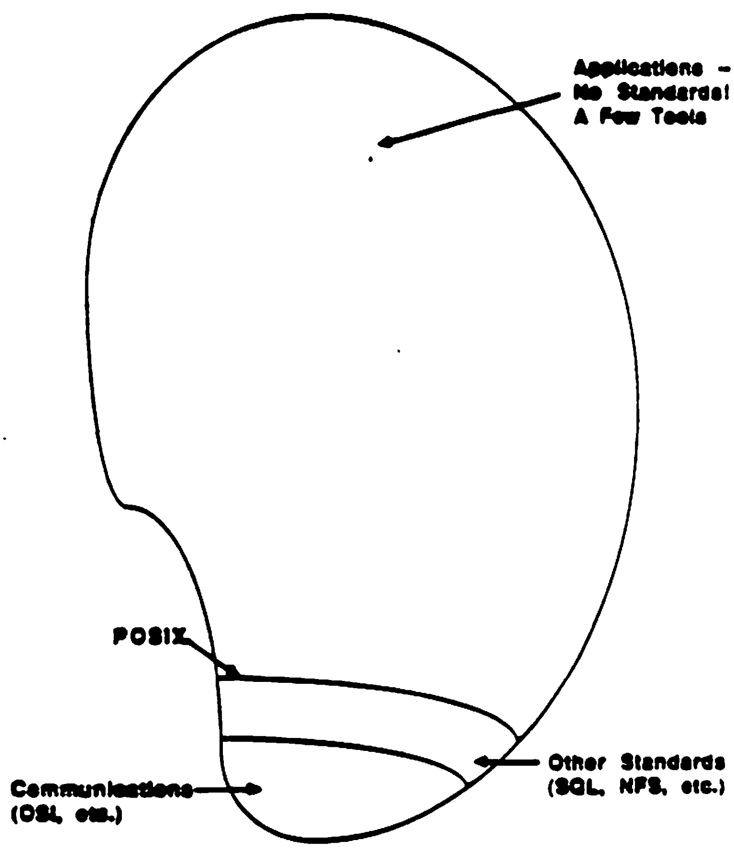
Wayne McCoy
National Institute of Standards and Technology (NIST)

Need for Standards



- Physical Integration
- Logical Integration
- Usage Integration

Current State of Standards



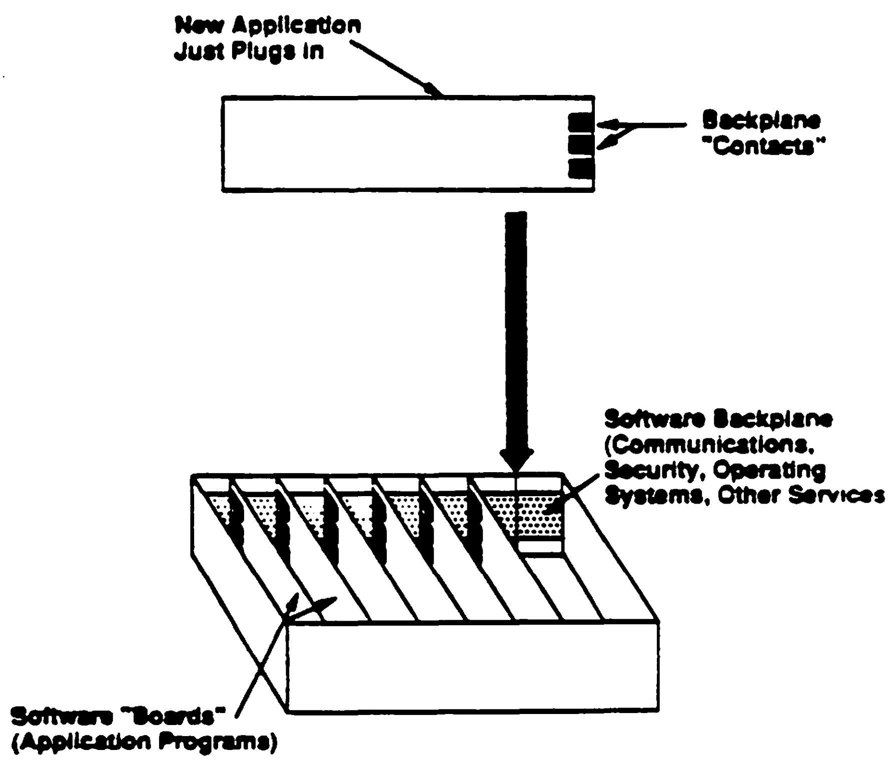
APPLICATIONS PORTABILITY PROFILE (APP)

Function	Element	Interface Specification
Operating System	Extended POSIX	FIPS 151 (IEEE Std 1003.1-1988)
		Shell & Tools (P1003.2,draft 8)
		System Admin (IEEE P1003.7)
Database Management	SQL	FIPS 127
	IRDS	X3.138 (proposed FIPS)
Data Interchange		
- Graphics	CGM	FIPS 128
- Product Data	IGES, PDES	NBSIR 88-3813
- Document Processing	SGML	FIPS 152
	ODA/ODIF	ISO/IS 8613
Network Services		
- Data Communications	OSI	FIPS 146 (GOSIP)
- File Management	NFS	IEEE P1003.x
User Interface	X Window System	Version 11, Release 3
Programming Services	C	X3J11 , draft X3.159
	COBOL	FIPS 021-2
	Fortran	FIPS 069-1
	Ada	FIPS 119
	Pascal	FIPS 109

Services Backplane Concept

- Integration through service access
- Common set of services
- Single interface
- Integration of standards and usage
- Concept as strategy
- Concept as tool foundation
- Concept as implementation

Software Backplane Concept



Goals

- Enhance Application Distribution Across Multiple Platforms
- Provide a Standard Interface to All Applications
- Simplify Application Development
- Provide a Migration Path to New Technologies
- Simplify Integration / Maintenance
- Provide a Strategic Hardware and Systems Software Direction
- Focus on Long-Term Solutions

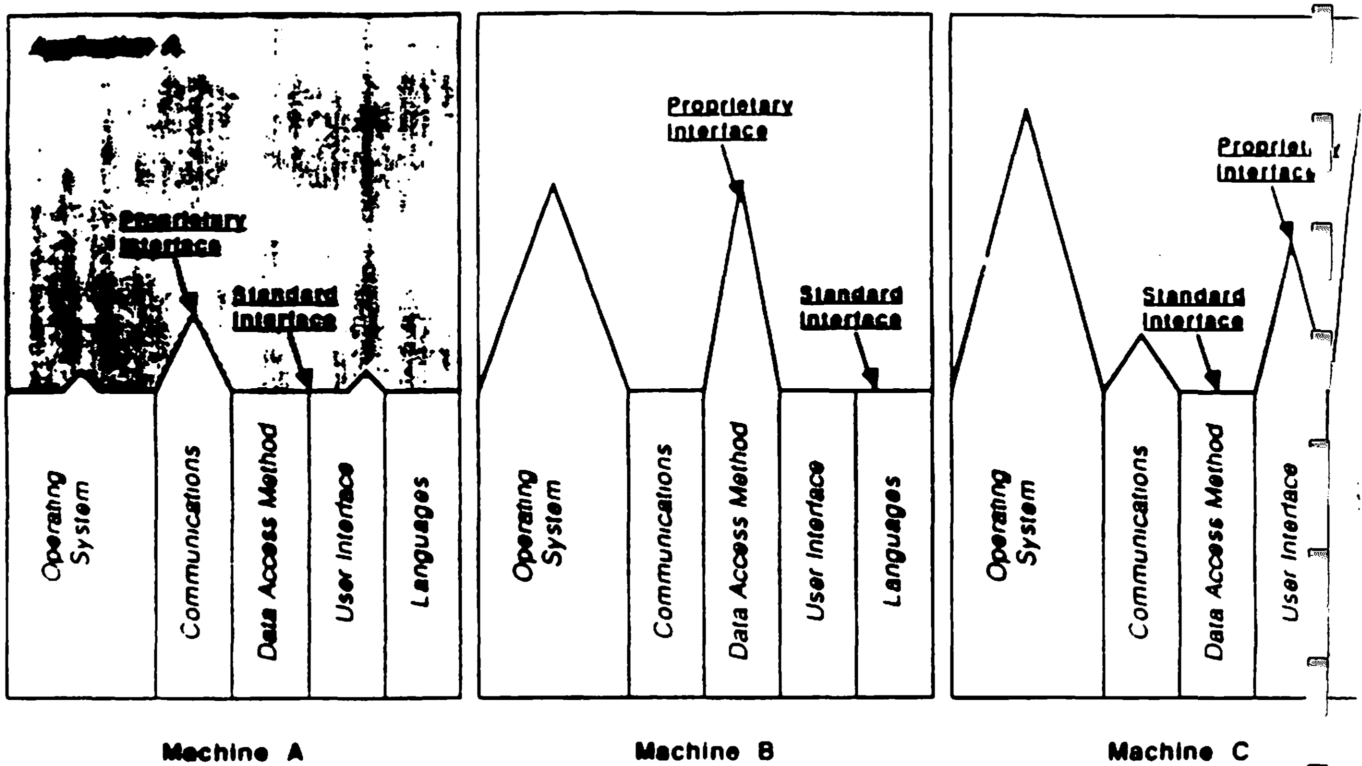
Benefits

- Positioned to Exploit Distributed Environments
- Increased Productivity
- Protection of Software Investment
- Increased Software Reusability
- Increased Overall System Quality
- Protection of Training Investment
- Increased Competition In The Marketplace
- Can Be Implemented Today

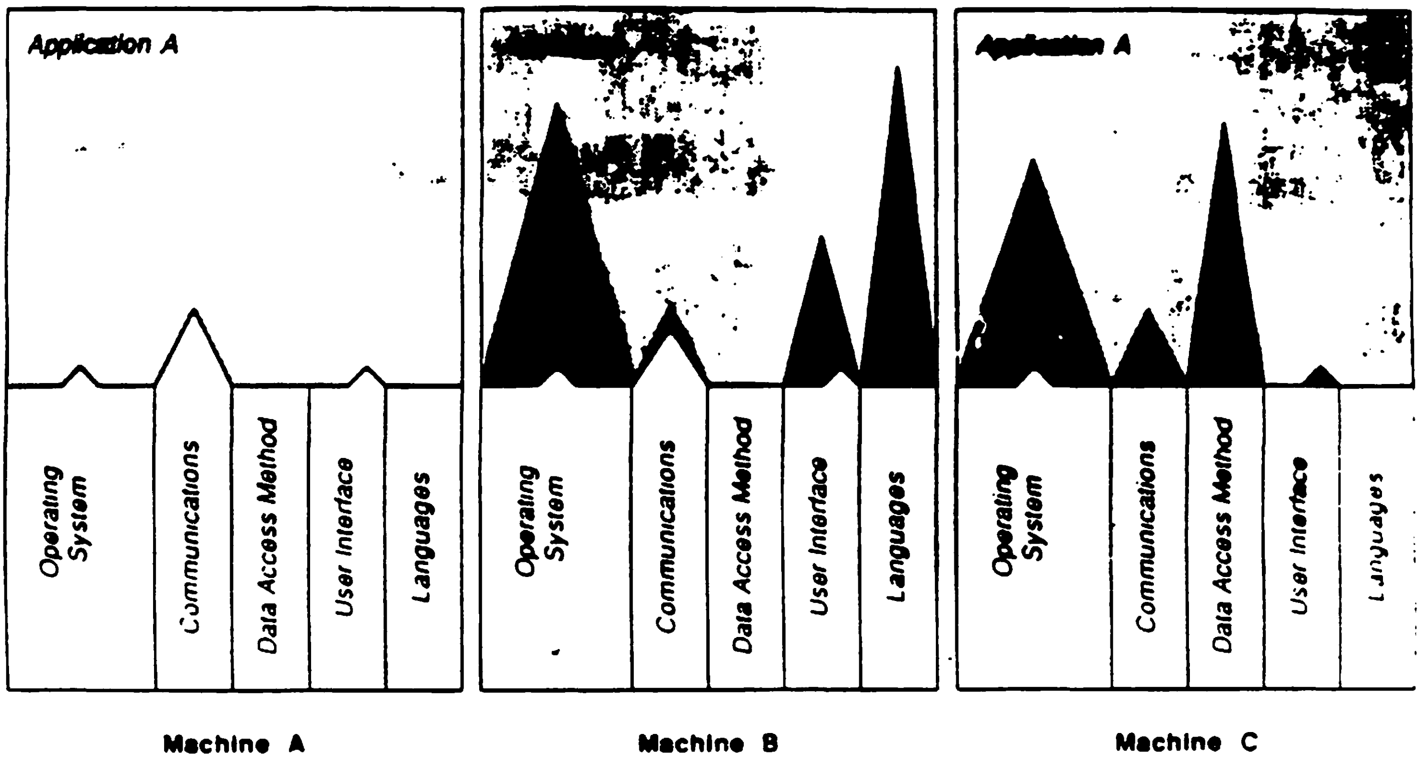
Common Service Access

- Services
  - Operating System
  - Communication
  - Security
  - Data Access
  - User Interface
- Single interface
- Hardware analogy

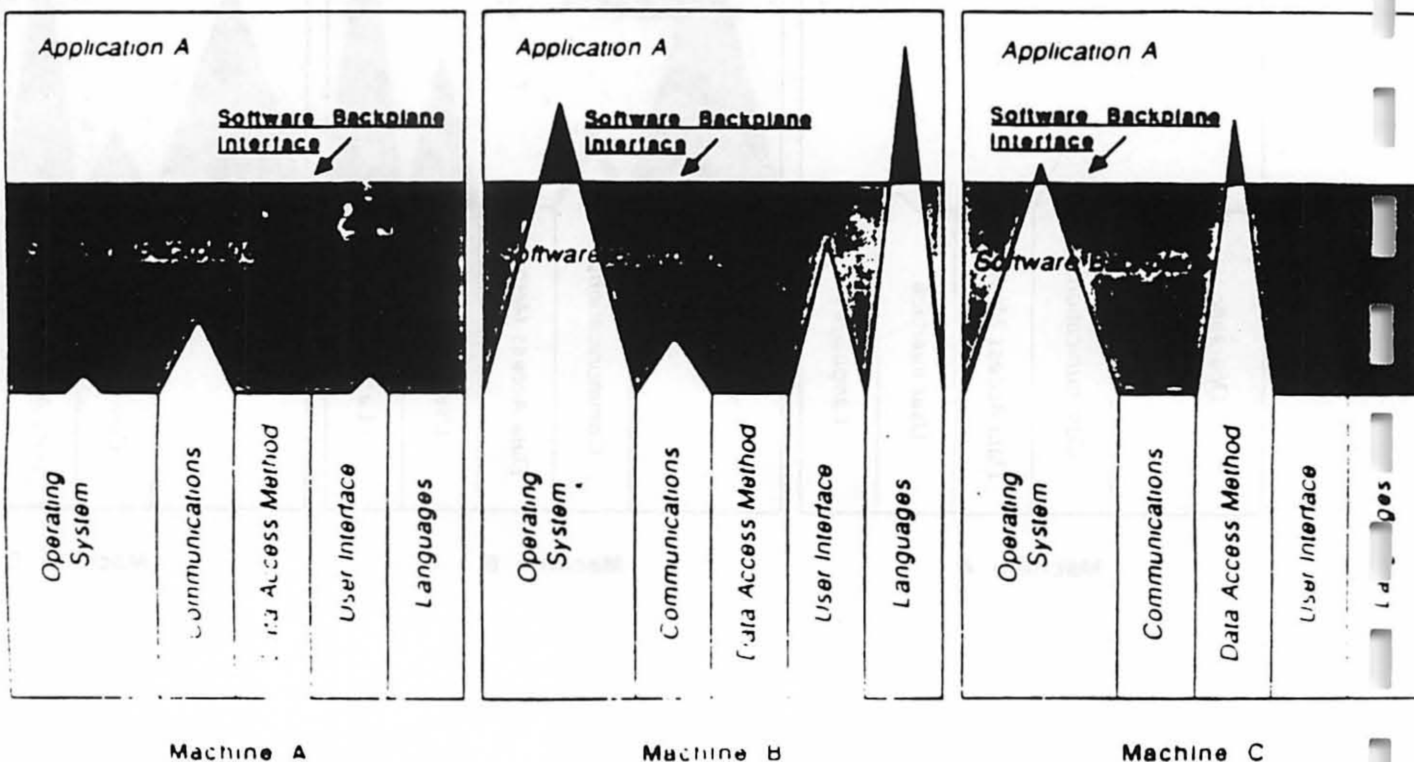
The Degree to which Applications Can be Distributed On Dissimilar Platforms, Using Standard Interfaces Wherever Possible



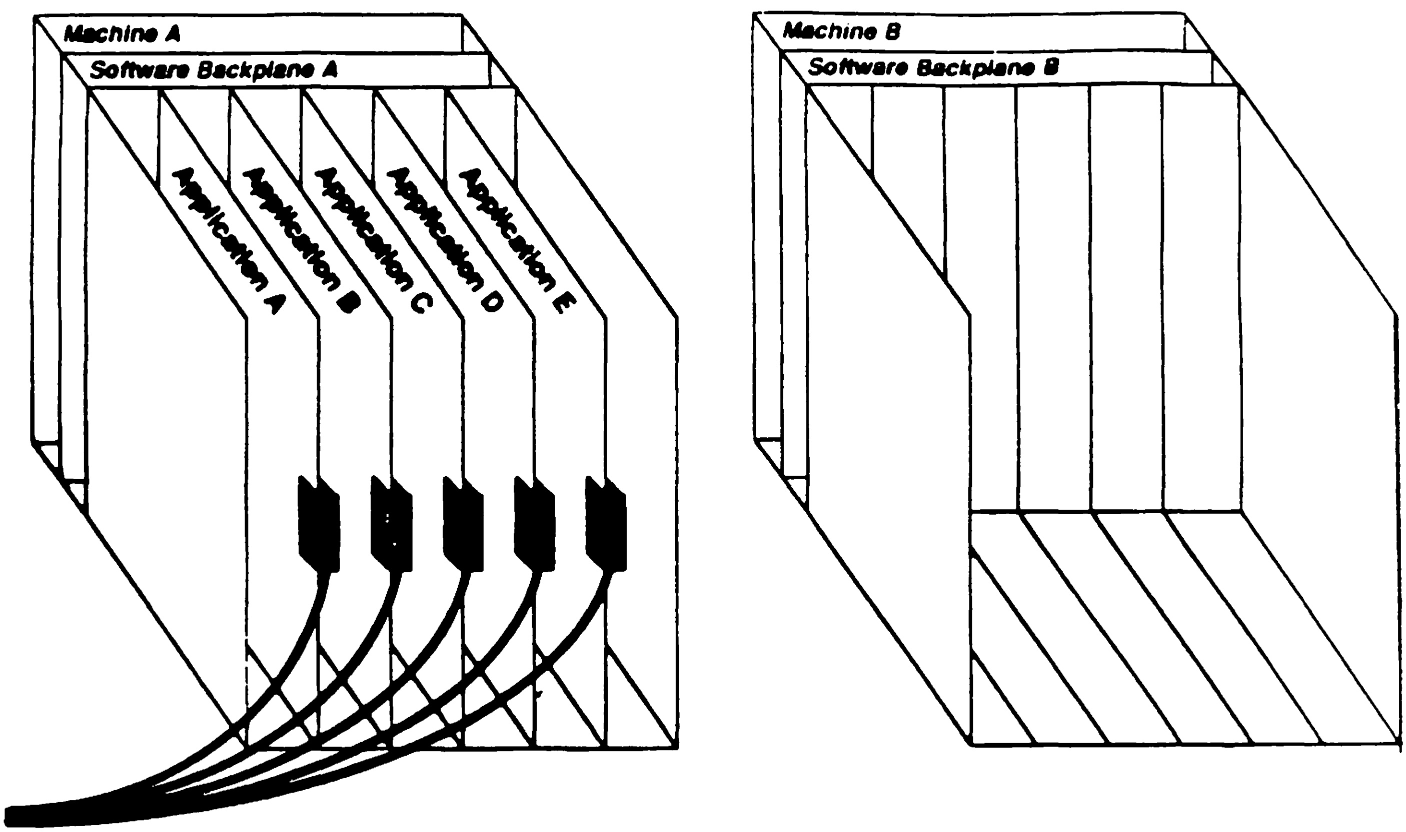
The Degree to which Applications Can be Ported Between Dissimilar Machine Architectures, Using Standard Interfaces Wherever Possible



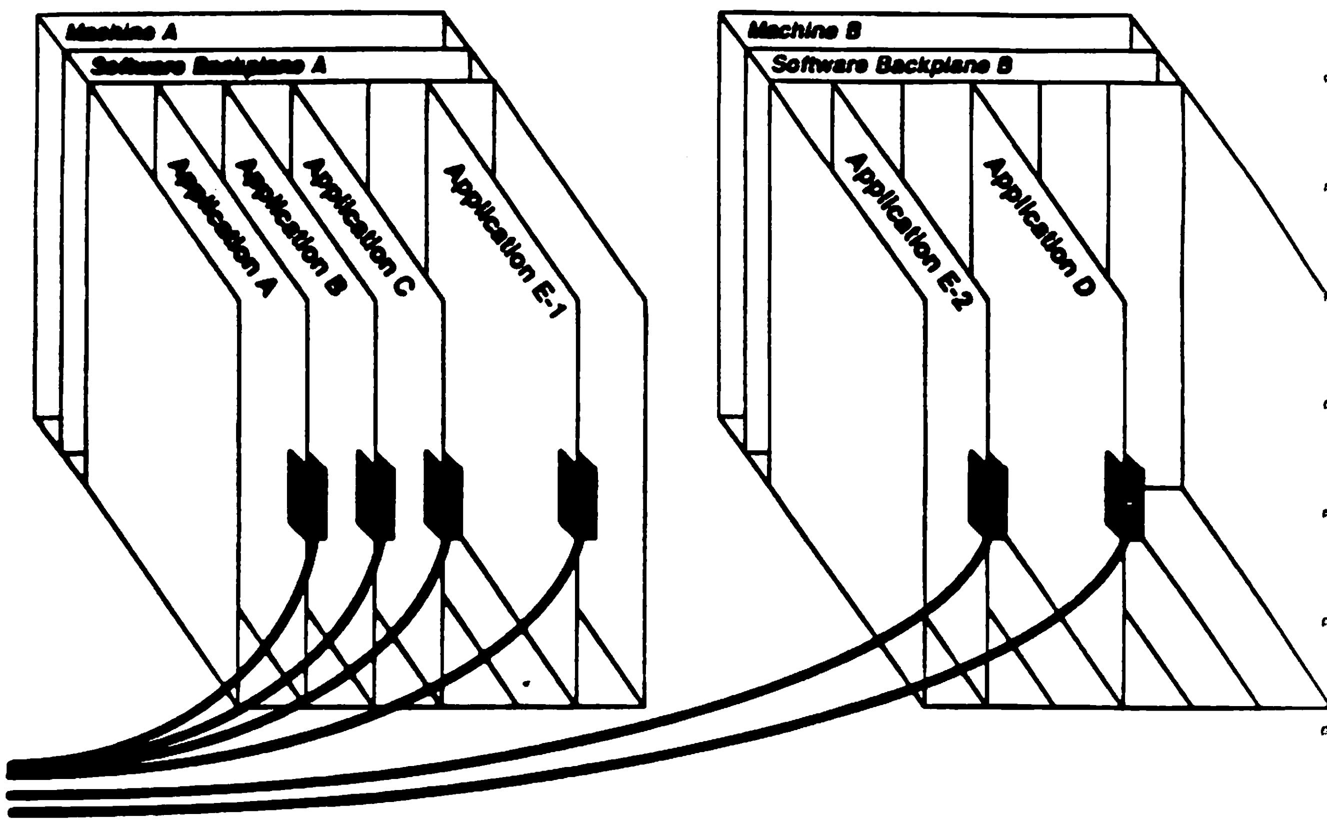
The Degree to which Applications Can be Ported Between Dissimilar Machine Architectures, Using a Standard Software Backplane Interface



A Structure for Developing ISDN Applications



A Structure for Developing ISDN Applications



Concept As Strategy

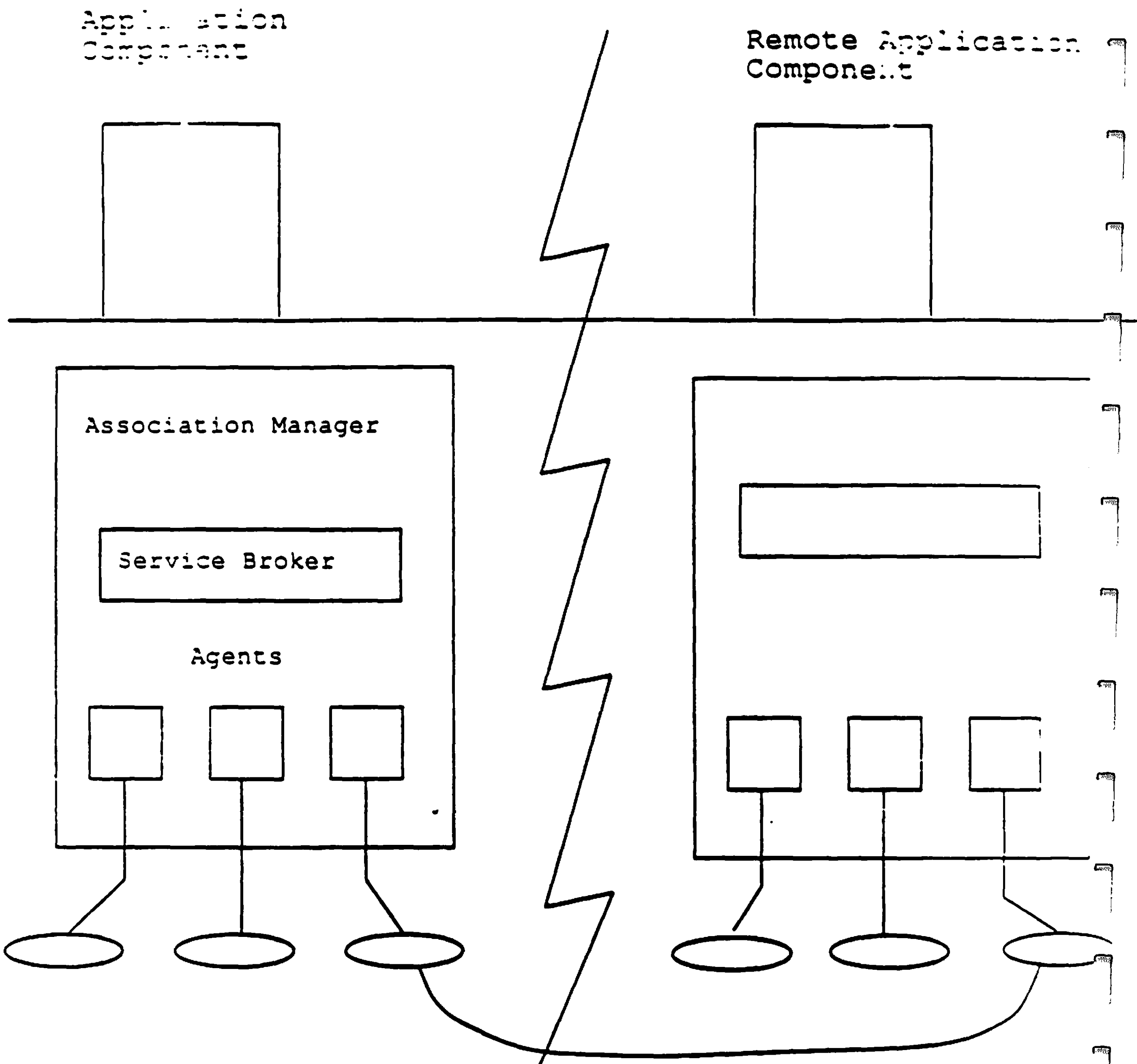
- Focal point for long range strategy
    - Converges diverse activities
    - Provides budgetary control
    - Establishes migration path
- Reduction of heterogeneity

Concept As Tool Foundation

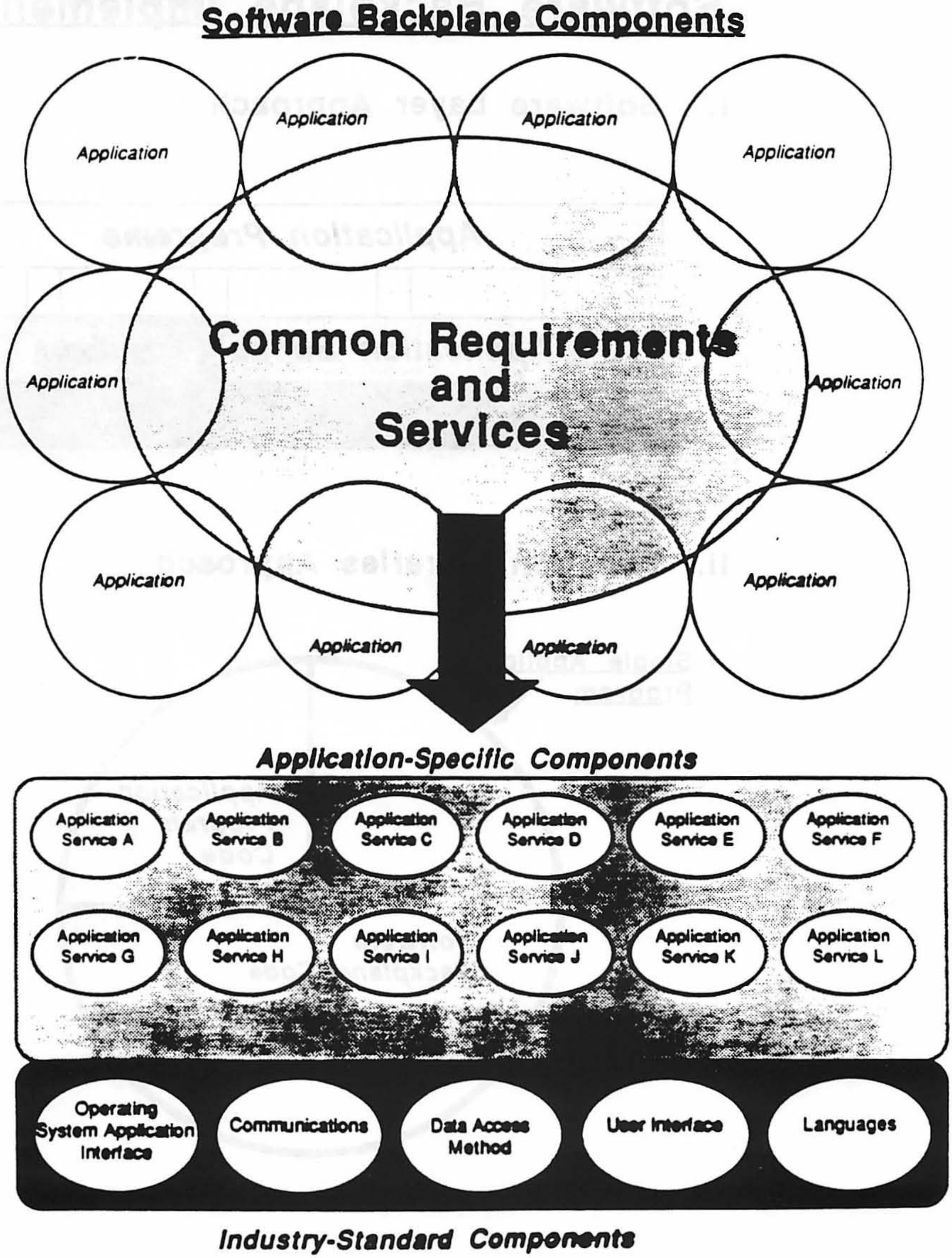
- Single interface to system
- Transparency of
    - Hardware
    - Operating System
    - Network
    - Database
- Increase competitiveness among tool builders

Concept As Implementation

- Common software layer on each system
- Single interface for applications developer
    - Deliver applications before hardware
    - Portability / interoperability
- Increase competitiveness among application builders

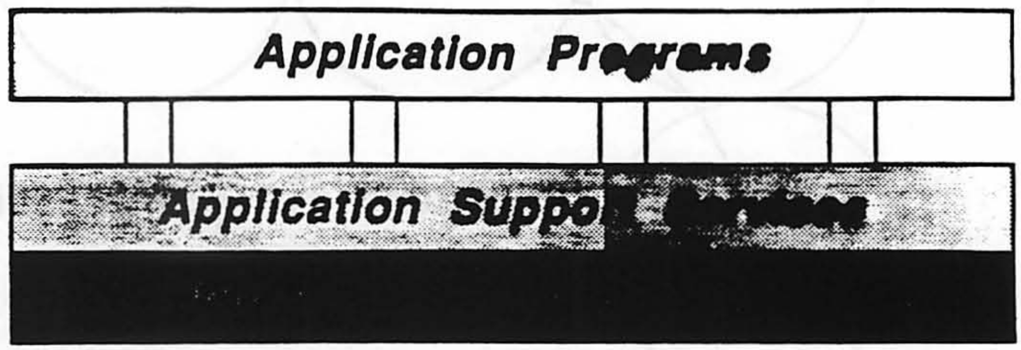

Remote
Association Manager
Service Broker
Agents

A Structure for Developing ISDN Applications

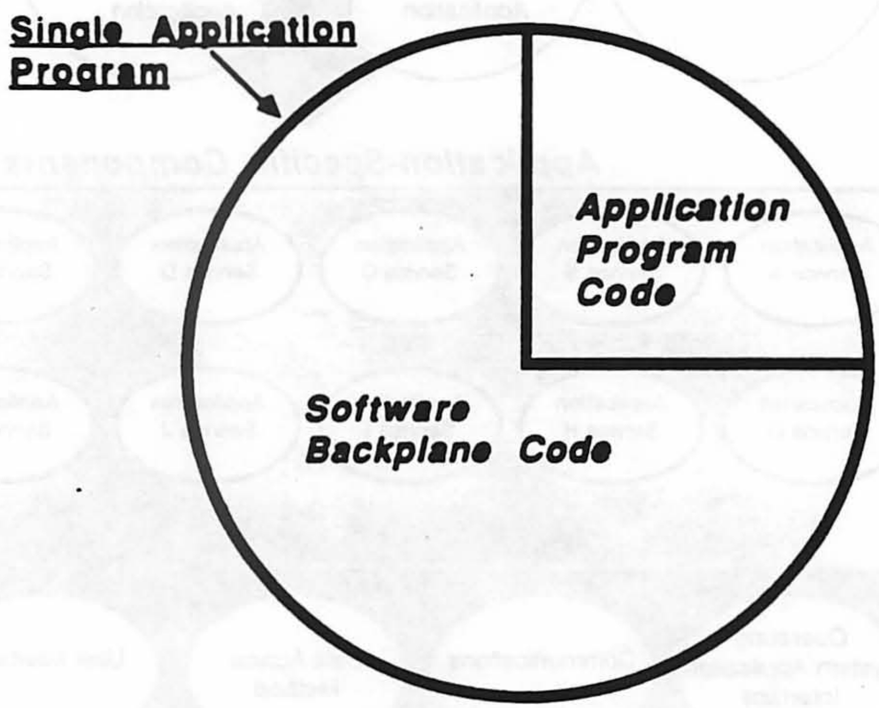


Software Backplane Implementation

I. Software Layer Approach



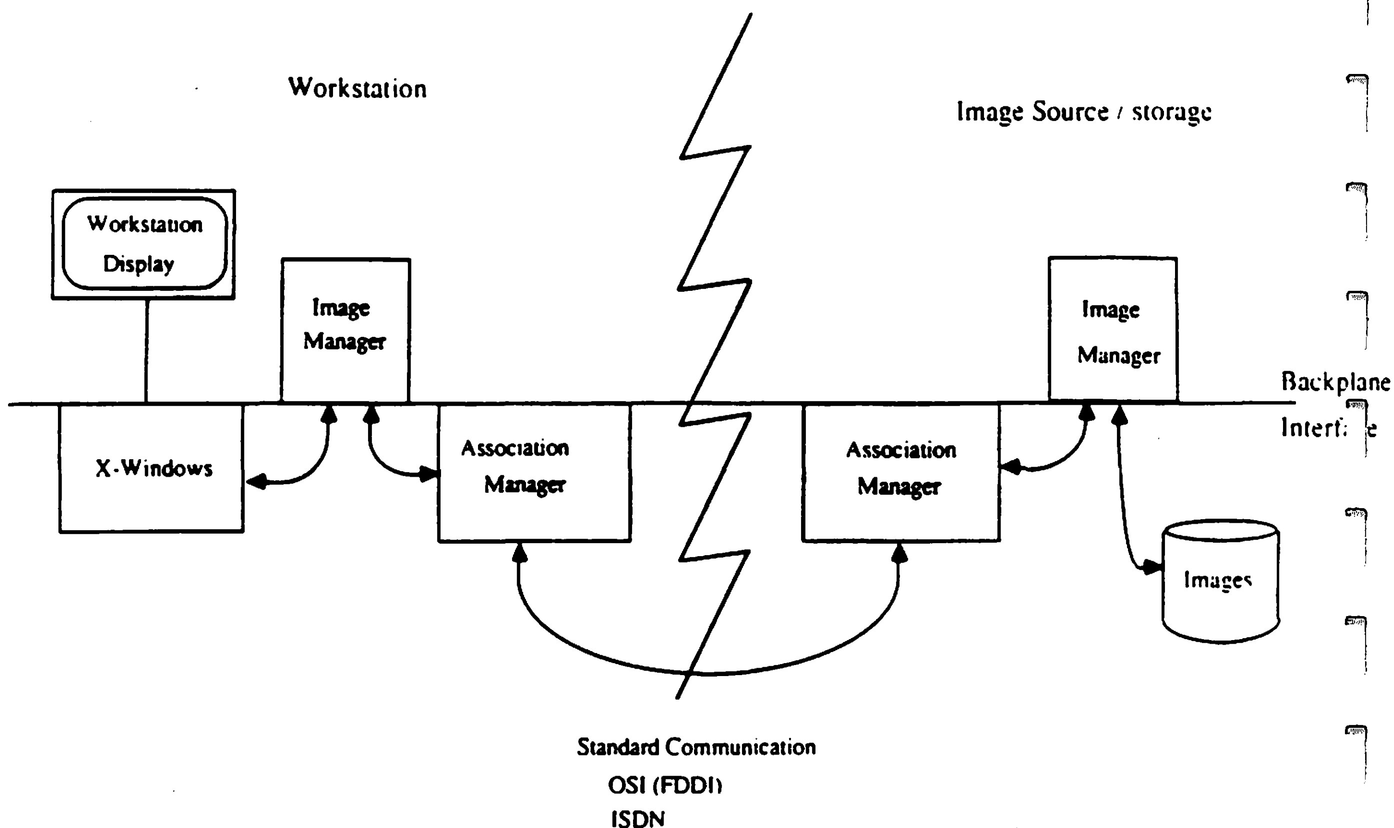
II. Function Libraries Approach



Software Backplane Trade-Offs

- May Sacrifice Machine-Specific Capabilities
- Performance May Not Be Optimized
- More Useful for Certain Kinds of Applications
- Portability Limited by Platform Similarity

Images in Backplane Environment



Workshop Summary

Workshop Summary

A number of different topics were discussed in an open workshop session held at the conclusion of the symposium. The following summarizes the ideas which came up at this session.

Project Evaluation

Everyone agreed that the demonstration system being installed at the Washington DC VAMC represents a wonderful opportunity to collect information about the effects of such an integrated image system on patient care, physician practices, and on educational and research activities. It was suggested that, as much as possible, data should be collected before the installation of the DHCP imaging system in order to provide a baseline for comparison. It was noted that care should be taken to be selective in the effects to be studied because the evaluation effort could easily be overwhelming and not result in useful data. Because the DHCP imaging system has the potential to change patterns of medical care and education. it may be difficult to make direct comparisons at a later date. There was a discussion of cost effectiveness as being different from cost benefit. Showing cost benefit may be difficult in this case because of the overwhelming effects the system could have on patterns of behavior on the part of clinicians and support personnel.

Because the system will improve communications between consulting and treating physicians, symposium attendees were interested in whether the system might improve the accuracy of diagnoses. Another area of anticipated benefit is the operational efficiency of health care delivery. Savings derived from increased clinical productivity might well be expected to greatly offset hardware costs. Therefore, it was emphasized that this demonstration system should be funded in order to provide the desired functionality, even if current hardware prices are relatively high.

Studies of cost benefit of picture archiving and communications systems (PACS) have been limited to effects related to the provision of radiology images. For the most part, these systems have been kept within departments of radiology, with only a few recent examples of viewing stations outside the department. Therefore, the availability of this application is restricted to a relatively small group of specialists, rather than the wider group of primary and secondary care physicians. It was felt that there is no general consensus at the present time about the cost-benefit of radiology picture archiving and communications systems.

HIS Integration with Images

The integration of images with an existing hospital information system presents a new and very exciting clinical tool and the VA appears to be in a uniquely advantageous position to play the lead role in its development and implementation. The critical nature of the following concept was emphasized: image providers must be selective about the image data to be included in a patient's record so as not to overwhelm the end user with extraneous data and also to avoid overwhelming the system's storage capacity.

Remote Access/Consultation

The ability to support remote image access for consulting physicians located outside the hospital was important to a number of physicians, especially radiologists and pathologists. The issue of whether or not an image is of diagnostic quality is critical to this question. A number of studies related to this issue are currently underway. It was noted that in the case of remote pathology consultation, it is especially important to have a pathologist select the appropriate image and text data to be communicated.

In cases where a patient is transferred to another medical facility, the issue of forwarding a patient's record including image data, provoked some interesting discussion. The VA has facilities to place patient's text data into a transfer format for communication in electronic mail messages. Images could be included in this type of message. Transfer can be effected across existing VADATS communication links. There is another ongoing project within the VA to develop a standard optical patient card that could contain image as well as text data. This card could be easily carried by the patient.

Education

Installation of the DHCP Imaging system will provide unique opportunities for medical education. It will allow physicians to collect their own reference libraries of images related to cases of special interest. The integrated hospital information system could serve as the source for an evolving reference library through its built-in search facilities. A number of coding schemes, such as SNOMED and ICD9, could be used for searching. Because the system collects data centered around the patient, the date of image acquisition is captured automatically. Old images can be compared with later ones, and disease progression can be readily observed.

User Interface

The ease with which the user can interface with the system will be critical to its success. It is important to determine who will be expected to operate the equipment and the various users' needs. This may vary by department. It will be necessary to have a prototype system operating in a working clinical environment in order to study these issues.

Users in different specialities will have different needs and requirements. Specific examples of these would include the need for true color representation of microscopic views of tissue specimens or gray level representation for x-ray images. A general software structure is needed which will support any level of resolution. The VA's concept of providing a clinical record which can present different views of clinical data for different physicians, i.e. a user-specific context, was described as important for the image system user interface. Hypertext and hypermedia user interfaces should be examined in the context of image data.

It was emphasized that the prototype workstation should support a high quality user interface for both input and display. This may be relatively expensive, but it is important to have the capacity to demonstrate the full potential of the technology. There was also a discussion of the attractiveness of windowing environments, and it was noted that standards for a good human interface are fundamentally more important than simply the use of multiple windows.

System Architecture Models

A number of system models were discussed during the symposium. These include the biomedical shell for image processing functions, the four layer distributed MUMPS model, the parallel processing model, the object-oriented model, and the software services backplane model. The need for a generic system model was discussed, as well as requirements for general software structures. MEDIX was brought up as an example.

Archiving Issues

The Picture Archiving and Communications System (PACS) industry has not yet resolved many of the image archiving issues . It is clear that image files must contain header information that would allow reconstruction of patient identity and required text data pointers. One question that is still being hotly debated is whether archiving should be organized to collect all of a particular patient's data on the same optical disk or whether all data should be archived chronologically. It is possible that both approaches will be necessary for useful retrieval.

Standards

Standards are extremely important in the effort to include images of various sorts in existing hospital information systems. The ACR-NEMA is probably the most useful existing image interface standard. However, the radiology device manufacturers have been slow in implementing this standard. In order to encourage industry to move in this direction, it was suggested that government agencies and private hospitals insist on this standard in procurement contracts.

Government agencies are interested in the emerging POSIX/GOSIP requirements. The X-windows standard is of particular interest in image-related systems as it provides standards for image handling. A number of universities are developing software related to x-windows.

The importance to the VA of software transportability was noted. All DHCP software is currently capable of functioning on any hardware and operating system that supports ANSI standard MUMPS. The VA intends to continue its high standards of portability with its image integration software.