TELERADIOLOGY

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OVERVIEW

The Teleradiology is a computer application which combines three major areas of computer related technology, which are Digital Image Processing, Data Communication Networking and Database Management System. The objective of system development is to reduce the cost of film development, to solve the problem of film archiving/accessing, to prevent loosing of patient's films, to extend radiological service to districts where experienced radiologists cannot be reached, and to establish a film library as by product of the system.

The Teleradiology system has been developing in foreign countries for many years. There are standards which have been developed such as Digital Imaging Communication in Medicine or DICOM (by American College of Radiology – National Electrical Manufacturer's Association, ARC-NEMA), regulations developed by FDA to be used as guide line in equipment purchasing. There are also commercial products from major manufacturers available such as Picture Archiving and Communication System (PACS) which is a database system for digital image archiving and retrieving, digital radiological devices such as CT, MRI, Ultrasound etc. which include DICOM as standard or optional function.

Though, in theory, the Teleradiology system provides remarkable advantages to public services and radiological studies, implementing the system requires carefully study in technologies, system operation migration and investment. It is obvious that the information technological industry is changing rapidly. For example, the price of a personal computer in 1994 was twice the price in 1995 while the performance and configuration was just half of the one in 1995. This situation continues to today and there is signs that this changing will continue for a decade. The worse is a desktop purchased three years ago cannot run today application without upgrading or repurchasing the whole set. Also, it is hard to find a sparepart. Investing in higher quality computers does not guarantee that the hospitals will not face the same situation. The manufacturers of UNIX based computers have to continue developing their computers to compete with PC industry. Using the UNIX operating system in Thailand is also an unpleasant thing. The solution requires a qualified system integrator to take care. The record shows that a single problem, if luckily, requires at least 1 month to fix. This is because the application software manufacturer is not the operating system manufacturer and in most case there is no conclusion that the problem is of the application software or operating software. The operating system and system software is also changing. Microsoft Windows changes from Windows 3.x to Windows 95, Windows NT changes from NT 3.x to 4.x within five years. These effect application software to be upgraded. System software such as Database management system changes from simple one to Object-oriented database. New features have been included in the software and these new features are available only in a new

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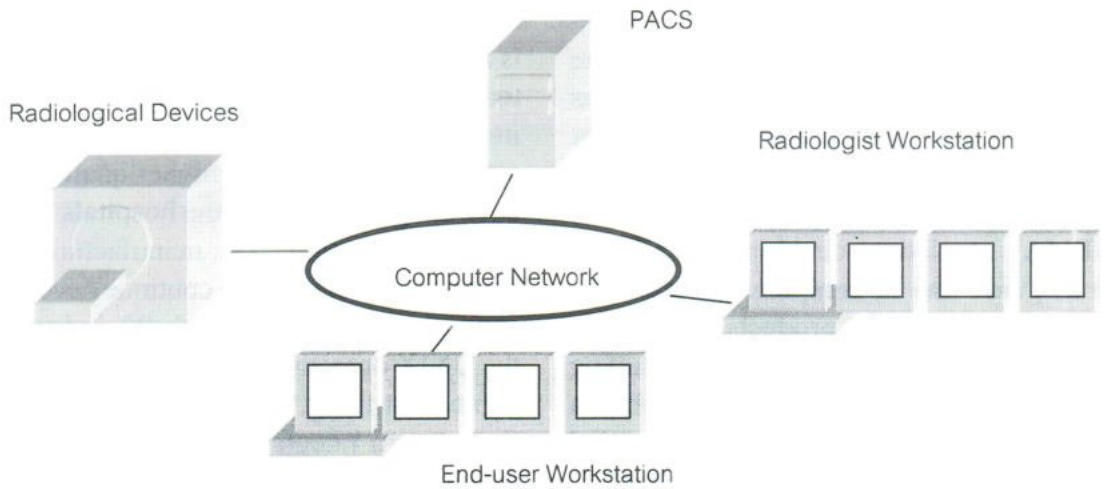
version of software which is applicable only for the new operating system. There was a new computer networking technology called Asynchronous Transfer Mode or ATM available in the late 1995 which provided a 155 Mbps trunk speed which is faster but less robust than FDDI. The committed trunk speed will be 622 Mbps and the specification has been developing while manufacturers is introducing proprietary features and put them in a proposed box. The investment in this technology for this project may cost 4 million US$ and may be obsolete within three years if the study is not done carefully enough.

THE COMPONENTS OF TELERADIOLOGY SYSTEM

The Teleradiology system, in general, composes of 5 major components:

- Radiological Devices
- Radiologist Workstation
- Picture Archiving and Communication System
- End-user workstation
- Computer Networking System



RADIOLOGICAL DEVICES

Radiological devices such as X-Ray, CT, MRI, PET, Ultrasound, Nuclear Medicine etc., in the Teleradiology system must be able to produce digitized images such that the images can be processed and stored in the computer system. Since the Teleradiology system has never been used in the hospitals, most of existing equipments require upgrading by adding DICOM interface modules to those equipments which currently producing digitized images and adding digitizers and DICOM interface modules to those equipments which currently producing analog images.

Is DICOM an essential part? DICOM plays a part in Teleradiology system as the standard protocol in acquiring digitized images from the devices. The hospitals may develop or allow the solution suppliers to develop some kind of control procedure to do the same thing. But this will not guarantee that the system will be able to communicate with other devices to be purchased in future nor provide image-acquiring services to or from the outside systems.

For the devices which produce digitized images, the DICOM interface upgrade will con-

nect the devices to the hospital network, receive requests from other devices, and transmit the images in DICOM standard image format to the requestors. The device operators may issue request to transfer the images from devices to store at PACS. In most cases, the DICOM upgrade modules must be purchased from the device manufacturer, if available.

For devices that do not produce digitized images, an image plate, which can transform X-Ray intensity to digitized images directly, can be used instead of the X-Ray films. This plate connects directly to a workstation, which will process the digitized images and transfer the images into the system.

For the devices that cannot put the plate in, or the devices that do not have DICOM upgrade parts, the films are still be developed and put in an X-Ray film scanner to produce a digitized image.

The CCD camera in the set of the X-Ray digitizing plate or the X-Ray film scanner should be able to produce gray scale image of 1,024 or 2,048 level with optical resolution of 360,000 pixels per square inch. The digitized images may be temporally stored in the workstation or PACS for further reading. The images should be compressed using standard compression method that can be perfectly restored. There is some suggestion that the compression ration should be 2.5: 1.

The result images should contain textual details such as medical reference numbers, the patient's basic data, the date and time of exposure,the laboratory reference numbers, etc., as parts of the images.

THE RADIOLOGIST WORKSTATION

The Radiologist Workstation is used by the radiologists to interpret the images. The software should facilitate the radiologists in various ways such as zooming, panning, image enhancement, filtering etc. The image processing function must not produce distorted images, which causes misinterpretation. It is recommended that the workstation should be equipped with at least 4 display monitors to display 4 images at the same time. The size of each monitor should be at least 18 by 24 inches (around size of largest film) with minimum of 1,024 gray level and 1,728 by 2,304 pixel area. A single keyboard and, a mouse or a pen should control system function.

The software should also allow the radiologists to put on white mark or circle on images easily and let the radiologists organize or format the images in the way that he or she expects the end-users to see. The diagnosis should be tightly binding with the images or image sets.

A film printer (a printer that can print a photographic image on a film) should be attached to the workstation to reproduce output in classical film media. The workstation should be able to work off-line, directly connected to the radiological devices using backup port such that it can produce output when the main system fails for a long time.

PICTURE ARCHIVING AND COMMUNICATION SYSTEM (PACS).

The PACS archives the images and the diagnosis results, searches for requested images and results. For a university hospital, the size of the database will be enormous if it accumulates the images for more than 6 months period. Thus the PACS should be separated into at least 3 subsystems. One for images which are still in use; one for only selected interesting cases and the other for references. The PACS for active cases should store the data in the high-speed, large disk storage/ disk arrays for better performance. The other 2 PACS should store the data in optical media such as compact discs or magneto-optical media to save the cost of storage. It is possible to eliminate the

PACS for archiving interesting cases by setting a WEB servers instead. The PACS for reference images will keep the images for latest 3 years then all optical media will be moved to another library system.

All PACSs must use DICOM as their standard protocol/ interface to communicate with other devices in the system. Since the PACS is one of the two most critical components in the system, the specification of both hardware and software must be carefully considered. Any damage on the PACS will cause the entire health services, which require the diagnosis result to be stopped. This is not acceptable for ER and OR. Thus the design of the hardware system and software for the PACS must provide high reliability and high availability and can operate 24 hours a day. The available PC or PC-base operating system may not be up to specification in this case. The hardware and all relevant software (the operating system, database management system, PACS application) must be designed for a fully fault tolerant service. This includes the backup power supply system, air conditioning system, computer and storage devices and supporting network systems. The system should have 3 redundant equipment sets operating in a hot-standby mode or the backup system should be ready for service within 3 minutes. Since the system will operate 24 hours a day, the database backing up system must be done during service (online backup) and must be able to do the backup in both entire database backup and incremental backup mode. In case of database failure, the database restoration mechanism should allow the undamaged part of the database to be usable.

The user interface of the PACS database administration system must be easy to use and understand. The developer of the PACS should design the UI, hiding the complicate SQL or system commands, making use of the GUIs to simplify the system operation, use clear messages and consistence choice of operation to communicate with the system administrators.

Since the PACS is the core of the entire system and will serve the users in many departments within the hospital as well as the entire university and outside health care units. The system must be a high-throughput system using huge redundant single server or clusters of smaller server. The PACS must also be designed ready to interface with other systems of the hospital such as the 'Patient Registration System' or the 'Hospital Management System'. The authentication system must be able to protect the system from accessing by unauthorized users and must have access logging mechanism, which can alert to the system administrators when abnormal accessing occurs.

END-USER WORKSTATION SYSTEM

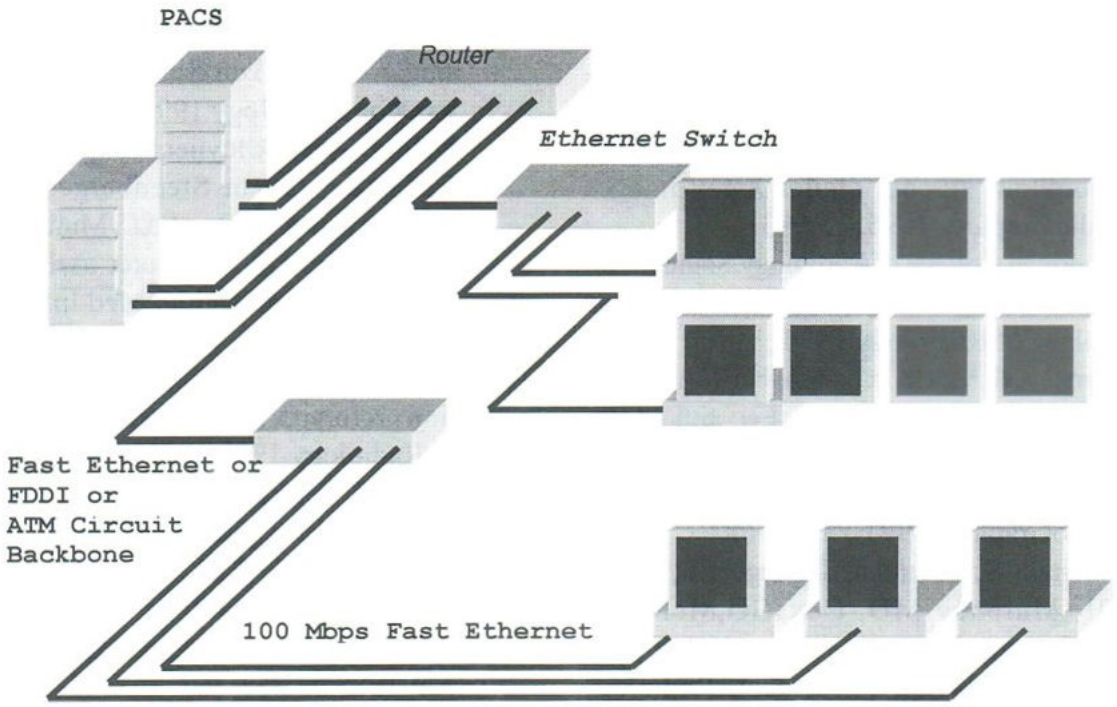
The End-User Workstation System can be divided into 3 types,a single display monitor – workstation system for general use,a multiple display monitor - workstation system for special examination area, asecured multiple display monitor system for ER, OR.

The workstation using in ER and OR should be designed similar to the "wheel box" which can be moved to anywhere within the room. The keyboard and pointing device should be specially designed such that the unit can be cleaned by a standard cleaning procedure of the room. The networking device should be of type infrared or RF to minimize the cable use. The box must be sealed to prevent toxic gas generated by electric short circuit from diffusing into the air. An UPS system and an alternate network port should be installed for use in case of power system failure or network device failure. The workstation system should contain at least 4 display monitors controlled by a single keyboard and pointing device. Each monitor should be 18 x 18 inches and should be able to display an entire film without scrolling.

All workstation should be designed using the same user interface and communicate with the PACS via DICOM standard protocol.

COMPUTER NETWORKING SYSTEM

The network system for the Teleradiology System must be a high bandwidth network. Most of the data transferring between each node in the network are image pixels, which is around 233 Mbytes per largest uncompressed image or 72 Mbytes per 2.5:1 compressed image (calculation is for 18 x 18 inches film at 600 dpi, 1024 level gray scale image). The 10 Mbps LAN with 2 Mbps throughput can transfer the images within 290 seconds or 4.8 minutes while the 100 Mbps circuit completes the same job within 29 seconds. Multiple of 100 Mbps or higher bandwidth circuits should be used along with balancing the number of an active mode per circuit. The switch device such as Fast Ethernet Switch should be applied to filter the irrelevant traffic from the port.



Since the system must be a high-availability system, the network must be a fault tolerant network. All devices and cabling system must be redundant including power supply to all connected networking devices. All devices and control software must be able to switch to alternate route automatically when a device or cable failure occurs. A network management system must be installed for fast failure locating and network monitoring. Any serious fault should be reported to system administrator automatically via red alert on network management station or paging system.

By connecting the network to the Internet will allow accessing to the Teleradiology System from outside the hospital. In such case, a "Fire Wall" must be installed to prevent unauthorized accessing since the images are private to patients. Setting up terminal server also allows accessing the system from limited origins. The hospital may install a secured WEB server connecting to the PACS to provide accessing images using Web Browser as displaying tool.

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