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Three-Tiered Integration of PACS and HIS toward Next Generation Total Hospital Information System

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Abstract

The Seoul National University Hospital (SNUH) started a project to innovate the hospital information facilities. This project includes installation of high speed hospital network, development of new HIS, OCS (order communication system), RIS and PACS. This project aims at the implementation of the first total hospital information system by seamlessly integrating these systems together. To achieve this goal, we took three-tiered systems integration approach: network level, database level, and workstation level integration.

There are 3 loops of networks in SNUH: proprietary star network for host computer based HIS, Ethernet based hospital LAN for OCS and RIS, and ATM based network for PACS. They are linked together at the backbone level to allow high speed communication between these systems. We have developed special communication modules for each system that allow data interchange between different databases and computer platforms. We have also developed an integrated workstation in which both the OCS and PACS application programs run on a single computer in an integrated manner allowing the clinical users to access and display radiological images as well as textual clinical information within a single user environment.

A study is in progress toward a total hospital information system in SNUH by seamlessly integrating the main hospital information resources such as HIS, OCS, and PACS. With the three-tiered systems integration approach, we could successfully integrate the systems from the network level to the user application level.

Keywords
HIS, PACS, OCS, System Integration

Introduction

The SNUH is a representative university hospital in Korea which consists of a main hospital building with 1,249 beds and a children's hospital building with 259 beds.

The SNUH started a long-term project to innovate the hospital information infrastructure. This project, started in 1993 and will continue until the early 2000s, includes installation of new high speed hospital network over the two hospital buildings, development of new HIS, OCS (order communication system), departmental information systems including RIS, and PACS that are based on up-to-date object relational database and client/server technology. The primary goal of this project is to develop a total hospital information system (THIS) in which all the information systems are integrated together and work as one logical system.

The importance of integrating the HIS/RIS with PACS has been addressed by a number of research groups, and various implementation strategies are suggested and attempted in numerous heath care facilities [1][2][3]. The event flow information such as admission, discharge, transfer (ADT), exam scheduling, and ordering information are acquired from HIS/RIS by way of RS-232 or network connection using proprietary or standard HL7/ DICOM protocols, and are transferred to the PACS for utilization in automatic creation and management of patient folders, image prefetching from the archive, distribution to the workstations, and storage management. [4] [5][6]. This way of systems interface has been regarded essential for the successful operation of PACS in clinical practice, and has been implemented in various hospitals.

Until now, however, the emphasis has been placed on the acquisition of HIS/RIS data to the PACS for efficient control and management of image data flow in the PACS. Thus the benefits of systems integration are mainly given to the PACS, and few of merits, if any, is returned to the HIS/RIS. With this kind of one-way interface environment, there are barriers in the flow of clinical information packets throughout the hospital. Only restricted kind of textual data flow between HIS/RIS and PACS, making both systems limited in their ability of information access and presentation. This limitation in system integration also causes the users' inconvenience of using different terminals to access to clinical information of the same patient depending whether the type of information is image or text.

There are several factors that restrict the systems integration level: the existing HIS/RIS has limited capability of information exchange; the connection channel has limited bandwidth and throughput; today's PACS architecture lacks the capability of handling complex data structure for clinical information.

However, with the advent of modern client/server technology along with the wide-band network architecture and high-end PC technology, the barrier of systems integration is disappearing. There is a trend in the hospital computing environment to adopt the client/server technology in the hospital information systems, in which PCs are used as HIS stations in stead of the dummy terminals, and high speed network back-bone is installed throughout the hospital. The open nature of the client/server system makes it easier to exchange information between different systems, and brings about the higher throughput of information exchange as well.

In addition, the low cost and high performance of today's PC enables to extend its use from the text based HIS terminal to the multimedia station that can be used for PACS service in a certain range [7][8]. With the help of these advances in computing technology, there is a strong possibility for the realization of total digital hospital where the various imaging and other medical information systems are fully integrated and appear as one logical system to the users [9].

In this paper, we describe the development work, which is in progress in SNUH, for the implementation of totally integrated hospital information system. In the hospital information infrastructure of SNUH, we will allow mutual communication of both textual data and images between systems, enabling access to the various medical records on PACS workstation and display of images on OCS stations as well. To achieve this goal, we took three-tiered systems integration approach: network level, database level, and user interface level integration.

Systems Description

This section describes the configuration of information systems in SNUH, which are integrated.

Hospital Information System

The SNUH HIS is a centralized system hosted on a mainframe computer (FACOM M770/10) running on OSF4/ESP operating system, and custom developed software package based on Fujitsu's proprietary network database. It processes the admission, discharge, transfer, scheduling, and billing procedures for above 1 million patients a year, and supports hospital accounting and administrative works as well. It is accessible with both dedicated dumb terminals connected via Fujitsu's proprietary start network, or PC-based terminal emulator connected to hospital LAN. The ADT information is transferred to the OCS in real-time via TCP socket based communication.

Order Communication System (OCS)

The SNUH OCS is a unix-based client-server system with two Sparc center 2000s as database servers each with 2 Sparc CPUs, 512MB memory, and 20 GB hard disks.

An object relational database (UniSQL/X, UniSQL, USA), and in-house developed software package are used to provide order entry and result reporting services to the clinical users. The end user stations are based on Windows 95 and Pentium PC, and are installed in 48 in patient wards in main hospital and children's hospital buildings.

The ordering information entered on the OCS stations are distributed to the departmental information systems, and then the exam results are returned and collected to the medical record database. Currently, two departmental information systems - RIS and LIS are integrated into the OCS.

Radiological Information System

The SNUH RIS is a client-server system with a Windows NT based database server with 4 Pentium Pro CPUs, 128MB memory, and 16 GB hard disks.

An object relational database (UniSQL/X, UniSQL, USA), and in-house developed software package are used to provide scheduling, registration, procedure tracking, film tracking, report transcription and approval, materials management, statistics report functions. Around 40 client RIS stations, which are based on Windows 95 and Pentium PC, are installed in reception desk, exam rooms, transcription room, and reading rooms.

It transfers such information as ordering, exam scheduling, exam cancel or change, and reports to the PACS, and receives back such information as exam complete, report approval, new report.

Picture Archiving and Communication System

The SNUH PACS is an in-house developed, high-end PC based system with client-server architecture. There are six servers running in cooperation for DICOM image acquisition, database management, image access service, and archive management. All the servers are based on Windows NT operating system and multiple Pentium Pro CPUs ranging from 2 to 4. The imaging modalities connected to the PACS are 5 CT/MR scanners, 4 CRs, 8 ultrasonography units, 1 DR. The acquired images are first stored on 90 GB RAID-3 type disk array and then are archived on a CD-jukebox in compressed format.

There are four 2K stations and twenty 1K stations in radiology department, in-patient wards. All the display stations are based on Windows NT and have dual Pentium Pro CPUs.

The SNUH PACS has been developed during last two years, and is in installation and evaluation phase now. The SNUH has a schedule to expand the PACS to support all the in-patient wards in this year and to the full scale by the end of 1999.

The data flow in PACS such as image routing, aging, compression/decompression, pre-fetching, and studies grouping is controlled by the event flow information transferred from the RIS and HIS. The RIS and PACS also communicates the report data each other to enable the approval and display of the radiology reports on the PACS workstation, and to record the reports entered on the display stations on the RIS database.

Communication Network

There are three types of network in the SNUH: the Ethernet base hospital LAN, ATM based PACS network, and proprietary star network for HIS terminals. The Ethernet based hospital LAN is used to support the OCS, departmental system, and e-mail system.

The hospital LAN has a collapsed backbone structure where the communication packets from the branching hubs are concentrated to the FDDI and Ethernet switching hubs (Power hub 7000/6000, Alantek. Inc., USA) and are processed there with high speed to avoid packet collision thus providing much wider bandwidth than standard network structure. Total of 2650 Ethernet ports are installed throughout the two hospital buildings.

An ATM network is used for PACS separately from the Ethernet based hospital LAN in order to avoid interference between communication packets of OCS and PACS that might occur if the large packets containing image and small packets containing clinical information collide on the same Ethernet. Two grades of ATM networking are used in the PACS in hierarchical manner in order to handle the communication traffic cost-effectively: the 155 Mbps ATM (Madge collage 740, Madge network, USA) is used for servers and diagnostic reading stations; the 25 Mbps ATM (Madge collage 280, Madge network, USA) is used for verifying and clinical review stations.

While much higher bandwidth is provided with ATM protocol, we utilized the common UTP cables, which are already installed for hospital LAN for almost of communication lines in the PACS except the fiber optic links between the ATM switches and the links to the servers.

A proprietary star network is used to support the dummy terminals of HIS. It consists of the coaxial cable and the Fujitsu proprietary protocol. Above 110 terminals are connected with these cables which are concentrated directly to the host computer.

Systems Integration Description

In order to accomplish totally integrated hospital information system, we took three-tiered system integration approach in which the HIS, OCS, RIS, and PACS are interfaced in three levels: network level, database level, and workstation level.

Network Interface

Network interface is the bottom level of our three-tiered system integration, and provides physical channel for interconnecting systems together. In order to enable mutual communication of image and textual data between systems, we integrated the various information systems by using high speed communication network, rather than using RS-232C connection.

The HIS is connected to the hospital LAN with a special gateway unit (MTX 9430) that provides channel interface to the host and four segmented Ethernet lines for LAN interface. The four Ethernet lines are connected to the Ethernet ports of the Ethernet switching hub that provides dedicated 10Mbps bandwidth for each port. Thus the interface between HIS and hospital LAN has total of 40Mbps bandwidth.

The interface between ATM network and the hospital LAN is accomplished by directly linking between the 25Mbps ATM switch and Ethernet switching hub. Since the 25 ATM switch used supports both the 25Mbps ATM, 10 Mbps half duplex Ethernet, and 20 Mbps full duplex Ethernet, no gateway was necessary for protocol conversion between them. Dual links are making between the two switches each with 20Mbps full duplex Ethernet thus provide maximum of 40 Mbps bandwidth. We have a plan to make an additional link between 155Mbps ATM switch and FDDI switching hub by using an ATM switching module in the FDDI switching hub in the near future.

Database Interface

Database interface is the middle level in our implementation of systems integration, and provides a way to make various information systems to act as single logical system. Figure 1 shows the schematic diagram of database interface between the HIS, OCS, RIS, and PACS.

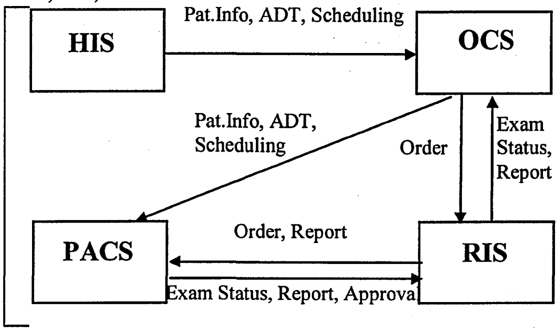

Figure 1 - Schematic diagram of database interface between HIS, OCS, RIS, and PACS.

Although we use the same kind of database for the OCS, RIS, PACS in the SNUH, direct access to the database of other system is avoided to prevent possible data corruption that would bring about serious problem. Instead, we developed a message communication program that runs on each system and acts as a gateway between systems on a TCP/IP socket basis.

An important feature of these communication programs is the fail over capability. The fail over capability was required to enable continual operation of each information system regardless of the temporary disconnection with any other system that may be caused either by network failure or system down. When the communication link is disconnected, each system continues to work as an independent system; after the communication link is recovered, the transactions occurred during fail time are automatically transferred to the opposite side.

HIS-OCS interface

The SNUH HIS is a closed system using a vender proprietary operating system and database. In order to make network communication with OCS that use UNIX and object relational database, we developed a network program that run on the HIS based on TCP/IP socket with the help of software engineer from vender.

The type of data transferred includes: admission, transfer, discharges, scheduling, together with the demographic data of the corresponding patient.

Currently, there is one way communication for sending data to OCS. We are working on adding another socket program for receiving patient scheduling and billing information from OCS.

OCS-RIS interface

The interface between OCS and RIS is accomplished by using two message communication programs running on each server.

Each communication program extracts the information that is to be sent from the database, converts them into SQL strings, and sends them using TCP/IP socket. When the program receives the message packets, it writes the packets on a queue file first, which are inspected line by line and then processed. If an invalid message string is encountered, it is rejected and written on a separate log file so that it may be checked and corrected afterward.

The OCS sends ordering information to the RIS, and RIS returns the exam status and report to each order using this socket based communication program.

RIS-PACS interface

A pair of socket communication programs accomplishes the RIS-PACS interface in the same manner as with OCS-RIS. The RIS replicates the ordering information received from the OCS to the PACS. The PACS identifies exams obtained from modalities using these ordering informations.

The RIS and PACS also communicate the reports together so that the reports may be displayed on the clinical review workstations. The reports transcribed on the RIS stations may be approved on the radiology reading stations, and the reports generated on the reading stations may be updated to the RIS database and then routed to the OCS.

The PACS keeps the reports in its database together with the exam information and images so that the reports may be quickly retrieved and displayed on the display stations.

PACS-OCS interface

The OCS sends the admission, discharge, and transfer information to the PACS in the same manner as with OCS-RIS interface. The PACS utilizes these information for management of patient folders, prefetching of old exams, and routing of newly generated images. The PACS creates patient folders on receiving of admission information. The old exams for these patients are automatically prefetched from the archive to the storage server, and then are registered to the corresponding patient folders. The patient folders are updated each time new exams are generated for the corresponding patients as well as the patients are transferred to another wards or clinical department. The images of new exams are also routed to the workstation to which the patient folder of the exam belongs.

When the discharge information is transferred to the PACS, the corresponding patient folder is deleted and the related images are cleared from the hard disk of the central server and display workstations.

Workstation Integration

Workstation integration is the top level in our implementation of systems integration, and provides the user with a unified user interface to access to various information systems on a single computer.

There are two kinds of computers installed in the wards: OCS station, and PACS station. The OCS station is based on the Windows 95 and is linked to the Ethernet based hospital LAN, while the PACS station is based on the Windows NT and is linked to the ATM based PACS network. Initially, two different application programs ran in the two kinds of stations: the OCS application program is responsible for entering orders and presenting the radiology and lab reports; the PACS client application is responsible for image display service.

We have integrated the two stations having different application programs to provide the users with an integrated working environment on a single computer. Fig. 2 shows the schematic diagram on the way the OCS and PACS workstation are integrated.

Since both the OCS station and PACS station application programs have been designed to run on the Microsoft's 32 bit operating system, it was relatively easy to make the two application programs run on a single computer either with Windows 95 or Windows NT.

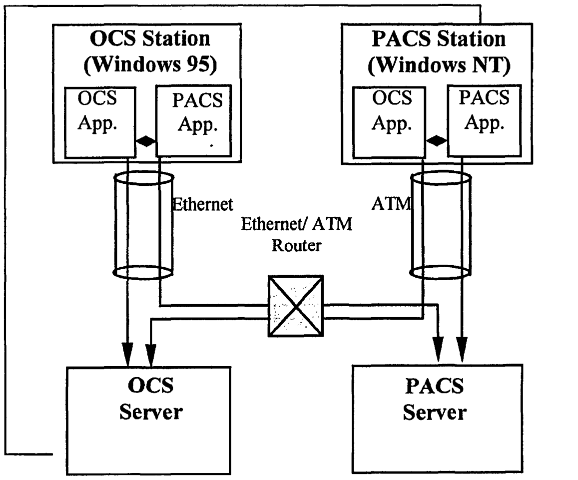

Figure 2 - A schematic diagram showing how the OCS and PACS workstation are integrated.

However, the PACS client application is structured to use much memory for fast image display while OCS stations are not configured to have sufficient memory, which resulted in a much slower response. Therefore currently, the PACS station is primarily used to support both applications. We are working on to make a light version of PACS client application that use much less memory with somewhat slower speed so that it may run on the OCS station without causing memory shortage problem.

Since the two applications are clients of different servers residing on the different network, each station makes two data paths to both the OCS and PACS servers across the hospital LAN and ATM network when both programs are activated The two applications are linked by an external call with which each application is invoked by the other with the patient's hospital number as an argument. In this setting, either program can be a master or slave. Usually the OCS program runs as a master, and the PACS program is invoked as a slave when the user calls on the image display service.

In this way, we could achieve an integrated working environment in which the users were provided with all the necessary information service without leaving the program or using different computer each time to access to the different information system.

Results

The network interfaces between the HIS and hospital LAN, and between hospital LAN and ATM network were set-up in Sept.

1996, and has been operational without significant problem except the several hours of down time for micro-code upgrade of the ATM and LAN switching equipment.

The HIS transferred about 300 ADT transactions and 4,200 out-patient scheduling data to the OCS a day. The OCS replicates the same data to the PACS, and sends about 1,000 radiology ordering information to the RIS a day. The same ordering informations and about 600 radiology reports are sent to the PACS from the RIS. The network interfaces and communication programs appear to have sufficient capability to process the data packets between systems even at the busiest time.

The integrated functionality of the PACS workstation is well accepted by the clinical users. The OCS program ran faster on the PACS workstation and the various clinical informations including images could be reviewed easily in an unified manner. The PACS workstation with integrated function is in evaluation phase in a sample ward and will be expanded after the necessary modification and optimization is made according to the feedback from the clinical users.

Future Development

Until now, we have focused on the implementation of systems integration within the hospital. For this purpose, the communication programs have been working satisfactorily in that they have sufficient processing speed with fail over capability. In the future, however, there may be requests to interface medical equipment or to communicate other healthcare facilities that have HL7 protocol. In order to prepare for that situation, we have a plan to make a separate HL7 interface that will work concurrently with the existing socket based communication programs and allow the communication with other systems via standardized protocol.

We are also working to develop an integrated information browsing module based on Windows 95 and Windows NT that will enable transparent access to the various hospital information resources including PACS and OCS.

The two application programs - OCS and PACS - will be integrated into a single application program in this module so that the clinical users may explore and display various clinical informations including textual and image data more easily and quickly. This module will provide both improved speed and user interface because the necessity for switching between application programs will be eliminated.

This browsing module will be installed on over 600 computers in SNUH including OCS and PACS stations and physicians' desktops, and will act as an integrated window into the hospital information activities in SNUH.

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