International Journal of Enhanced Research in Management & Computer Applications, ISSN: 2319-7471
Vol. 3 Issue 12, December-2014, pp: (36-43), Impact Factor: 1.296, Available online at: www.erpublications.com

Distributed Healthcare System Framework for Dynamic Medical Data Integration

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Abstract: The healthcare industry is making a huge progress in providing an efficient medical care for patients. Although the healthcare information systems are being developed and deployed in several countries around the world, these systems face many challenges when delivering the required medical treatment to a large portion of the populace. Many hospitals and medical centers lack the required coordination and information sharing that would help improve the medical care. In addition, most patients have incomplete or missing health records which would have been very useful for the healthcare staff to provide better care for their patients. In this paper, a design of distributed healthcare system prototype is introduced. The proposed system integrates the various hospitals and medical centers that are implementing this system together in a single virtual intranet network using VPN technology. The connected hospitals operate in a P2P architecture to share their patients' health records with each other ensuring their availability at all times.

Keywords: Medical Information System, EHR, VPN, Distributed System , P2P, Distributed Database.

INTRODUCTION

Historically, the development of EHR was derived by the need to support healthcare and to improve its quality [1]. The earlier attempts began when academic medical centers developed their own systems in the 60s and 70s. In the 80s, benefits has been seen in the industry-wide standards and organizations were formed to address the issues that would ease the worldwide use of electronic medical information. In the mid-60s, the EHR systems were known as "clinical information systems". After then, EHR came to light in the national political forum, pointing the concerns about the effect of record-keeping on public health [2]. Although many hospitals developed and implemented EHR systems for their internal use, the patient records are not shared between them [3]. Currently, there is a growing demand for remote access to those hospitals' information systems, where decisions made by the healthcare professionals depends on the patient's health state information. It is fundamental for the quality of patient care and hospital management to fulfill these information needs [4]. The ability of the internet to distribute information to geographically separated users, its availability, and the rapid progress of public networking facilities provide an infrastructure for the interaction between the hospital information systems to share medical data [5]. However, distributing content at a large scale is costly with a classical client-server architecture (C/S), this is the reason why providers started to move to Peer-to-Peer (P2P) content distribution that enables them to significantly reduce their cost without penalizing the experience of users [6].

This paper discusses the design of a distributed healthcare system that automatically connects several hospitals together in a single network enabling them to share patients' health records with each other and maintain their availability at all times to achieve a better healthcare for the patients.

MEDICAL INFORMATION SYSTEM

The medical information system that is implemented into each hospital of the distributed healthcare system represents the basic medical information system architecture, it consists of several sub-systems which are integrated together to enhance the traditional healthcare services. Hospital Information System (HIS) is used for hospital and clinical process administration and management, Radiology Information System (RIS) is used in the department of radiology for managing and tracking patients, films and supplies, and Picture Archiving and Communication System (PACS) is used to capture, manage, store and view diagnostic images. These systems work together to provide numerous functionalities, such as imaging, medication management and diagnosis reporting. As illustrated by literature [7].

ELECTRONIC HEALTH RECORDS (EHR)

The term electronic health record (EHR) is widely used to describe the concept of a comprehensive collection of a patient's health and healthcare data generated by one or more encounters in any healthcare delivery setting. Therefore, it is proposed to include data that is not only particularly relevant to a subject's medical treatment but also to a subject's health in general, this data is used to support patient healthcare by providing relevant medical information about a patient whenever and wherever it is needed. As suggested by literatures, this information contains patient demographics, progress notes, problems, vital signs, laboratory data, past medical history, immunizations, medications, radiology tests and reports [1][2][3][4]. Creating a complete health record for a patient successfully requires time, effort and resources, however those records are not widely shared between hospitals and clinics, because many hospitals have developed and implemented EHR systems for their internal use only, and standardization process for the medical information exchange is still in progress.

UNDERLYING TECHNOLOGIES

This system's design relies on the use of several technologies to achieve its goals, these technologies are: Peer-to-Peer (P2P) [8], Distributed database [9], and Virtual Private Network (VPN) [10].

SYSTEM OVERVIEW

This section describes the suggested workflow of the healthcare process of the proposed system as shown in Figure 1. In the beginning, after the system is firstly installed and started in a hospital, is to register staff users of this hospital by the administrator, who has a default account provided with the system. After the registration is complete the staff users are ready to carry on their daily tasks. By joining the use of both VPN server and trackers, the staff users are not restricted to their hospitals' networks or locations.

When a patient visits a hospital for the first time, s/he is required to register himself/herself at the reception, at which the receptionist fills the appropriate fields, in the client application, with the patient's personal information. The patient's information is cross referenced with other patients' information to check if the patient was already registered. He is then given a unique identification (ID) number which will be used in all future visits to any hospital connected to the system. The information is then stored in the databases in the HIS server and a notification is sent to the administrator to approve the registration. After the approval is completed the information is sent to the trackers for other hospitals to use. When the patient registration is completed the patient is able to visit any of the hospitals connected to the system, in which the receptionist is able to create new cases for the patient by using the patient's ID number then direct him to the proper medical department depending on the reason of the patient's visit. When the HIS server receives the new case creation request it will perform two separate tasks:

The first task is that the HIS server will give the newly created case a unique ID number that will help identify the patient's case data. It then sends a notification of the new case to the intended physician. The second task is that the server will verify the existence of the patient's profile and health records in its database, if it was the patient's first visit to this hospital the profile is requested from the trackers then stored in the database. The HIS server will cross-check the patient's health records stored in the HIS database with those registered in the patient's roadmap in the trackers (contains a list that registers the patients' health records and the ID of the hospital in which it was created) then create a list of the missing records' ID numbers. Each of the missing records is then handled by a separate thread, which sends a request to one of the hospitals that were previously visited by the patient.

While the requested health record data from the HIS database is being prepared to be transferred to the requesting hospital, the HIS servers of the two hospitals direct their RIS servers to connect with each other and transfer the radiology tests data associated with the requested records. If a hospital is missing the requested health record data it will inform the requesting hospital then it request that health record from one of the remaining hospitals. This process insures the completeness of the patient's health records before it's requested by the physician.

When a notification is selected by the physician, a request is sent to the HIS server to send the patient's profile and health records to be viewed by the physician. The system also allows the physician to request radiology tests to be performed for the patient; a request is, thus, sent to the RIS server which will send a notification to the technician in the intended radiology department.

After performing the radiology test, the diagnostic images files are uploaded to the Archive. Then the radiologist is notified of the new test. The radiologist is now able to view the diagnostic images and write his report after which a notification is sent back to the physician. At this point the physician is able to view the radiology tests results and their reports.

After the physician submits the diagnosis and treatment for the patient, the case is closed and added to the patient's health records in the HIS database. The HIS server registers the new health record in the patient's roadmap in a tracker database; which will be replicated in all the other trackers, then sends the complete record data to all other hospitals that were previously visited by the patient and are connected to the system's network during the update process. This process keeps the patient's health records up-to-date in all hospitals.

The health records of that patient in any hospital that was unavailable or disconnected from the system network during the update process will be incomplete, until the HIS server notices and requests the missing case data from other hospitals when the patient visits the hospital or when it receives a request for this case from another hospital.

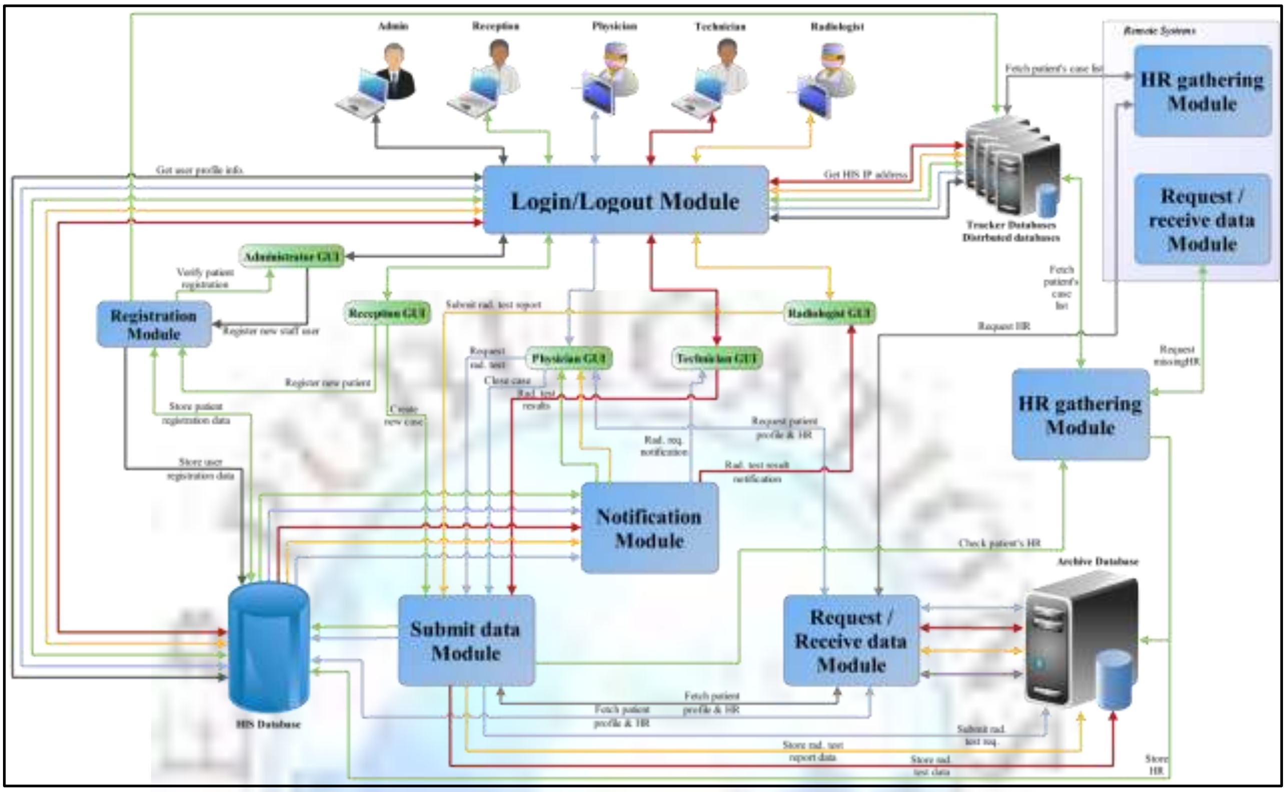

Figure 1. Proposed System Workflow.

SYSTEM NETWORK DESIGN

The network shown in Figure 2 represents an intranet network that is used to integrate all the hospitals' networks, shown in Figure3, together in a single network by utilizing a server running the L2TP/IPSec VPN protocol, which was described and used in [10], to enable data exchange between servers located in those hospitals.

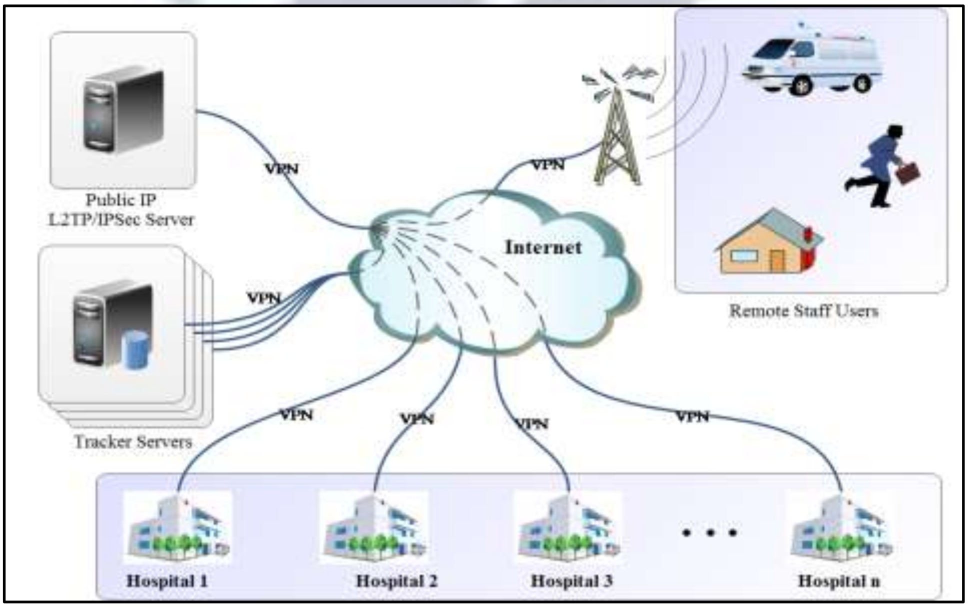

Figure 2. Distributed Healthcare System Network.

The VPN extends the private intranet across a public network (the Internet) ensuring a secure and cost-effective connectivity between the two communicating ends, which is achieved by encapsulating the IP datagram, as shown in Figure 4, sending it to an intermediate destination before it is forwarded to its original destination, as described in [11].

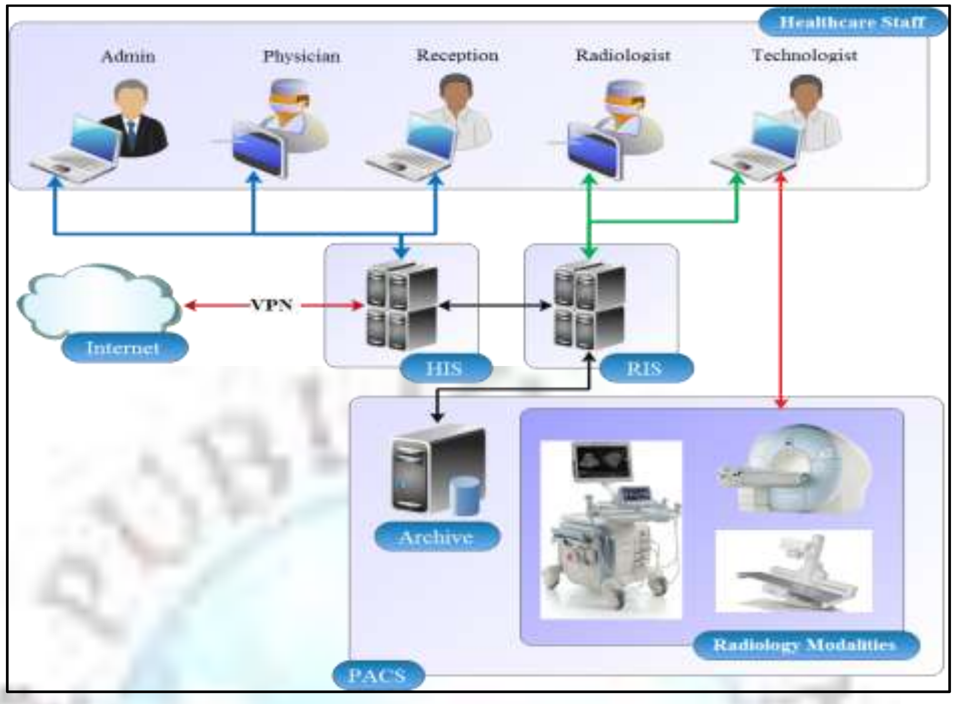

Figure 3. Hospital Network

The use of the VPN technology also allows the outdoor staff users to interact with their hospitals' servers from any location as long as they have an internet access. The VPN server is a public IP server that is responsible for creating and running the L2TP/IPSec service. Gateway routers are used to connect the hospitals networks to the VPN network while the outdoor staff users can connect to the VPN server directly.

Allowing the different hospitals' servers to communicate with each other directly opens the door for the use of P2P technology where the servers may act as (peers) and share their resources (i.e. EHR) with each other directly. This P2P network implements a log and lookup server (tracker), as illustrated in [8], in which the servers should register both themselves and the EHR they create. The P2P architecture shown in Figure 5 represents this architecture where all peers depend on a central server I order to discover other peers and their contents.

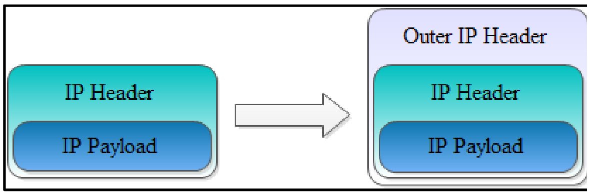

Figure 4. IP Encapsulation. [11]

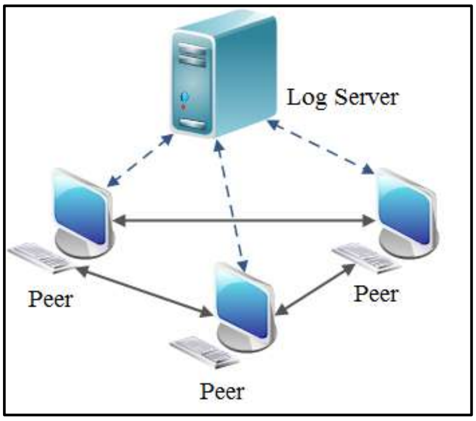

Figure 5. Log and Lookup Server Discovery Technique. [8]

SYSTEM ARCHITECTURE DESIGN PHASES

The system is designed as a three layered architecture, shown in Figure 6, which consists of the user interface, server logic and database storage layers. This architecture grants the system the necessary robustness, flexibility and resistance to potential changes, it also makes the application development and implementation easier and more efficient.

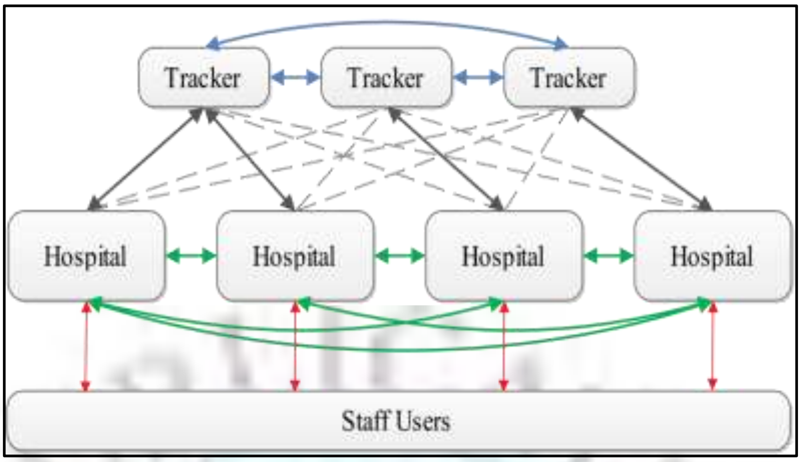

Figure 6. System's three Layered Architecture.

The interface layer offers the staff users a friendly and convenient entry to communicate with the system while the server application logic layer performs the controlling functionalities and manipulating the underlying logic connection of information flows; finally, the data modelling job is conducted by the database layer, which can store, index, manage and model information needed for this application.

a. Databases Design Phase

As shown previously in Figure3, the system contains three types of database servers (tracker, PACS, and HIS databases) that are implemented using MySQL.

•Tracker: is a distributed database system that consists of several database servers that use replication, as described in reference [9], which insures that all the database servers have a complete copy of the same data and have an architecture similar to the one shown in Figure 7. These servers function as a log and lookup server for the P2P network which is used by the HIS servers (peers) to locate each other in the network. They are also used to insure that hospitals have complete copies of their patients' EHRs by assisting the HIS servers in identifying and locating any missing records.

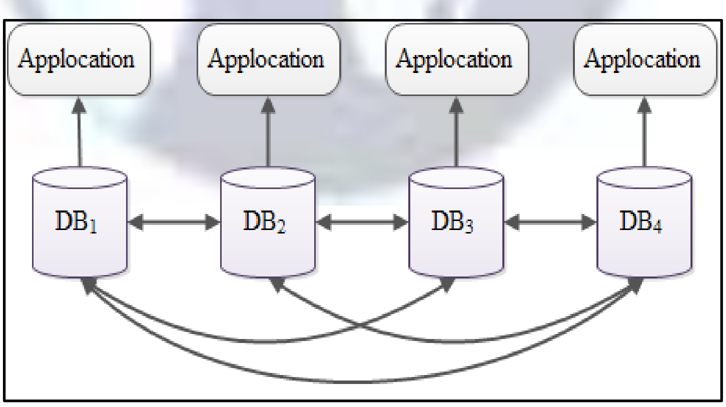

Figure 7. Simplified Distributed Database architecture. [9]

•Archive: is a part of the PACS system that is responsible for storing the radiology tests data.

•HIS: is the main database in the hospital that stores all the local clinical and administrative information for the hospital.

b. Servers Design Phase

The HIS servers in this system are designed to perform two important functions. The first function is to manage the hospitals' everyday tasks assisting the healthcare staff to provide the best treatment for the patients. The second function is to ensure the hospitals' databases have complete copies of their patients' EHRs by exchanging EHRs with each other. The exchange process is initiated for either one of the following two reasons: when the HIS server discovers that it is missing a patient's EHR(s), or when a new record is added to a patient's profile in which case the HIS server sends the new record to all the hospitals that were previously visited by the patient.

The HIS server may discover that it is missing a patient's health record when it is requested by either the physician or another HIS server. The HIS requests the list of hospitals that were previously visited by the patient from the tracker then divides the EHR to several parts and requests one part from each hospital. If any of those hospitals does not have the requested record, it also requests the record from the other hospitals.

c. User Interface Design Phase

The users (applicants) can access the data on the servers through client applications. Each staff type has his own client application that provides them with the necessary functionalities to perform their required tasks. This layer manages sending and receiving data to and from servers then it displays this data for the user. Figure 8 shows the physician's GUI while he is examining a patient's radiology test sent from the PACS system.

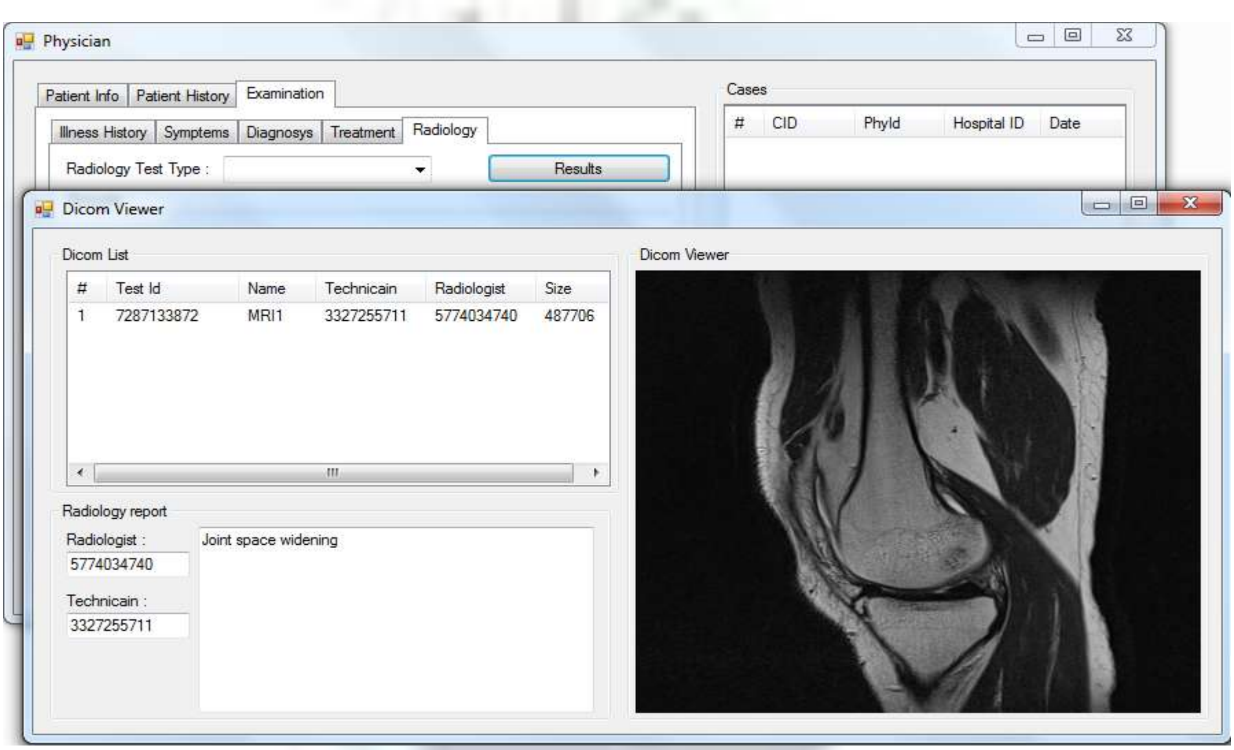

Figure 8. Client GUI for the Physician.

PROJECT ENVIRONMENT AND RESULTS

The EHRs distribution is triggered by certain events that makes the HIS server, shown in Figure 9, in a hospital check its patients' EHRs, as described previously, then request the missing records from other hospitals. The first event is when a new case is created for a patient, as shown in Figure 10, the HIS server checks its database for this patient's information and EHRs, if there are any missing data it is requested from other hospitals. This process ensures that the physician is able to view all the necessary data (patient's information and EHRs) about this patient which might help improve his illness diagnosis and treatment.

The second event is when an HIS server receives a request from another server for an EHR that it doesn't have. This HIS server will also start the process to locate and fetch this missing record from other hospitals that already have it. The third and last event is when the physician closes a case after submitting diagnosis and its treatment, the hospital's HIS server sends requests to all other HIS servers that their hospitals were visited by the patient. These servers will request the new case data as if was a missing record.

Because the system was designed as a distributed system, clients are unaware of the data exchange between the peer servers. Therefore, the process can only be detected by the presence of the exchanged EHRs. Figure 11 shows the physician's GUI displaying a radiology test performed on the patient in another hospital, which was previously shown in Figure 8.

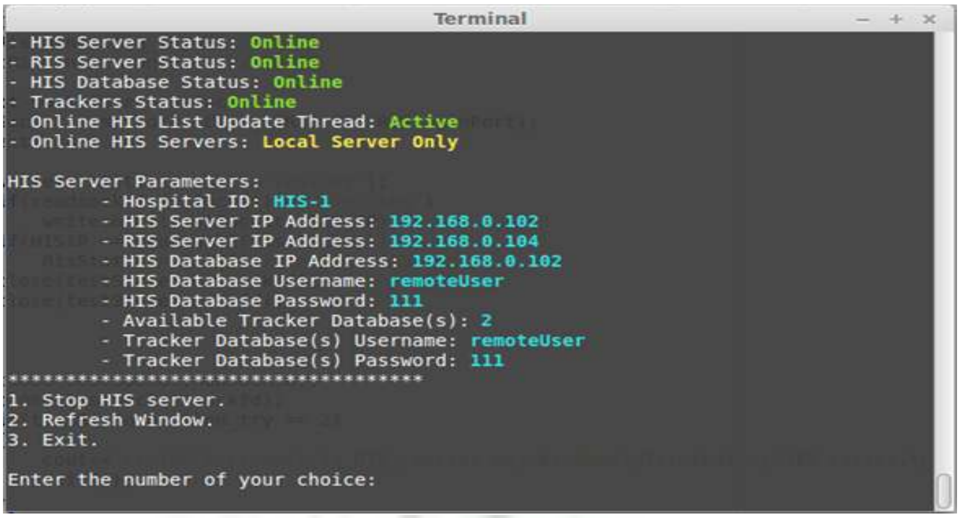

Figure 9. HIS Server Interface.

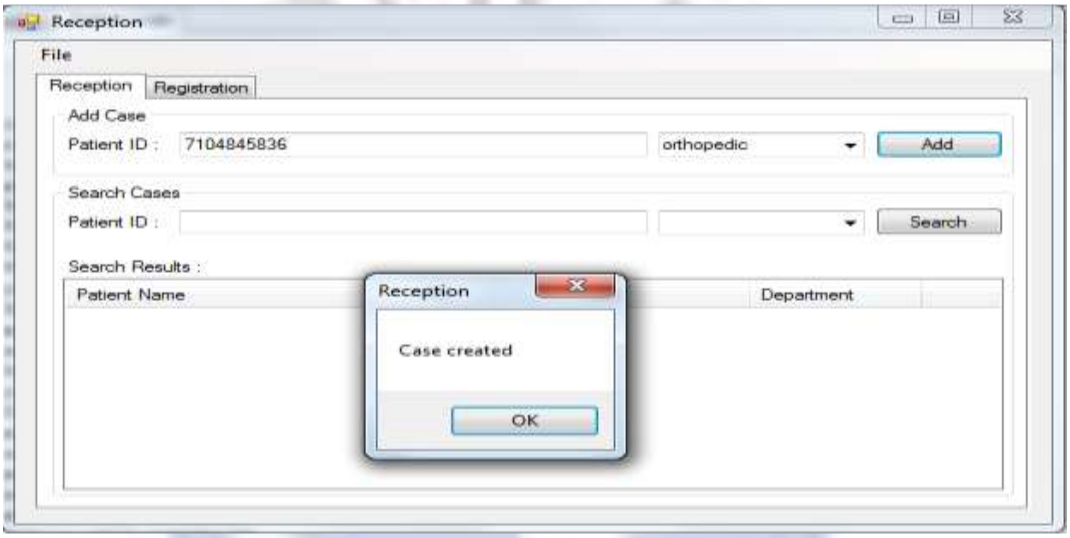

Figure 10. New Case Created by the Receptionist.

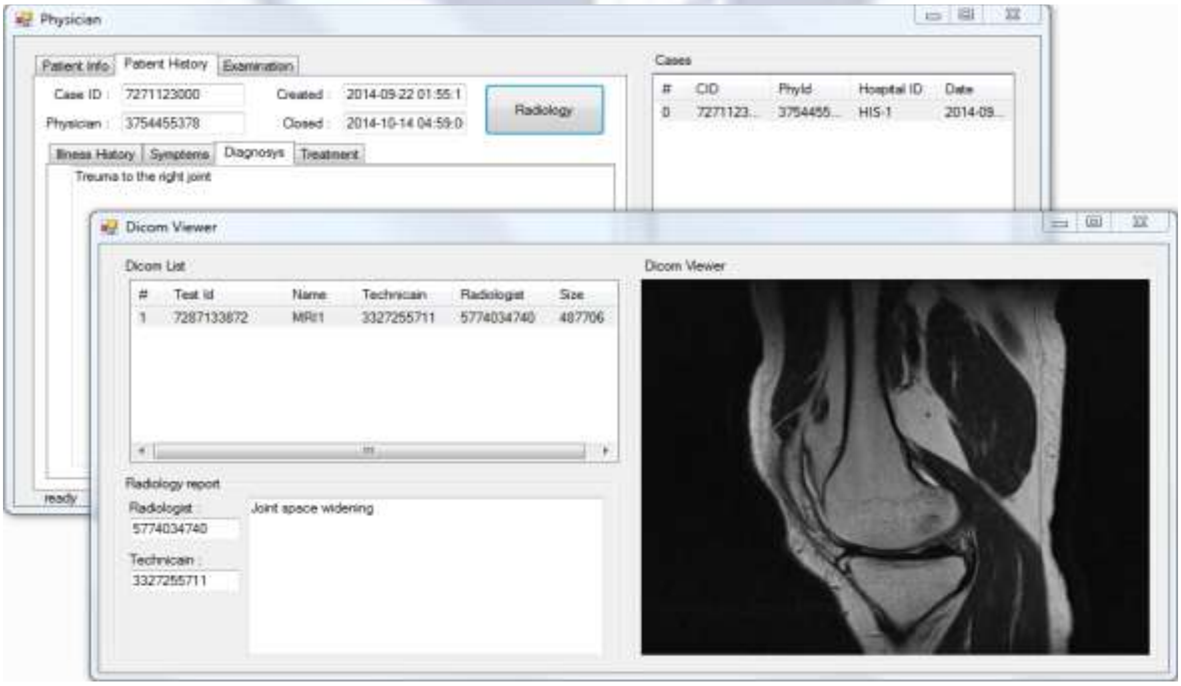

Figure 11. patient's EHR Viewed by the Physician.

References

[1]. A. Hoerbst and E. Ammenwerth, "Electronic Health Records: A Systematic Review on Quality Requirements", Methods of information in medicine (Methods Inf Med), Vol-49, Issue-4, pp:320-36, Germany, 2010.

[2]. Omni MD, "EHRs vs. Paper-based Systems: 5 Key Criteria for Ascertaining Value", White paper, Available: http://www.omnimd.com/ files/WP-EHRs-vs-Paper-based-Systems.pdf, pdf, (Accessed: July 2014).

[3]. Y .Gomi, H. Nogawa and H. Tanaka, "Toward secure distribution of electronic health records: quantitative feasibility study on secure E-mail systems for sharing patient records", Journal of medical and dental science (J Med Dent Sci.), Vol:52, Issue:4, pp:229-236, Japan, 2005.

[4]. A. Winter, R. Haux, E. Ammenwerth, B. Brigl, N. Hellrung and F. Jahn, "Health Information Systems: Architecture and Strategies", 2nd edition, Springer, London, 2010.

[5]. J. Kim, D. D. Feng, T. W. Cai and S. Eberl, "Integrated multimedia medical data agent in E-health", Studies in health technology and informatics (Stud Health Technol Inform), Vol-121,pp:70-73, Netherlands, 2006.

[6]. S. Le Blond, A. Legout and W. Dabbous, "Pushing BitTorrent Locality To The Limit", The International Journal of Computer and Telecommunications Networking (Computer Networks), Vol:55, Issue:3, pp:541-557, 2011.

[7]. Edlic Nga-Lik Yiu and Edwood Nga-Wood Yiu, "Network Management for Picture Achieving and Communication Systems", M.Sc. thesis, Simon Fraser University, Engineering Science, Canada, 2007.

[8]. U A. Kini and S. M Shetty, "peer-to-peer networking", Resonance Journal, Vol-6, Issue-12, 2001.

[9]. S. K. RAHIMI and F. S. HAUG, "Distributed Database Management: A Practical Approach", 1st Edition, Wiley-IEEE Computer Society, United States, 2010.

[10]. M. Gupta, "Building a virtual private network", 1st Edition, Premier Press, United States, 2003.

[11]. C. Perkins, "IP Encapsulation within IP", RFC-2003, 1996.